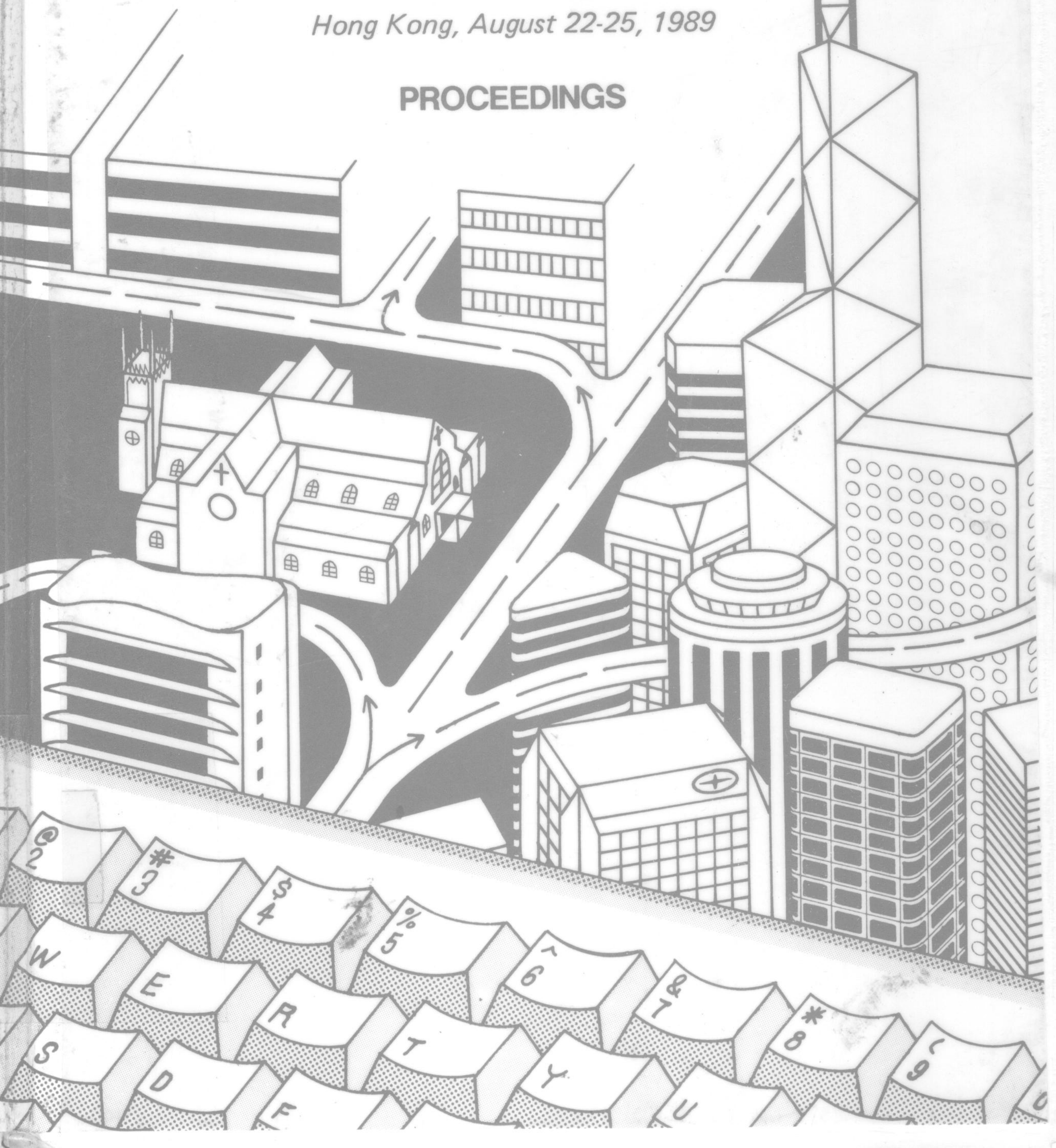
INTERNATIONAL CONFERENCE ON COMPUTERS IN URBAN PLANNING AND URBAN MANAGEMENT

Centre of Urban Studies and Urban Planning
University of Hong Kong

Hong Kong, August 22-25, 1989

PROCEEDINGS



INTERNATIONAL CONFERENCE ON COMPUTERS IN URBAN PLANNING AND URBAN MANAGEMENT

Proceedings

Centre of Urban Studies and Urban Planning
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Sponsored by

Australian Urban and Regional Information Systems Association (AURISA)
Eastern Regional Organization for Planning and Housing (EAROPH)
Hong Kong Institute of Planners (HKIP)
Information Technology Division, American Planning Association (APA)
Royal Australian Planning Institute (RAPI)
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PREFACE

This volume contains the proceedings of the International Conference on Computers in Urban Planning and Urban Management, organized by the Centre of Urban Studies and Urban Planning, University of Hong Kong and sponsored by the Australian Urban and Regional Information Systems Association (AURISA), Eastern Regional Organization for Planning and Housing (EAROPH), Hong Kong Institute of Planners (HKIP), Information Technology Division, American Planning Association (APA), Royal Australian Planning Institute (RAPI), Royal Town Planning Institute (RTPI), and Spatially-Oriented Referencing Systems Association (SORSA), held at the Loke Yew Hall (Main Building) of the University of Hong Kong, Hong Kong, in August 22-25, 1989.

With rapid development of computer technology, especially microcomputers, computers are more widely used in urban planning and management than a decade ago. The main objective of the Conference is to provide an international forum to exchange experience and review the latest advancement in the use of computers in different sectors of urban planning and management, and to discuss the organization and impact of computer technology on urban planning and management.

The Organizing Committee of the Conference is chaired by Anthony Yeh and Michael Batty with the assistance of a panel of international advisors :

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Ron Sharpe	CSIRO Division of Building, Construction and Engineering, Australia
Anthony Yeh	Centre of Urban Studies and Urban Planning, University of Hong Kong, Hong Kong

I would like to thank the authors for preparing the timely and valuable papers that have made the Conference a succes. The Conference is organized with the support of the Urban Studies and Urban Planning Trust Fund, University of Hong Kong. The sponsorship of Sun Microsystems Inc. in meeting part of the cost of the publication of the proceedings is gratefully acknowledged.

Anthony G.O. Yeh

COMPUTER AIDED LANDSLIP POTENTIAL MAPPING
AND ITS APPLICATION TO
LAND USE PLANNING AND DEVELOPMENT CONTROL

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ABSTRACT

This paper describes the results of research, promoted by the UK Department of Environment and Welsh Office on landslip potential mapping in a trial area of the United Kingdom. The methodology involves the analysis and rating of those characteristics of the landscape which make an area susceptible to landsliding. Computerised methods of data storage, analysis, and map production provided the only practical method of handling the large amount of data concerned. The paper also describes how prior assessment of the impact of the maps on development control enabled problems to be anticipated and resolved before the maps were fully implemented. Landslip potential maps are a useful tool of landslip management, providing explanatory documents are available to both planners and developers

INTRODUCTION

The research was carried out in the Rhondda Valleys of the South Wales Coalfield This area is dominated by a large number of shallow landslides and a smaller number of deep-seated rock slides They are believed to have originated mainly in the severe climate which existed in the area in late glacial times. Most are stable under present-day conditions but some have been reactivated by human interference, especially during industrial development in the late 19th and early 20th centuries. Some 346 landslides have been identified, occupying about 9% of the 100km^2 of the administrative area of Rhondda Borough.

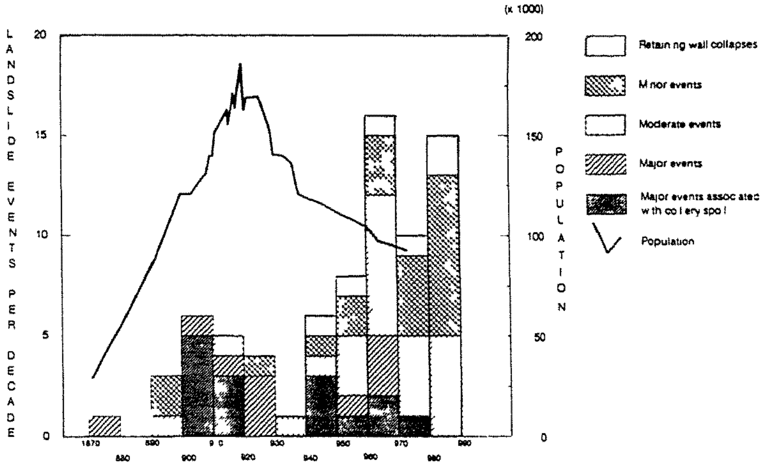


FIGURE 1 : Temporal distribution of landslides in Rhondda

The temporal distribution of landslide events, determined from archival research is shown in Figure 1, in which a subjective scale has been used to classify their magnitude. The preponderance of moderate and minor events in the last few decades is due to the better availability of records, and is considered representative of present-day conditions. Major events are comparatively rare; most resulted from the tipping of colliery waste but this activity has now declined. Thus, the area does not have a high degree of landslide hazard, although the impact of major events has involved expenditure of several million pounds.

LANDSLIDE HAZARD MANAGEMENT STRATEGIES

In such an area various methods may be implemented to reduce the effects of landsliding on the community. Landslide management in Rhondda and other parts of the United Kingdom has concentrated on the 'active' strategies of implementing stabilisation measures, monitoring of unstable slopes and acquiring of property at risk.

These are essentially the techniques of crisis management, implemented on an ad hoc basis as responses to threatening landslide occurrences. They are expensive to apply, are associated with large social impacts and often involve complex legal issues. It has been demonstrated elsewhere in the world that a more cost-effective means of mitigating landslide risk is through the 'passive' techniques of land-use planning, development control procedures and discouraging development in hazardous areas.

The main objective of 'passive' techniques is to prevent development in areas susceptible to movement or to ensure that development only occurs after appropriate investigations and design to ensure that any inherent stability problems are overcome. In order to make these strategies effective, a landslide hazard data base is required in a form which can be used by regulatory agencies and decision makers, many of whom do not have ready access to geological expertise. To meet this need, the concept of landslide hazard maps has been advanced (Varnes, 1985) which show the relative susceptibility of areas to landsliding by an appropriate scheme of zonation.

The last twenty years have seen the development of numerous national or regional mapping programmes in areas subject to landslide hazard. They have been comprehensively reviewed elsewhere (Hansen, 1984; Brabb, 1984; Einstein, 1988) and fall into two main categories:

- "direct" mapping of landslides and associated landforms;
- "indirect" methods of analysing the factors contributing to instability.

Hazard zones may be based on isolines which indicate the distribution of landslide areas, on irregular units of land following individual geomorphological boundaries or on regular units ("cells" or "elements"). The basic units of land used in the zonation process are dependent on the methods used to collect and interpret the data. Some of the mapping techniques have used computers to establish a landslide data base with a system of check lists, and to analyse the data using regression analyses to produce computer-generated maps.

LANDSLIP POTENTIAL MAPPING METHODOLOGY

The methodology chosen for the trial mapping in Rhondda was an "indirect" one, aimed at identifying and quantifying those factors which appear to be most significant in defining the location of discernible landslides so that the relative susceptibility of intervening areas might be predicted (Halcrow, 1986). The stages involved in the collection and analysis of data used to prepare the landslip potential map are illustrated in Figure 2

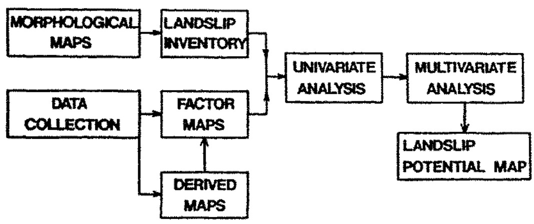


FIGURE 2 : Landslip potential mapping methodology

Firstly, landslide locations were mapped from morphological surveys which included aerial photoreconnaissance and field verification. Factor maps were then prepared which showed variations in the attributes of each factor by a simple zoning scheme. Some 20 factors were considered, but the availability of data eventually restricted the number to the following:

- slope aspect
- slope angle
- lithostratigraphic units
- superficial deposit types
- superficial deposit thickness
- dip in relation to ground slope
- faulting
- groundwater potential
- erosion potential
- mining strains
- mining tilts
- excavation and tipping

Univariate analyses were performed to derive a rating which is a measure of the degree of association between the landslides and each factor zone. The rating was the ratio of the incidence of landslides in a factor zone to that in the area as a whole, ie:

$$\text{Rating} = \frac{\text{proportion of a factor zone occupied by landslides}}{\text{proportion of the entire area occupied by landslides}} \times 100$$

Thus, factor zones with ratings greater than 100 would tend to indicate a positive association with landslides and therefore an attribute which favours instability. Values less than 100 suggest the converse with attributes which favour stability. Various combinations of ratings, with and without weightings, were then evaluated using simple formulae, to define the landslip potential as a number. The aim of these multivariate analyses was to match high values of landslip potential with known landslide areas. The formula finally selected had the following form:

$$LP = \frac{RP_{n2} \times (RP_{n4} + RP_{n5} + RP_{n8})}{300}$$

where RP_{n2}, RP_{n4}, RP_{n5} and RP_{n8} are the ratings for slope angle, superficial deposit type, superficial deposit thickness and groundwater potential respectively.

COMPUTING

The method used in the project was based on the relationships between factors and landslips. To define these relationships a large amount of data had to be handled accurately, reliably and quickly. This could only be done using computers and involved the following steps:

- o Establishment of a suitable file structure
- o Entry of data from source maps
- o Analysis and manipulation of data
- o Plotting of the results from analysis

All computing was done using an IBM PCAT. This was lined to an A0 size Ferranti System 4 digitiser, which was used to input data to computer files. A dot matrix printer and Hewlett Packard HP7475A plotter produced hard copy. The software (Table 1) consisted of three types of program. Those which handled more than one file simultaneously which used the facilities of Fortran; those which directed output to peripheral devices which and were written in Basic; spreadsheets with their graphics which were used for analysis.

PROGRAM	DESCRIPTION	SOURCE LANGUAGE	PROGRAM SIZE (kb)	OUTPUT SIZE (kb)
	DATA INPUT			
DOEDIG	Used to produce computer files from source maps	FORTRAN	35	35
	UNIVARIATE ANALYSES			
DOECAL	Used to determine the number of elements in each factor zone and how many were affected by landslips	FORTRAN	35	20
FRAMEWORK *	Spreadsheet used to analyse data from DOECALC also used in multivariate analysis	-	400	20
HISTRAW	Plots univariate analysis data	BASIC	20	20
	MULTIVARIATE ANALYSIS			
MULRAN	Multiplies ratings to obtain landslip potential values	FORTRAN	40	35
SUMRPN	Adds ratings to obtain landslip potential values	FORTRAN	40	35
PARMUL	Program finally used to obtain landslip potential values	FORTRAN	40	35
	PLOTTING PROGRAM			
DATPLOT	Plots computer data files	BASIC	40	50-400
	UTILITY PROGRAMS			
RENUMBER	Renumbers groups of cells in data files	FORTRAN	35	35
ADDLDSLP	Combines data files and landslip data files	FORTRAN	35	35

* Trade Mark - program produced by Ashton Tate

TABLE 1 : Programs

File Structure

The storage of data in grids was the form most suitable to the project. To accurately represent information using grids the element size has to be sufficiently fine (Newman et al, 1978). However, it need not be finer than the smallest developable plot of land, which in this study was taken to be 50 metres square. The entire study area was thus divided into 40,041 elements and contained within nine base maps each covering a nominal 25km^2. Each computer data file was structured to contain the 10,000 elements of a base map. This represented a substantial amount of data as at least four factors were logged for each map, as well as the landslips themselves. These data were contained in a total of sixty separate files.

A rigid system of control of data files was required because each file was visually quite similar. This was assured by maintaining a detailed catalogue of each file. Their structure was aso designed to allow them to be clearly viewed on a VDU, thus enabling these ASCII files to be more readily amended using line editors.

Data entry

An AO size digitiser was used to transfer information from the factor and landslip maps to computer files using the program DOEDIG. Each file was checked by overlaying printed output from the program DATPLOT on the original map on a light table.

Data analysis

The first part of the analysis involved using the program DOECALC to determine the number of elements in each factor zone the number affected by landslipping. Relationships between factor zones and landslips were obtained using the spreadsheet of the integrated package FRAMEWORK. The graphics associated witl FRAMEWORK were too limited to obtain the maximum benefit from the information being processed. Spreadsheets were therefore linked to the plotting program HISTDRAW to obtain clearer graphical output of landslip distribution and ratings for each factor (Figures 3 and 4).

The ratings for each factor zone were then accumulated in a formula to define the landslip potential of each element. Initially, all factors were included, but it was subsequently found that factor ratings with low standard deviations could be omitted without adversely affecting the overall result The programs MULRPN and SUMRPN were used to investigate both multiplying and dividing the ratings, the results being evaluated according to the following criteria:

- the percentage of non-landslip elements should decrease with increasing landslip potential;
- the percentage of landslip elements should increase with increasing landslip potential;
- the ratio of landslip elements to non-landslip elements should increase with increase in landslip potential.

These analyses were evaluated using spreadsheets. It was found that multiplying the ratings resulted in a few elements with very high values, whilst it was apparent that adding them gave insufficient emphasis to certain factors. Ultimately, the formula already described was adopted for which the program PARMUL was written.

Plotting

The program DATPLOT was used to check digitised data, assist in analyses and plot both factor maps and landslip potential maps in the form shown on Figure 5. The data files were plotted to produce maps in colour, with text added from spreadsheets. Landslip potential maps were then enlarged to 1 : 10000 scale and provided with an explanatory legend prior to use.

IMPLEMENTATION IN DEVELOPMENT CONTROL PROCESS

In order to make use of the maps, procedures had to be established by which they could be used within the UK's existing planning legislation by the local planning authority (LPA) concerned. Under this legislation, planning permission is required for most forms of development from the LPA, which determines each application using a

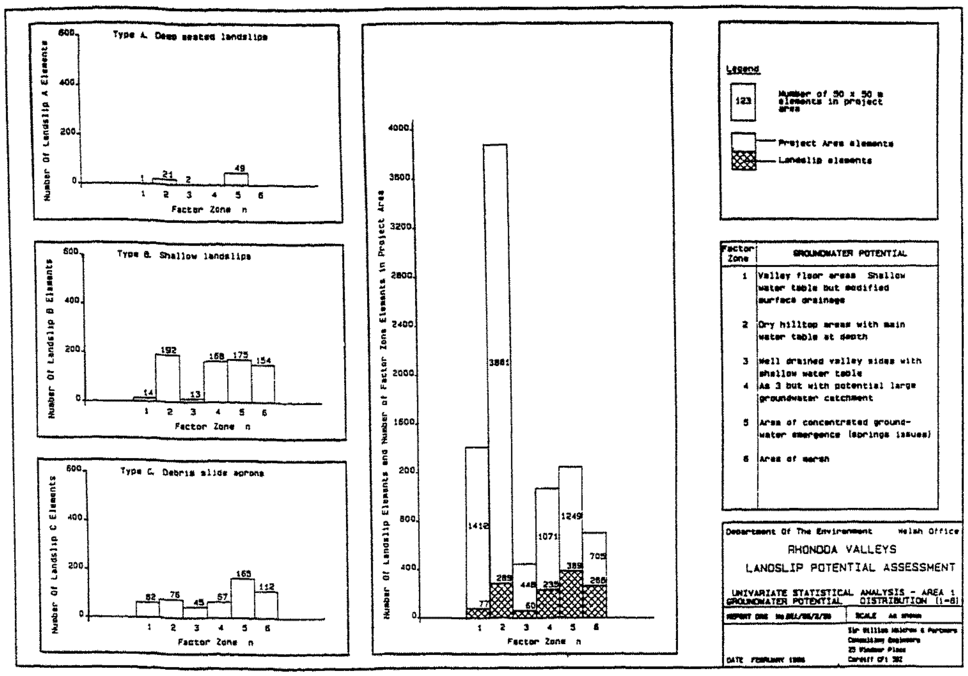


FIGURE 3 : Typical analysis of distribution of factor zones and landslides

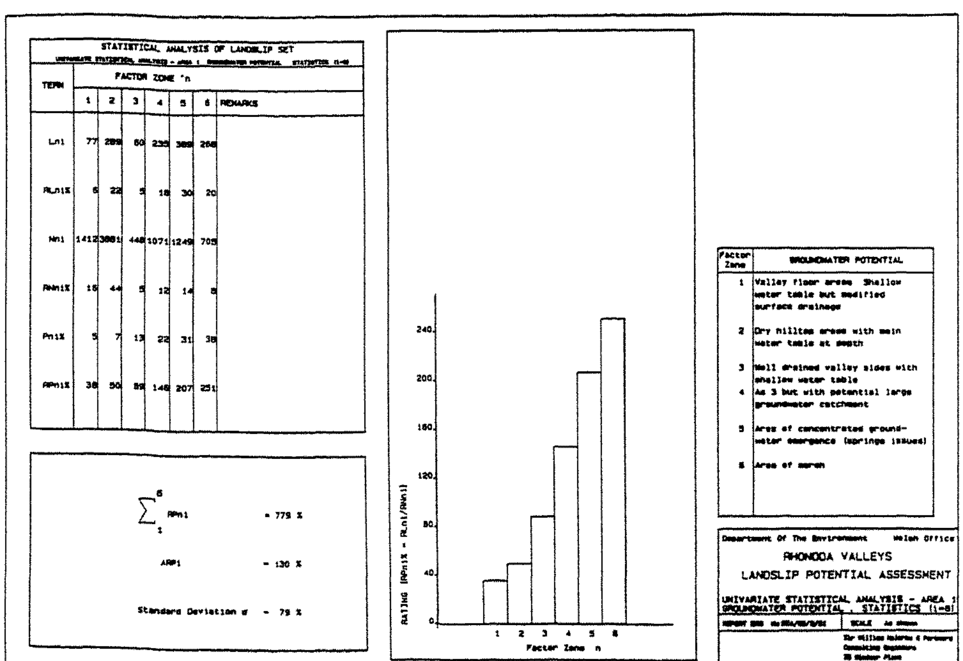


FIGURE 4 : Typical analysis showing ratings derived for factor zones

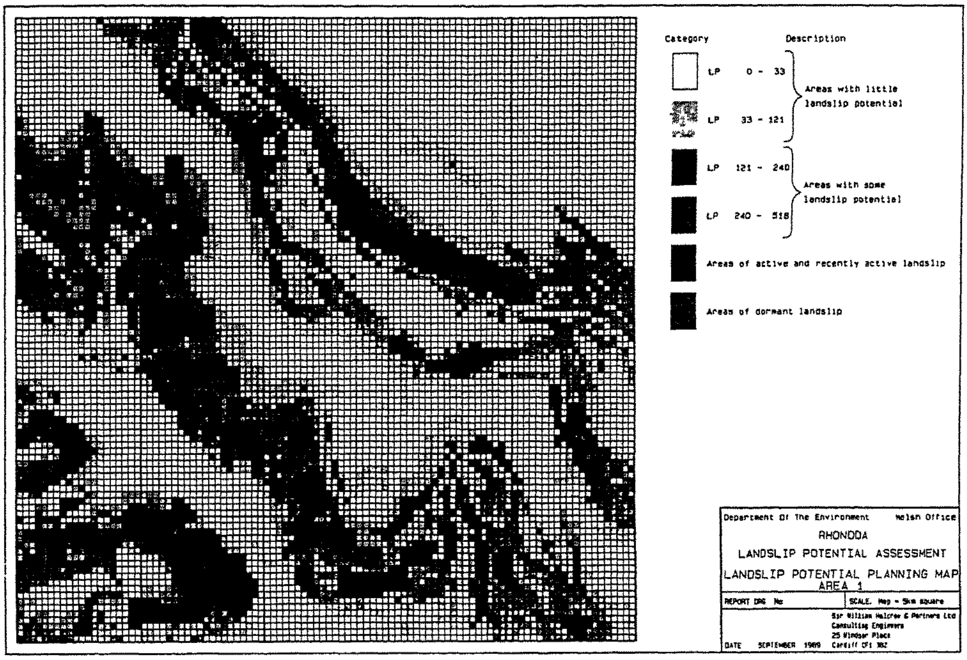


FIGURE 5 : Landslip potential planning map

relevant planning criteria. The LPA has to be satisfied that the development can be used safely and that it will have no detrimental effects on existing amenities. The LPA can request a developer to provide information to confirm that these criteria can be met. However, the developer remains responsible for ensuring that the land on which the development is constructed is stable and that it will not be affected by foreseeable instability outside its boundaries. Thus, procedures had to be devised to assign a category of landslip potential to each development proposal, and to provide appropriate planning response options for each landslip potential category.

Initially, maps were zoned with four categories of landslip potential. These were designated "minimal", "slight", "moderate" and "high", with all known areas of landsliding designated as "high" irrespective of their calculated landslip potential values. It was proposed that the landslip potential category might be assessed by determining the highest landslip potential of the elements covered by the area of the proposed development and of those immediately surrounding it. Those with the 'moderate' and 'high' landslip potential categories could require a geotechnical stability report. These early proposals, described by Siddle et al (1986) were made without detailed knowledge of the number, type and distribution of planning applications and there was clearly a need to test whether they were appropriate, manageable and effective.

Rather than test the procedures in a "real" trial period of use, it was decided to test their notional impact by carrying out a 'back analysis' of previous approved planning applications over a representative five year period in a typical area which accounted for 29% of all approved planning applications in Rhondda over the period concerned (Jennings et al, 1987).

APPLICATION TYPE	PERCENTAGE				CODE
DOMESTIC EXTENSION	80	83	68	66	
GARAGE	7	9	13	13	
HOUSING	3	3	10	18	
OTHERS	10	5	9	3	

APPLICATION TYPE	PERCENTAGE				CODE
DOMESTIC EXTENSION	73	84	79	72	
GARAGE	5	8	10	10	
HOUSING	0	2	5	7	
OTHERS	22	6	6	11	

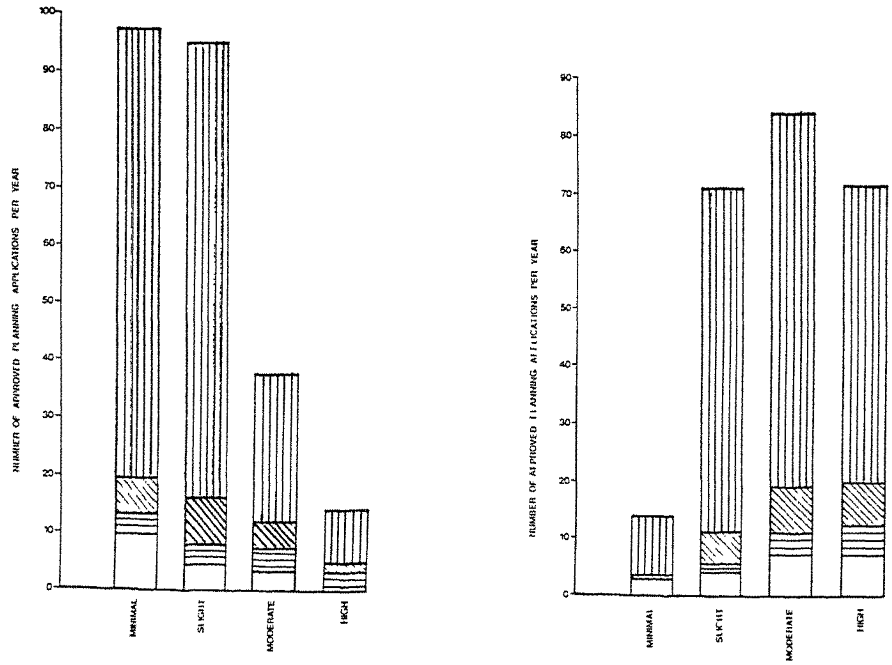


FIG. 6: (a) Distribution of new development in landslip development and
(b) the same development using planning procedures originally envisaged

Figure 6a shows the average annual number of planning applications approved in each category of landslip potential, classified by the main types of development. However, if as originally proposed, the elements surrounding the development were taken into account when defining the landslip potential, the number of developments within the moderate and high landslip potential categories was increased at the expense of those in the lower categories (Figure 6b). The average annual number within the moderate and high categories was 156, indicating that within the entire Borough more than 500 planning applications per year could be expected to fall within the moderate and high landslip potential categories and could require specialist geotechnical investigation. It was considered too stringent for the level of landslide hazard and could have had the detrimental effect of inhibiting development initiatives.

As a result of the impact study, zonation of the maps themselves was modified to the form shown in Figure 5. Active and dormant landslide areas were shown as two categories. Two other categories - "little landslip potential" and "some landslip potential" replaced the combined previous minimal/slight and moderate/high categories. The effect of these modifications was to accentuate the landslide areas and to provide a more appropriate terminology for landslip potential. The procedures for using the maps in development control were modified (Figure 7) as were the possible planning responses for each landslip potential category (Figure 8). Small household developments (mainly extensions to existing property and garages) were to be approved without the need for a geotechnical report, providing that it could be demonstrated, using a simple check list, that there would be minimal disturbance of the site.

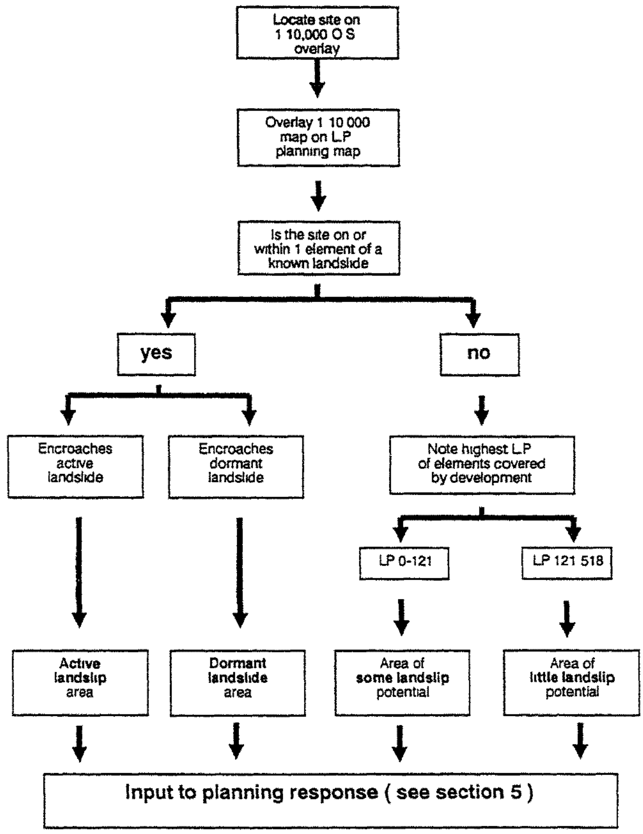
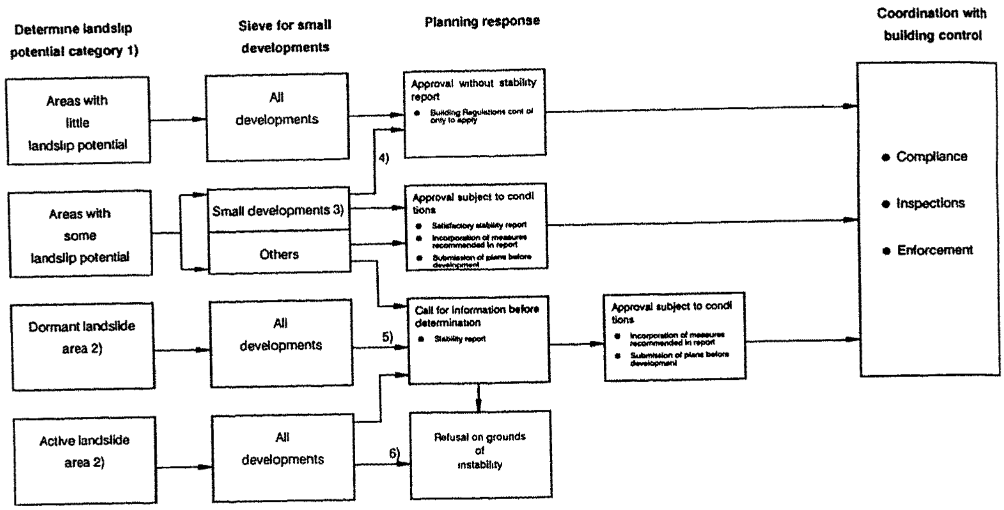


FIGURE 7 : Assessment of landslip potential procedure

It was estimated that these procedures would result in approximately 30 planning applications per year which would require a geotechnical report from a 'Competent Person'. It was felt that this figure was commensurate with the level of landslide hazard in the area and it would not present an unreasonable burden on the local planning authority or would-be developers.

COMMUNICATIONS

Kockelman (1986) has noted the importance of communication in publicising landslide data as part of the strategy of mitigating landslide risk. In the case of landslip potential maps, it was essential that the interfaces between data preparer and users was bridged. This was achieved by the preparation of 'Planning Guidelines' for use by the LPA and a 'Guidance Note' for developers (Halcrow, 1987).



1) See section 4 of Guidelines
2) Dormant/active landslide areas include adjacent elements irrespective of their landslip potential
3) Small developments are building extensions & garages
4) For small developments meeting the criteria listed in para 5 2 of Guidelines
5) Information requested only when other planning criteria are likely to be satisfied
6) Refusal on grounds of instability may be cited without call for information where other planning considerations are not satisfied

FIGURE 8 : Planning response options for each landslip potential category

The Planning Guidelines is a 30 page document giving the LPA, which has no specialist experience in slope stability, basic information on:

- the main types of landslides, their occurrence and impact
- opportunities to reduce risk through the planning process
- how the maps are to be used
- circumstances in which each planning option might be used
- components of a model 'stability report'
- procedural aspects
- a glossary of technical terms

The Guidance Note is a leaflet, issued with each planning application form, which gives advice to developers about construction near unstable ground. It describes:

- the types of potentially unstable land
- the responsibilities of the developer and LPA
- the landslip potential maps
- the method by which the LPA will take account of potential instability
- the requirements for a stability report
- a suggested sequence of investigation and design

The landslip potential maps, Planning Guidelines and Guidance Notes are now undergoing a monitored period of trial use within the LPA.

CONCLUSIONS

Landslip potential maps are a useful tool of landslide management as they enable decisions on development to be made with advance knowledge of likely slope stability conditions. The format of the maps described in this paper are ideally suited for this application as they are readily understandable by non-technical users and yet are a synthesis of technical information. However, the importance of providing user groups with adequate information about slope stability problems as well as the maps themselves is emphasised. They study also demonstrated the importance of evaluating the impact of using the maps, before being fully implemented in development control.

The particular method described in the paper, as with most "indirect" methods of landslide hazard mapping, was ideally suited to computerisation because of the large amount of data and analysis required. Plotting of the maps by computer enabled modifications to the zonation to be made rapidly and will enable them to be easily updated as more information becomes available.

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BOOLEAN MAPS AND THE RATIONALIZATION OF OPPORTUNITIES AND CONSTRAINTS IN PHYSICAL PLANNING

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ABSTRACT

The recognition of opportunities and constraints offered by the physical landscape and its cover is a necessary precursor to development planning. Whilst aerial photographic interpretation and a geomorphological evaluation of landform can rapidly furnish most of the data, conclusions on opportunities and constraints can be of a generalised nature. If the paper products instead form a digital database, then Boolean mapping can provide a more rigorous and communicable approach. Boolean maps are the outcome of overlay analyses incorporating logical operators that allow the direction of analysis to be controlled so that outcomes are rationalized for specific proposed land uses or activities.

INTRODUCTION

Planning is the process of selecting a course of action based on the evaluation of alternatives for achieving goals (perceived objectives) preferrably by the optimal use of resources. Plans are necessarily evolutionary as not only may objectives change in response to society, but that in monitoring the implementation of previous decisions, further appraisal and modification of actions may be required. Inevitably then, planning becomes an exercise in the control and guidance of a rolling development programme.

Critical to the planning process is the availability of relevant information regarding the character and dynamics of society and its physical setting. Land is a primary resource and information regarding its suitability and availability is a cornerstone of planning. Fundamental to any evaluation of alternatives is the recognition of appropriate opportunities and constraints as presented by the physical and social landscape.

Geo-informatics is the new science having spatial information, particularly in graphic form, as its core domain. Included within it are the use of geographic information system (GIS), land information system (LIS) and multi-purpose cadastre techniques. The basic operations of a GIS is illustrated in Figure 1 and is shown in parallel to the general planning process. This paper is concerned with recognition of opportunities and constraints as facilitated by GIS.

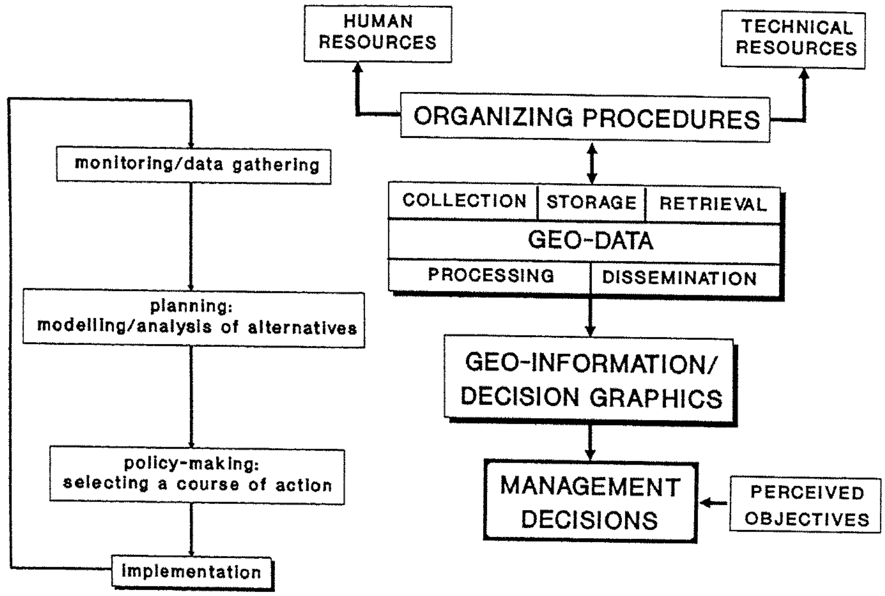

Figure 1 : Basic operations of a GIS in relatition to the general planning process.

TERRAIN EVALUATION

Terrain evaluation is the appraisal of a landscape in the context of specific development projects. The appraisal includes both the physical, vegetation and land use aspects of the landscape. The objectives are twofold. Firstly, it is to facilitate all who are concerned with to project a thorough familiarisation of the site's characteristics. Secondly, it is a means of identifying relevant opportunities and constraints. It is therefore an integral part of the data collection and analysis stages of the planning process and is a catalyst for deriving concepts.

Landform is the basic unit for evaluating terrain conditions as it represents an ecological unity resulting from the interaction over time between materials (rock and soil), processes (weathering, erosion and deposition), vegetation and the form itself. Thus each landform has a definable range of visual characteristics and associated range of engineering properties that are repeated wherever that landform is found. These visual characteristics can be readily identified from aerial photographs or in the field allowing a wide range of information about the physical landscape to be deduced and mapped. Aerial photographic interpretation can simultaneously provide information on the distribution of vegetation and land use classes.

Relevant opportunities and constraints are identified through the process of derivative mapping. Thus, for example, the basic geomorphological data can be used to derive a landslide hazard map or zones of flood succeptibility. Whilst some aspects can be very successful, two areas of difficulty can arise when considering planning proposals. The first is that some items of data, such as gradient and relative relief, are tedious and time consuming to manually derive over large areas. Secondly, the opportunities and constraints pertinent to a particular proposed land use or activity may differ for others and if rigorously pursued, many different opportunities and constraints maps would have to be derived for a planning study. For example, the critical class intervals for gradient which influence agricultural activity are different from those that are relevant for housing development, or, what may be a constraint for housing may be an opportunity for reservoir construction and so on. Given these difficulties, the overall results for opportunities and constraints mapping may be of a generalised nature.

BOOLEAN MAPPING

Terrain Attribute Databases

Much of the problem outlined above stems from the traditional reliance of the map as a paper product. Essentially static, they are difficult to manipulate. If instead the data is encoded and incorporated within a database, then the flexibility introduced allows a wider range of analyses. The process for a low-cost system is illustrated in Figure 2. Referring to Figure 2, topographic data (1) is stored in the computer as a grided digital terrain model (2). This data is used to construct block diagrams (3) and calculate derivative information (4), such as gradient, aspect and relative relief, for storage in a terrain attribute database. The remainder of the layers of the attribute database are completed with information derived from the terrain evaluation process of aerial photographic interpretation (5-7). Classifications and analyses can then be carried out by computer (8) and the results plotted (9). Data may

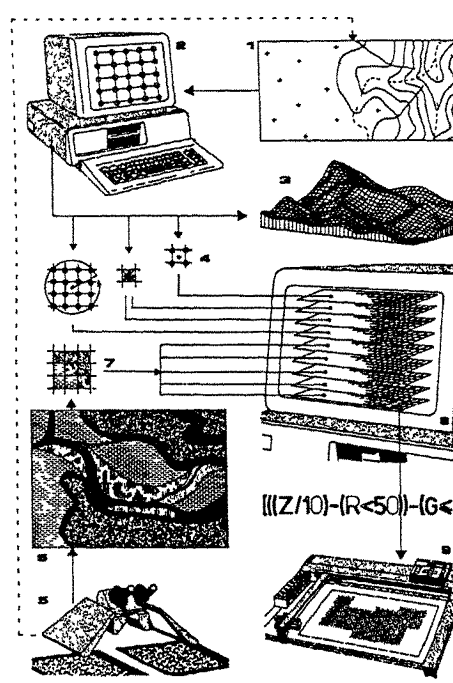

Figure 2: Low-cost GIS

in fact be stored in vector or raster format, but whilst cartographically poorer, raster format is very much more amenable to Boolean overlay analysis. For a more detailed treatment of GIS data formats and analytical capabilities, refer to Burrough (1986).

Heuristics

Combinatorial analysis of the different data layers may be either mathematical/statistical based or heuristics based. In the former, each layer is treated as a factor in an equation, such as a soil loss equation to derive a map of soil loss potential. However, planning issues of opportunities and constraints are rarely governed by such formulae. More often than not decisions are based on heuristics, that is the application of empirical rules or judgements derived from particular knowledge or experience.

Overlay analysis, as traditionally envisaged using paper or polyester layers, resulted in a proliferation of smaller and smaller polygons with the addition of each layer. Moreover, as noted above, each of these layers is fixed thus limiting the range of analyses possible. With the computer-assisted approach, the use of logical operators coupled with the possibility of redefining class intervals on class compositions, results in a more flexible and clearly understood result with those areas not pertaining to the analysis or not containing certain attributes being left blank. The operators used are those of Boolean logic as illustrated by Venn diagrams in Figure 3.

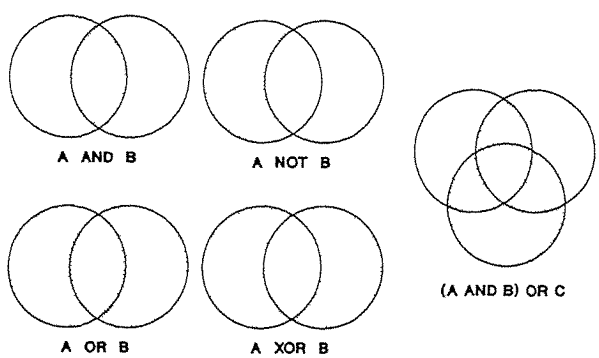

Figure 3: Venn diagrams showing to result of applying Boolean logic

AN EXAMPLE: MAPPING DEVELOPMENT POTENTIAL

To show how Boolean mapping allows the direction of analysis to be controlled so that outcomes are rationalized for specific proposed land uses or activities, a practical example is given.

A planning study has been carried out for the southern coastal strip of Lantau Island (Territory Development Department, 1989). The largest of the outlying islands of Hong Kong, it is also one of the least developed. Despite its relative inaccessibility, the area is becoming increasingly in demand for recreational pursuits by the urban population of the Territory. A framework was required to direct future development, whilst preserving the character of the natural landscape. As in any such study, a wide range of issues, such as transportation, village expansion, potential for resort development, the utilities network, sewerage treatment and waste disposal require to be considered. These needed to be reconciled with a very diverse landscape ranging from beaches, coastal flats, rolling foothills to mountainous terrain over short distances. Boolean mapping was used as a means of rationalizing opportunities and constraints for a range of issues and is believed to have been the first such use of the technique for a planning study min Hong Kong.

The terrain attribute database comprised of the following data layers on a 25m x 25m grid: elevation, slope form, gradient, relative relief, aspect, soil type, estimated depth to rockhead, drainage, groundwater, land cover issues and hazards. The example illustrated in Figures 4a and 4b shows, for a small area, the steps used to identify land of good development potential. Not all the layers of the attribute database are needed for this analysis which involves the following eight steps:

- Step one : classify the gradient of each cell to reflect ease of access road construction. Thus the first two classes are for major and minor roads at grade respectively. Then assuming a road width of 10m and cutting at 45°, the remaining classes represent roads running across the slope with cuts up to 5m, 10m, 20m and greater than 20m respectively. This type of irregular and very specific class interval would have been very difficult to derive manually without the use of a digital terrain model.

- Step two : those cells which are considered to be too steep for sensible access road construction by virtue of the likely engineering works involved and the resulting high cut slopes scaring the landscape, are removed from further analysis.

- Step three : those cells having unacceptable hazards such as slope instability are also removed from further consideration.

- Step four : cells having existing land uses which preclude future development such as County Park, water catchment area or no-excavation zones above tunnels or other major services are also subtracted.

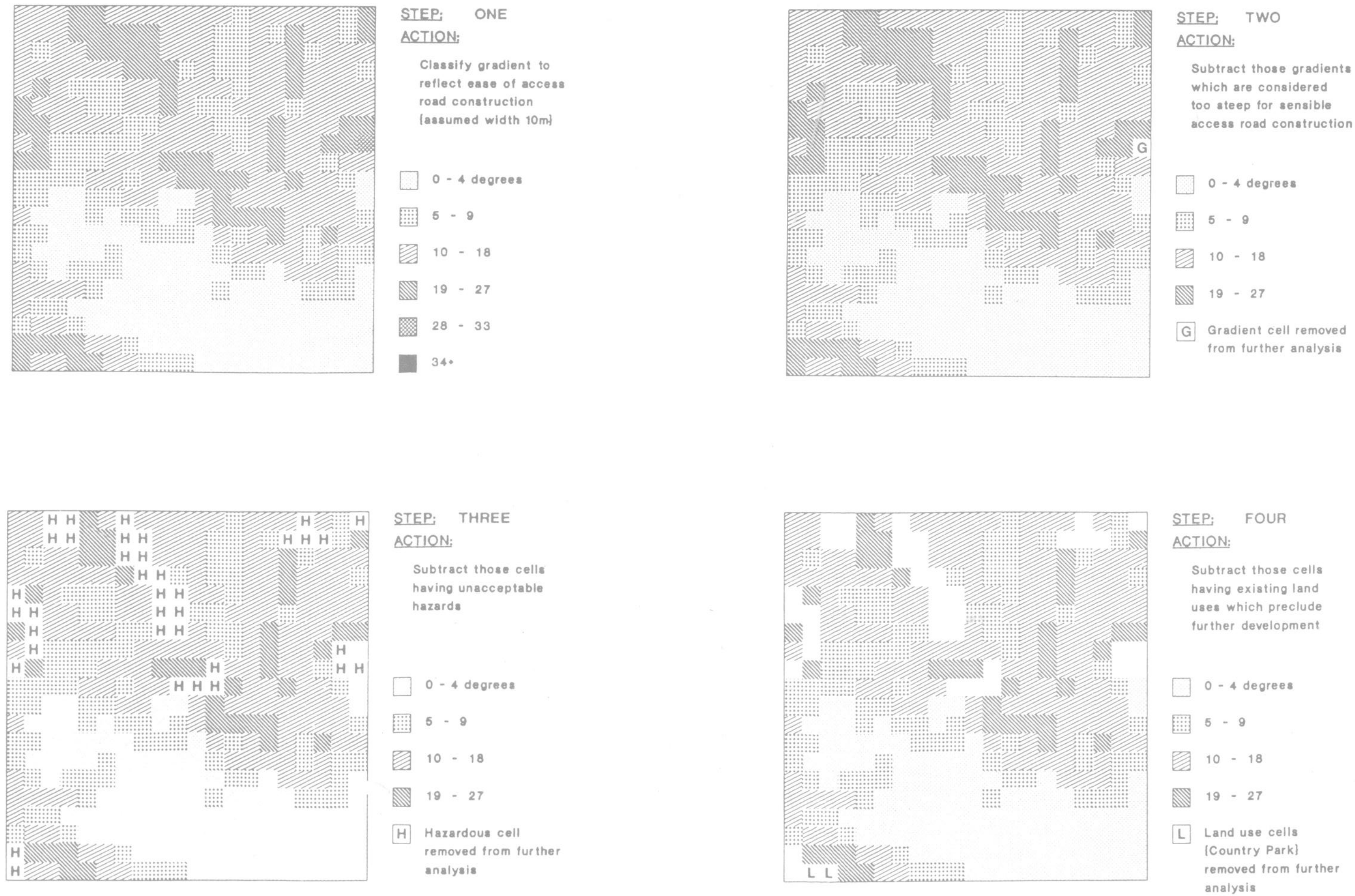

Figure 4a : Steps one to four of Boolean mapping example

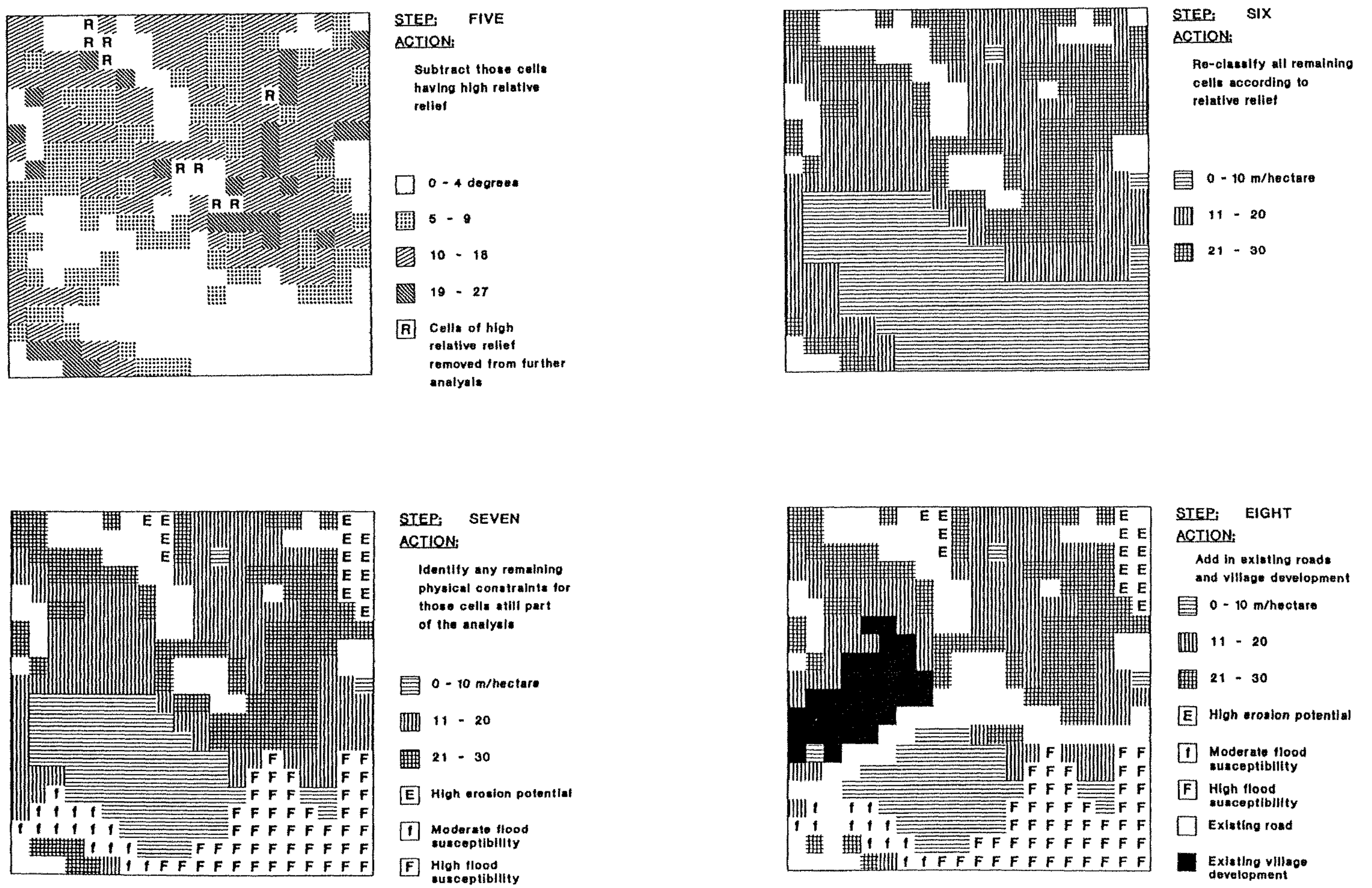

Figure 4b : Steps five to eight of Boolean mapping example

- Step five : further subtract those cells having high relatıve relief (> 30m/ha.); the significance of relative relief is given below.

- Step six : all the remaining cells are re-classified according to relative relief. Relative relief is the absolute range in elevation for a given area, in this case for one hectare surrounding each grid cell. This will reflect the degree of dissectedness and can be taken as a measure of the amount of site formation work required to form platforms for development. It is another item which would be extremely radious to derive manually.

- Step seven : this allows the recognition of any remaining constraints from the physical landscape. Areas of high erosion potential would require special precautions if developed whilst areas of flood susceptibility would require special drainage, embankments or reclamation in order to realise its potential.

- Step eight : this adds in for context the existing village developments and roads.

The final map of development potential is given in Figure 5 and facilitates decisions as to which broad areas could successfully undergo development. By way of extension, if reclamation of flood susceptible areas is desirable to achieve larger lots, then a new Boolean mapping could be carried out to identify suitable sources of soft fill and so on.

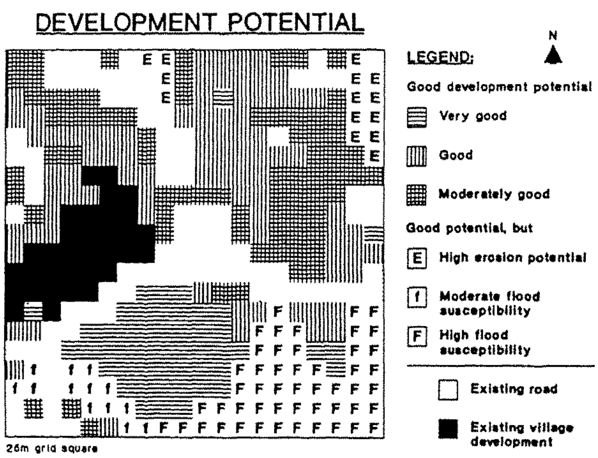

Figure 5 : Final Map of Development Potential

CONCLUSIONS

Boolean maps are the outcome of overlay analyses incorporating logical operators that allow the direction of analysis to be controlled so that outcomes are rationalized for proposed land uses or activities. Although possible manually, the advantages of a computer database approach are:

- analysis are much quicker allowing a wider range of analyses and the possibility of carrying out sensitivity analysis;
- data can be included in the analyses which previously were considered too time consuming or tedious to derive and manipulate manually;
- problems and paths to their solutions need to be closely defined thus allowing the results to be closely scrutinized and better understood;
- digital cartographic output, particularly when in colour, permits more effective communication of the results to professionals within the team.

As a low-cost approach that is easily programmed, these types of analyses are likely to find widespread use in urban and regional planning.

ACKNOWLEDGEMENT

The author gratefully acknowledges the NT/South Development Office, Territory Development Department, Hong Kong Government for permission to publish this paper.

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GEOTECS - A SIMPLE COMPUTER MAPPING SYSTEM FOR PLANNING AND RESOURCE INVENTORY IN HONG KONG

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ABSTRACT

This paper describes a simple computer system used in the Geotechnical Control Office of Hong Kong Government for land planning and natural resource inventory. The system, known as GEOTECS (Geotechnical Terrain Classification System), is based on a two-hectare grid cell framework which covers the Territory.

GEOTECS was designed to support the terrain classification studies which were the basis for the regional Geotechnical Area Studies Programme (GASP) reports completed between 1979 and 1985. It contains information on: slope gradient, terrain, geology, erosion, geotechnical constraints, slope instability, vegetation, land use, topographic relief, slope aspect and rainfall.

GEOTECS has been applied to a number of applications involving planning, land management and natural resource assessment in the Territory. The system is used by the Geotechnical Control Office for regional and strategic purposes at scales from 1:50 000 to 1:200 000.

INTRODUCTION

In 1977 the Geotechnical Control Office (GCO) was established within Hong Kong Government, mainly in response to a number of major landslide disasters. Possibly the most dramatic of these were the Kotewall (Po Shan) Road landslip in 1972, and the Sau Mau Ping fill slope failures of 1972 and 1976. The Kotewall Road landslip, which resulted in the collapse of a twelve-storey building, occurred in an area of intensive multi-storey development in the Mid-levels district of western Hong Kong Island (Figure 1). This incident, possibly more than any other, demonstrated the need for a better understanding of the geotechnical constraints associated with terrain in the Territory.

A task of the newly-formed GCO was to ensure that future development in the Territory could proceed safely within an environment of steep slopes, high seasonal rainfall and intense socio-economic pressures for rapid development. With this in mind, the Office embarked on a programme of land resource mapping and geotechnical investigations, primarily to assist in planning and development of the Territory.

One of the first major acts of the Office was to initiate, on safety grounds, a moratorium on building development in the Mid-levels area of Hong Kong Island in May 1979. Arising from this ban on development, a series of terrain classification studies commenced in September 1979. These studies were at scales of 1:2 500 and 1:20 000 and were known as the Geotechnical Area Studies Programme (GASP).

The mapping programme was based on the production of conventional line maps for planning, land management and engineering feasibility applications within Government. Nonetheless, the need for a computer system to handle the land inventory information generated by the studies was recognised at an early stage. A simple computer system was developed to support the 1:20 000 regional GASP studies and to provide a databank of resource information.

The system was named the Geotechnical Terrain Classification System (GEOTECS), and had a relatively simple capability for the production of statistics and plotter-drawn maps. The design constraints on the development of the system were:

(i) the use of existing computer hardware available within Government in 1979,

(ii) an initial limit of only 1 to 2 megabytes for the size of each of the data files for this project,

Figure 1 - An oblique aerial photograph looking east across the Mid-levels district of Hong Kong Island in June 1972. The area is intensively developed and the Kotewall Road landslip is in the foreground.

(iii) the need to reflect the diversity of the terrain and existing forms of development (Figure 2) at mid to small scales (1:50 000 to 1:200 000), and most importantly,

(iv) to be operational within a three month period from November 1979.

During the regional GASP studies, small data banks were established as separate storage files for each of the eleven areas. Consequent on additional memory being allocated in 1986, the eleven area files were merged to form a single database for the Territory.

A number of publications deal with the GASP, and include examples of GEOTECS applications: Brand (1988); Brand, Burnett & Styles (1982); Geotechnical Control Office (1987a,b,c); Geotechnical Control Office (1988a,b,c,d,e,f,g,h); Styles & Burnett (1985); Styles, Hansen & Burnett (1986); and Styles & Hansen (1989).

Figure 2 - An oblique aerial photograph of the Quarry Bay area of Hong Kong Island in 1985. Squatters, disused quarries, water storage facilities, Country Park, multi-storey private and public housing highlight the contrast in land use which must be considered in the design of mapping systems.

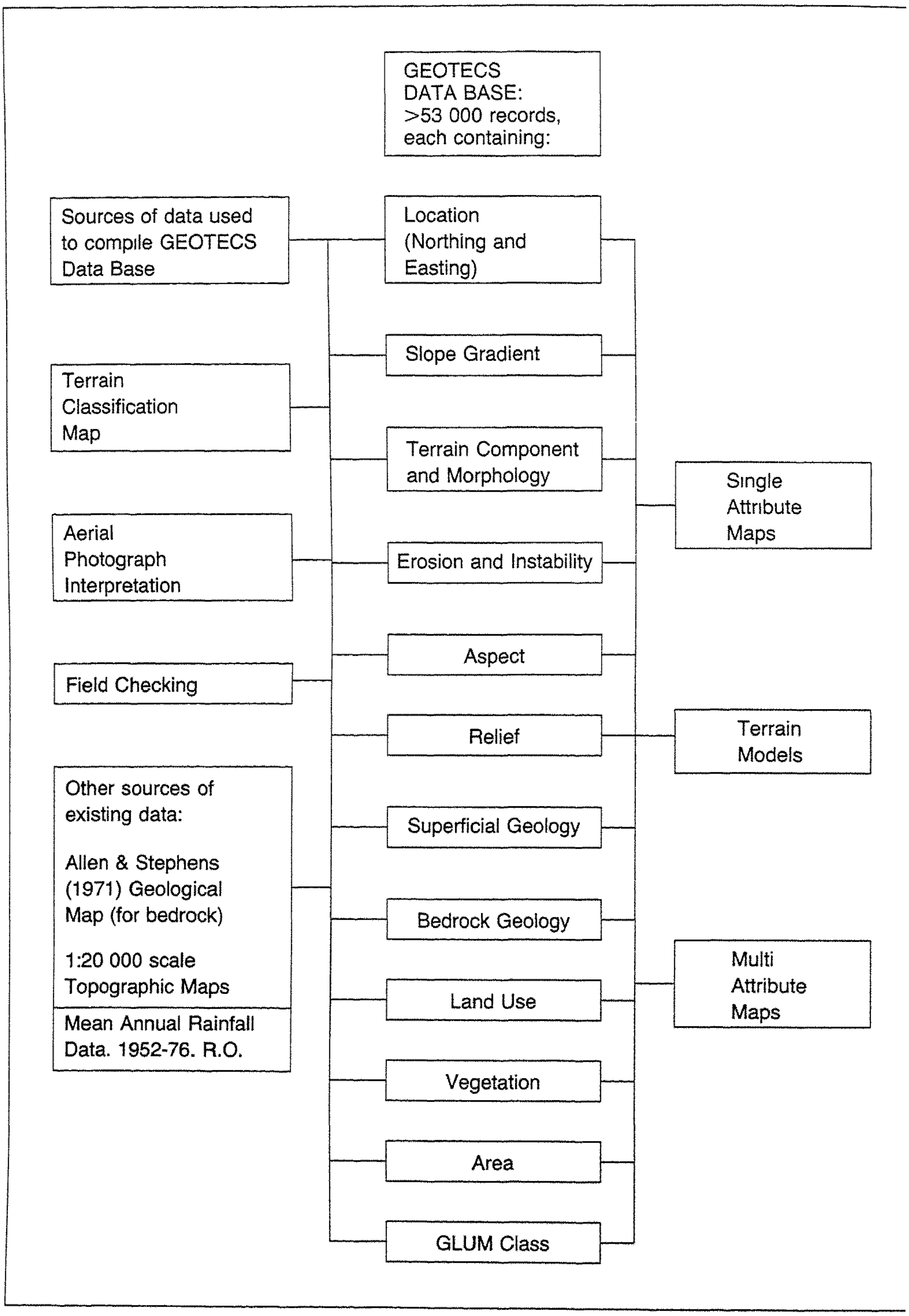


Figure 3 - A schematic of the GEOTECS system: sources of data, general content and types of maps and plots.

GEOTECS SYSTEM

The GEOTECS data bank consists of more than 53 000 grid cells for the land area of the Territory. Each cell is about 2 ha in size and contains information on: slope gradient, slope aspect, landform, geology, erosion, slope instability, land use, vegetation, geotechnical limitations, rainfall and relief.

Much of this information was extracted from the eleven regional 1:20 000 scale terrain classification maps; however, land use and vegetation resulted from separate aerial photograph interpretation (API), and bedrock geology, relief and rainfall were from other sources. Figure 3 provides some background about the sources of data and content of the system. A GEOTECS map of the Territory at a scale of 1:300 000 is given in Figure 4. The map consists of a photographic reduction of a computer-plotted slice superimposed onto a conventional base map. It contains an inset showing a section of the map at a commonly used scale. Cadastral information or locality names are not contained in the system.

The system operates on the ICL 2976 mainframe computer of the Hong Kong Government and can be accessed from any VDU terminal linked to this computer. The data bank and operating software occupy only about 4 megabytes. GEOTECS uses the Statistical Package for the Social Sciences (SPSS) software for data manipulation and the production of area statistics, and the SPSS and Calcomp software packages for map production.

The data stored in GEOTECS is defined for a grid cell framework derived from the Hong Kong 1980 Metric Grid. The grid has its origin at 847000N, 801000E. Each kilometre on the northern and western axes of the metric grid is divided into seven equal parts, giving 49 grid cells per square kilometre. Each cell covers an area of approximately 2.04 ha, providing data coverage of a similar magnitude to that of the original GASP line maps. The grid starts at the northwestern corner (0,0), with the latitudinal co-ordinates increasing southwards, and the longitudinal co-ordinates increasing eastwards. Each grid cell is referenced by its northeastern corner.

DATA PRESENTATION

GEOTECS enables the production of computer maps which assist in the presentation of terrain attributes and other data on a Territory-wide basis. The distribution of land resources can be evaluated for planning and engineering purposes. Computer-generated maps or statistical tables can be based on any single attribute or combination of attributes stored within the system.

Due to its 2 ha grid cell base, GEOTECS is recommended for use at scales of approximately 1:50 000 or smaller (i.e. 1:50 000 to 1:300 000) for strategic planning and resource inventory purposes.

With the aid of GEOTECS, solutions to many problems can be found *without* the need for expensive studies or large numbers of

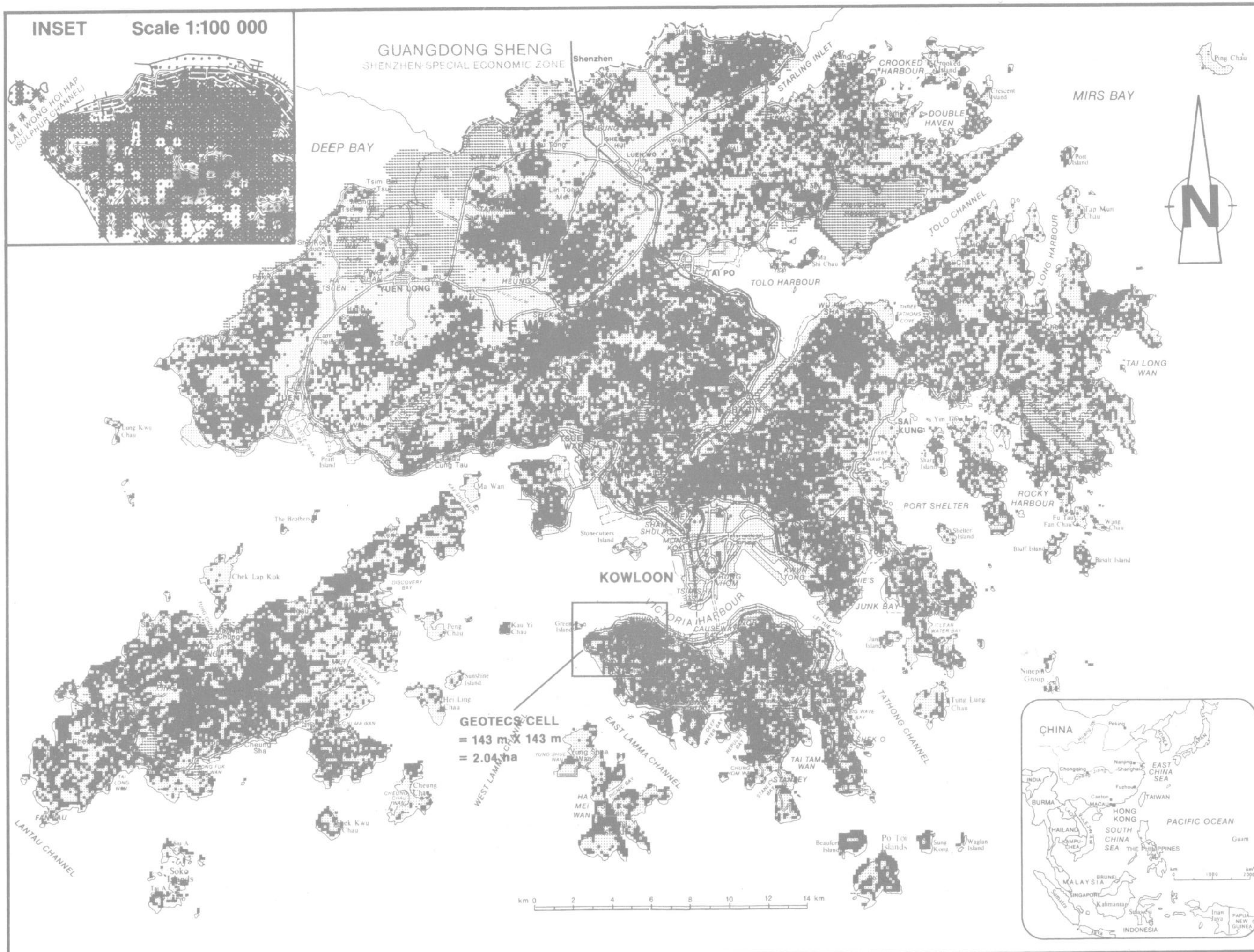


Figure 4 - GEOTECS map of the Territory showing the 52 000 ha of terrain with high to extreme geotechnical limitations(*). The map is a photographic reduction of a GEOTECS slice reproduced on a conventional base map. The scale is approximately 1:300 000. The inset high-lights the western end of Hong Kong Island at a normal production scale of 1:100 000. Each character (*) represents one grid cell of about 2.04 ha.

staff on the ground. Some examples of uses by Government are:

- Preparation of a geotechnical hazard zonation for squatters. Initially, GEOTECS was used to identify the locations of unsafe slopes occupied by squatters, and provided the basis for a non-development clearance policy.

- Identification of areas prone to flooding. Following serious flooding in the northern New Territories in July 1988, GEOTECS was used to highlight the extent of some 5 400 ha of floodplains.

- Potential sources of land-based fill for the study of harbour reclamation and urban growth (SHRUG). GEOTECS was used to identify undeveloped terrain with general suitability for borrow.

Some illustrations of a range of computer-generated maps and plots are given in Figures 4 to 8. The GEOTECS maps in Figures 5 to 7 are extracts from 1:100 000 scale maps of the Territory. The information contained in the data block in the upper left hand corner of each of these Figures is for the entire Territory.

The computer format allows an extremely flexible approach to map production. Computer-generated, single- or multi-attribute features can be combined with survey base maps by conventional reprographic methods.

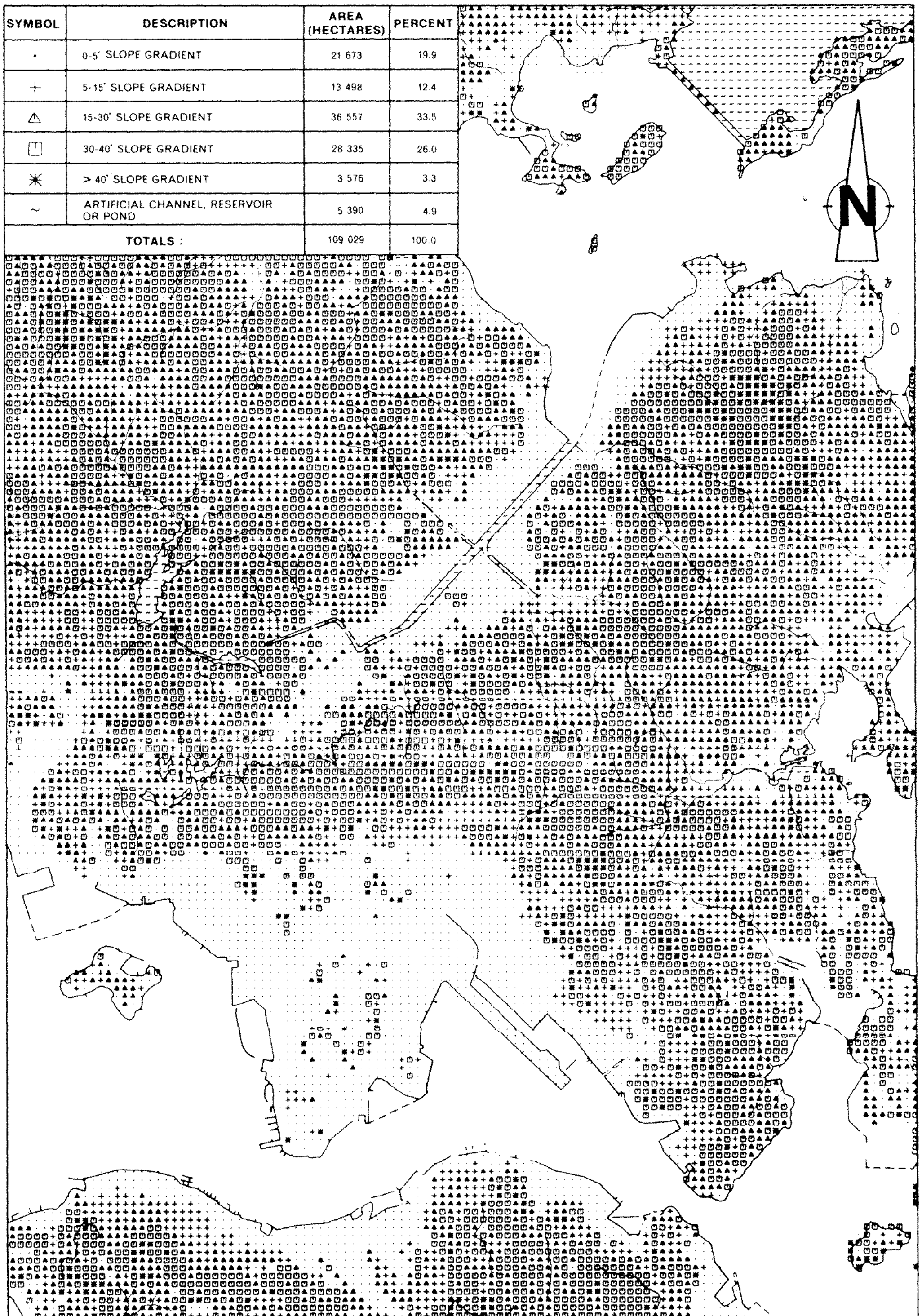
Single-attribute Maps

An extract from the 1:100 000 scale GEOTECS Slope Gradient Map of the Territory is given in Figure 5. This map is a single-attribute map showing the general distribution of slope gradients. The data block contains the classes of slope gradient mapped during the GASP studies. For example, an impression of the overall terrain can be gained from the fact that some 70% of the Territory is steeper than 15° in gradient.

Multi-attribute Maps

An example showing the distribution of terrain with high to extreme geotechnical limitations is presented in Figure 4. This is a reduction of a multi-attribute map prepared from a number of terrain features including slope gradient, terrain component, geology, erosion and instability. It provides an indication of the magnitude of geotechnical constraints affecting the Territory.

An extract of another example of a multi-attribute GEOTECS map is in Figure 6. This map groups together the various forms of slope instability in the Territory. Whilst some 52 000 ha or about 47% of the Territory is affected by geotechnical constraints; slope instability is manifest on about 23 000 ha of this terrain.



SYMBOL	DESCRIPTION	AREA (HECTARES)	PERCENT
·	0-5° SLOPE GRADIENT	21 673	19.9
+	5-15° SLOPE GRADIENT	13 498	12.4
△	15-30° SLOPE GRADIENT	36 557	33.5
□	30-40° SLOPE GRADIENT	28 335	26.0
✳	> 40° SLOPE GRADIENT	3 576	3.3
~	ARTIFICIAL CHANNEL, RESERVOIR OR POND	5 390	4.9
TOTALS :		109 029	100.0

Figure 5 - An extract from the 1:100 000 scale GEOTECS Slope Gradient Map. The data block presents information for the entire Territory.

An extract from the 1:100 000 scale GEOTECS map illustrating existing development, reclamation, undeveloped terrain and Country Park is presented in Figure 7. This map highlights the principal forms of land utilization. An interesting feature of the data contained on this map is that, although about 15% of the Territory is quite intensively developed, some 80% remains as Country Park and other undeveloped terrain.

Terrain Models

Data on the topographic relief can be used to form simple three-dimensional models of the terrain. The angle and the direction of view can be altered depending on the required perspective. Examples are presented in Figures 8 and 9. A view of the Territory from the southeast is given in Figure 8, whilst a large-scale model of Hong Kong Island is given in Figure 9.

TARGET MAPS

The most powerful use of GEOTECS is for the production of target maps for the assessment of strategic options. These single-, or multi-attribute maps are conceptual in nature and are designed for planning, engineering and land management needs. The maps are most successful when designed to highlight only one dominant feature. Some examples of Target Maps are:

- Flood-prone terrain,
- Reclamation,
- Erosion,
- Undeveloped terrain with potential for borrow,
- Undeveloped terrain with low to moderate geotechnical limitations outside Country Park.
- Residential development near woodland.
- Vegetation on undeveloped terrain.

USAGE

It is good practice to provide users with guidance on the use of maps, whether produced by computer or by conventional methods. In the case of GEOTECS products, all published maps contain a printed statement about the recommended level of usage, general purpose and source of data.

GEOTECS maps should not be used to evaluate sites smaller than 5 ha in size. They are designed for planning, resource inventory, land management and engineering feasibility studies at a regional and strategic level. They should not be used at scales larger than 1:20 000 and are recommended for use from 1:50 000 up to a scale of 1:300 000.

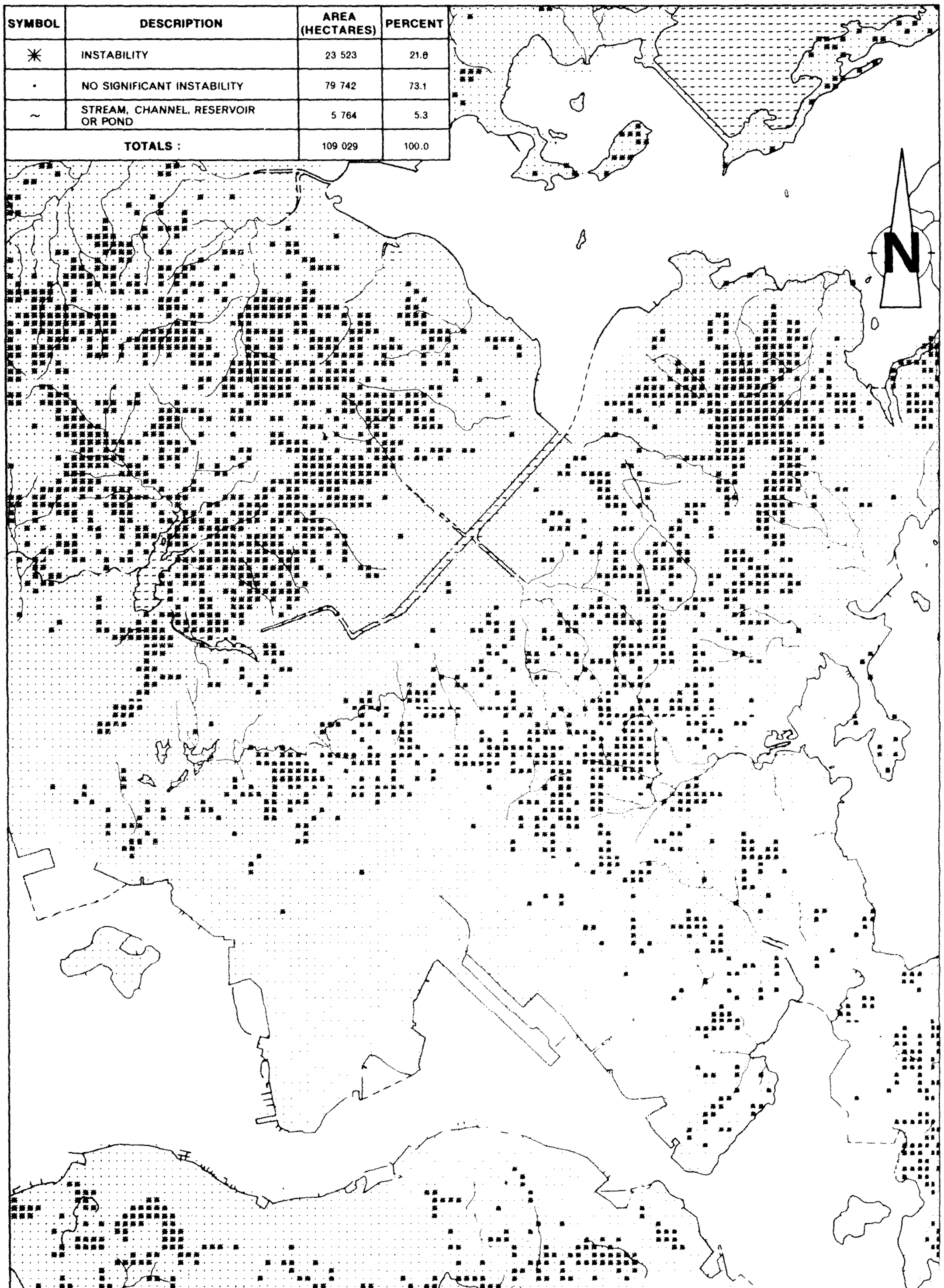
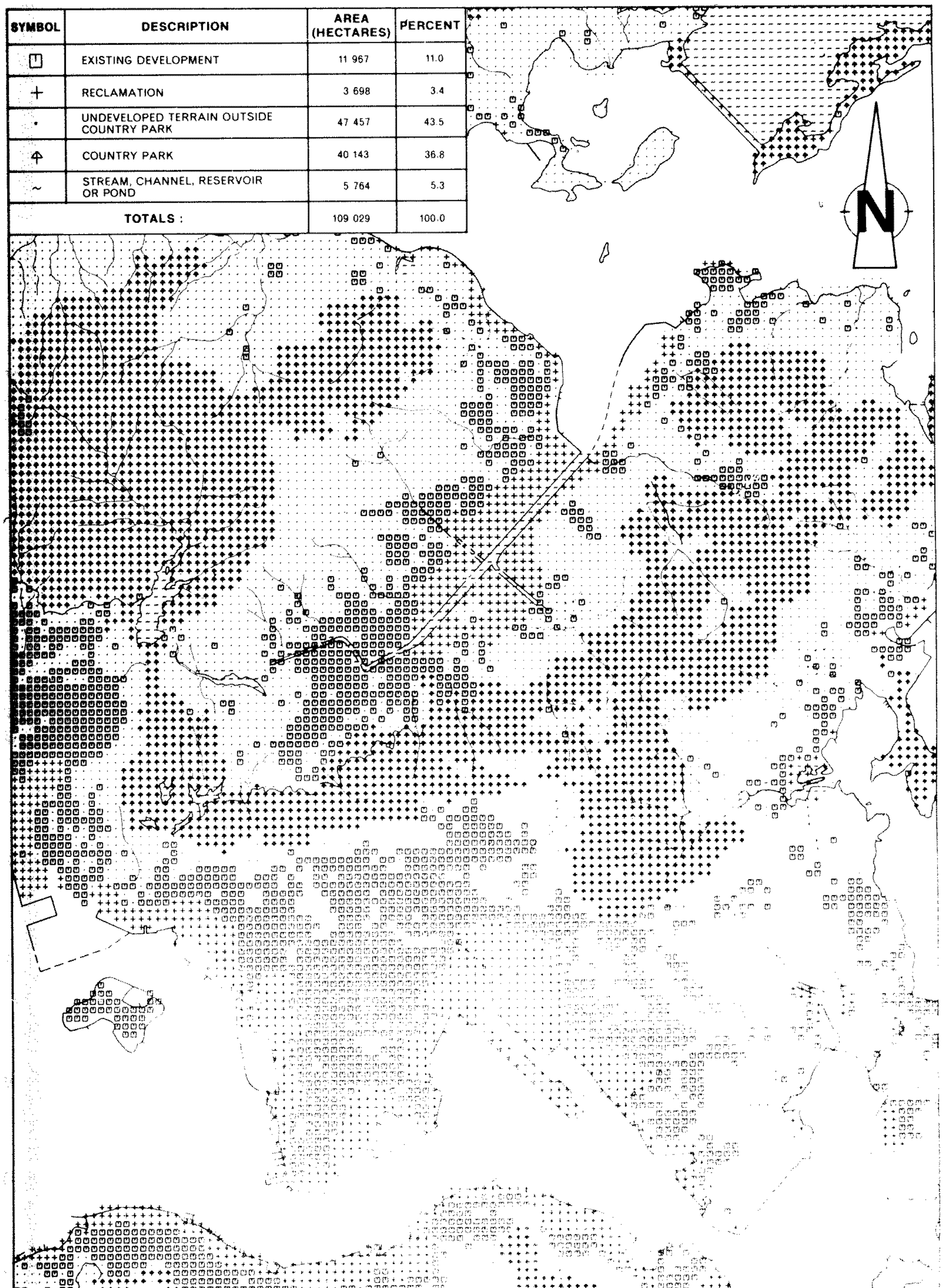


Figure 6 - An extract from the 1:100 000 scale GEOTECS Slope Instability Map. The data block provides information for the entire Territory.



SYMBOL	DESCRIPTION	AREA (HECTARES)	PERCENT
□	EXISTING DEVELOPMENT	11 967	11.0
+	RECLAMATION	3 698	3.4
•	UNDEVELOPED TERRAIN OUTSIDE COUNTRY PARK	47 457	43.5
	COUNTRY PARK	40 143	36.8
~	STREAM, CHANNEL, RESERVOIR OR POND	5 764	5.3
TOTALS :		109 029	100.0

Figure 7 - An extract from the 1:100 000 scale GEOTECS Map showing major forms of land utilization. It highlights the general distribution of existing forms of development, reclamation, intensive forms of undeveloped terrain and Country Park. The data block gives information for the entire Territory.

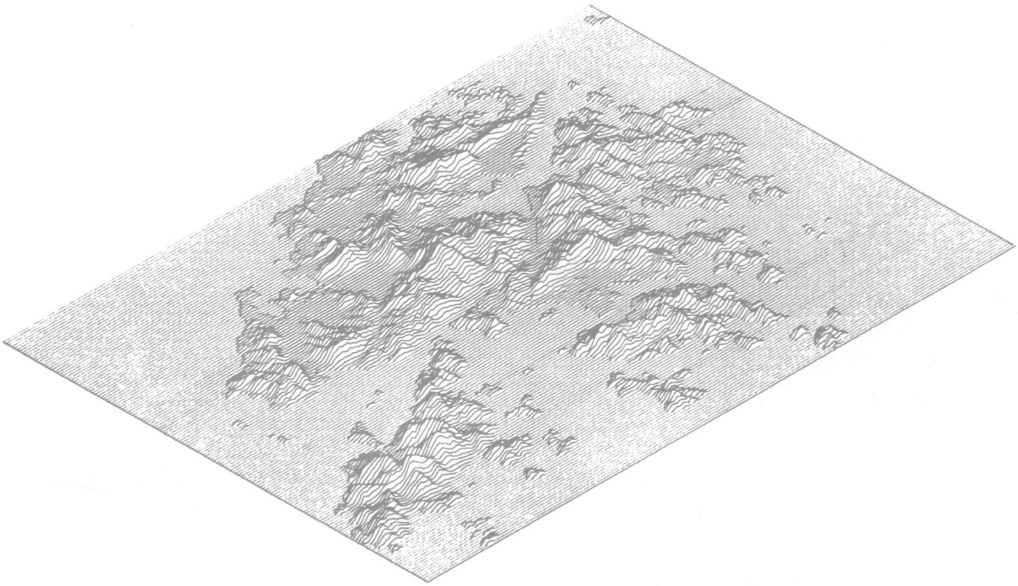


Figure 8 - A terrain model of the Territory viewed from the southwest.

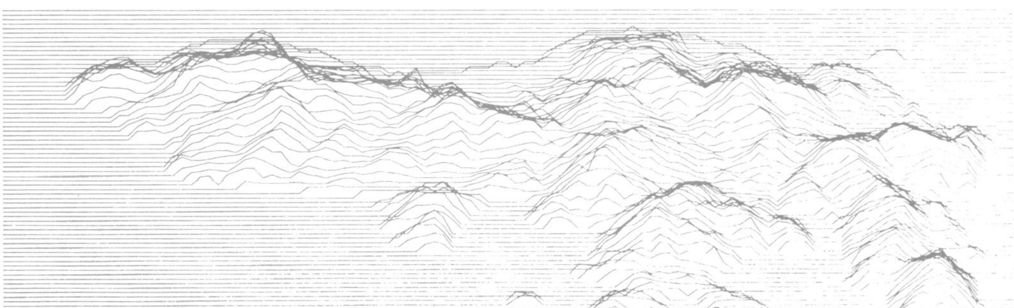


Figure 9 - A terrain model of Hong Kong Island viewed from the south.

CONCLUSION

It is possible to gain great value from simple computer mapping systems without the need to develop sophisticated software, or to commit either extensive staff resources or high expenditure. Very effective results can be achieved, even with what might be considered dated technology, possibly because the most important factor in usage is the impact of the product on the decision-maker, whether it be a map, model or data table.

A most important issue in the development of a computer data base for planning and land management purposes is that the level, accuracy or relevance of data contained in the system, is comparable and compatible with the range of uses of the maps and other products. The best value in a computer mapping system containing land inventory data, can be achieved if the data contained in the system approximately equals the level of usage, i.e. user expectations must not exceed the performance criteria of the system. From experience, there seems to be considerable difficulty in this goal being achieved - software designers and in some cases, system managers, may become more interested in the technology and operational performance of the system than in the quality and representativeness of the stored data.

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COMPUTER AIDED LANDUSE TRANSPORT ENVIRONMENT ANALYSIS SYSTEM

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ABSTRACT

This paper presents an integrated system for the comprehensive evaluation of the environmental impacts at the detailed design, project plan and master plan levels in urban transportation planning. The framework is based on an integrated model for the interaction among the three elements Landuse, Transport and Environment. This system is integrated with a Geographical Information System (GIS) and consists of several interactive modules that fall into three main categories: i) map display, ii) simulation and iii) evaluation. Finally, the possibilities of practically applying this system in urban transportation planning is also discussed.

1. INTRODUCTION

By the turn of the century, almost half of humanity will live in cities; the world of the 21st century will be largely an urban world. Over only 65 years, the developing world's urban population has increased tenfold, from around 100 million in 1920 to 1 billion today. In 1940, one person in 100 lived in a city of 1 million or more inhabitants; by 1980 one in 10 lived in such a city. The increasing pace of urbanization and the resulting environmental degradation and lack of green spaces demand close monitoring of the infrastructure development in these cities.

Urban Environmental Problems

In the twentieth century urban transport has increased accessibility for both resources and people through the mobility, flexibility and convenience it offers. While urban transport has thus contributed to the improvement of living standards for the urban dwellers, the benefits they offer have been progressively diminished by their environmental deterioration. Figure 1 shows the trends in environmental pollution from traffic in selected cities of the industrial world.

The growing awareness among the urban dwellers about the deteriorating environment has resulted in a variety of legislative measures to preserve the environmental quality. One of the major causes of environmental deterioration is urban transportation, because it not only directly but also indirectly affects the environment. Then, in the planning and implementation of improvements in urban transportation, it is essential to carefully consider the conservation of environmental quality against the other economic benefits.

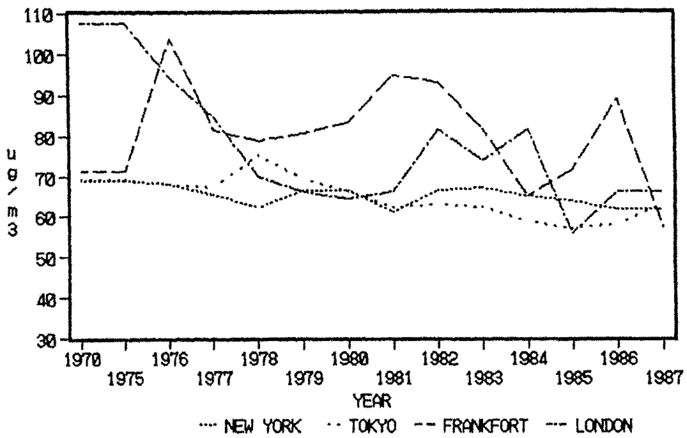


Figure 1. CONCENTRATION OF NO_2 IN SELECTED CITIES OF THE WORLD

Tools for Urban Environmental Analysis

The proliferation of computers have necessitated changes in the approaches for environmental analysis. Computers are a great advantage in the automation and simulation of environmental consequences. The computer graphics assist in the easy presentation and understanding of environmental impacts. With the application of user-friendly softwares the analyses and evaluation of project alternatives are feasible in the assessment. (Teicholz, 1983).

2. ELEMENTS OF URBAN TRANSPORTATION PLANNING

The Levels in Urban Transportation Planning

In any urban region, the transportation planning and design are carried out at a number of levels of detail and decision making. The analyses and decisions change from one level to another level of the planning. Also, the urban transportation planning is not a unique task but a set of sub tasks of different scales and scopes. Table 1 shows the different analyses and decisions required at the different levels of planning. For example, at the detailed design level, the estimation of noise and air pollution from road traffic requires a microscopic view of transportation system. But the analysis of changes in the landuse as a result of a new master plan must be done at a much macroscopic level with estimates made over a longer period.

The Interaction among the Elements in Urban Transportation Planning

The understanding and analyses of the interaction among the Landuse, Transport and Environment as shown in Figure 2

Table 1 STAGES IN URBAN TRANSPORTATION PLANNING

	MASTER PLAN	PROJECT PLAN	DETAILED DESIGN
Plans for	Urban Scale	Local Scale	Design and Implementation
Plan Contents	Network design New Transport modes	Traffic control over a large area	Road design signal control Anti-noise wall
Plan Period	20 Years	10 Years	Based on Proposal
Map scale	1:50000 or less	1:10000 ~ 25000	1:5000 ~ 2500
Locational data	Zones	Street blocks	Individual buildings
Road data	location of major trunk roads	location and structure of minor trunk roads	location and detailed structure of all roads possible
Traffic data	daily volume, etc.	daily volume by mode, etc.	hourly volume by mode, etc.
Forecast	Changes in Population Employment Landuse Travel demand	Changes in Travel pattern Road traffic	Hourly variation of traffic by mode
	Total emission of pollutants in the area	Population exposed to pollutants in the area	Level of pollutants near the buildings
Policies for conserving Environmental Pollution	Zoning for urbanization promotion, New transport modes, new roads	Zoning in the local area, Route design, Road tax	Land development project Parking control, Anti-noise wall

are very important to effectively evaluate the impacts of improvements in urban transportation. Existing studies have considered the Landuse and Transport interaction in detail and explicitly.

<u>Landuse-Transport Interaction</u>

In a typical Landuse and Transport interaction model, the behavioral aspects of the residents and firms to locate and travel are included in the modeling to represent the interaction (see Nakamura et al., 1983). The link from Transport to Landuse is represented by including criteria such as accessibility in the allocation of activities to given land parcels in a manner designed to simulate a typical economic market mechanism. The link from Landuse to Transport is represented by translating the resulting land uses into their trip generation and distribution characteristics, which are used in planning the transportation facilities. The resulting changes in accessibility will then affect the future location of activities.

Only a few environmental factors such as residential environmental quality have been included in the behavioral models considered in the Landuse and Transport Interaction. In order to consider the policies that are based on other environmental factors it is necessary to consider the links with Environment more explicitly as will be discussed here.

<u>Landuse-Environment Interaction</u>

The environment pollution from firms and households sufficiently represents the link from Landuse to Environment. Industrial pollution, residential wastes like garbage, sewage do affect the environment. The link from Environment to Landuse is partially achieved by public policy to conserve the environment and partially due to the behavior of the locators. The application of policies for controlling the industry location can change the environmental pollution. The residential location choice intrinsically considers the different environment factors too. The decision to leave a polluted location is more vivid if not the decision to choose one because the environment is better.

<u>Transport-Environment Interaction</u>

Environment effects of road traffic is very comprehensible. The road traffic results in noise and air pollution in the neighbor roads. While such direct impacts of Transport clearly represents the link from Transport to Environment, the link from Environment to Transport is mainly achieved by public policies. The lack of behavioral interaction necessitates more policies to conserve the environment in this respect. Immediate traffic pollution counter measures such as building noise barriers like walls, hedge are effective on the local surroundings. But they do

Figure 2 ENVIRONMENT—LANDUSE—TRANSPORT INTERACTION

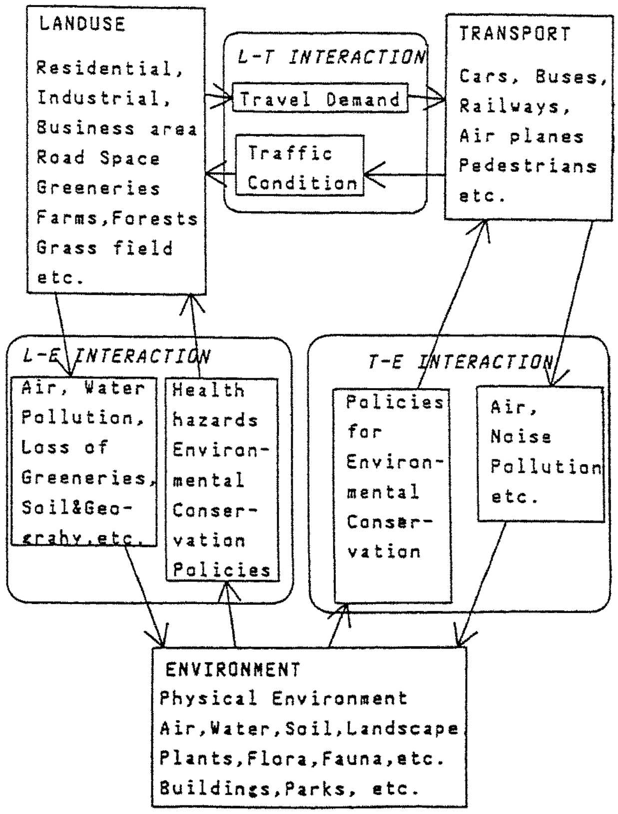
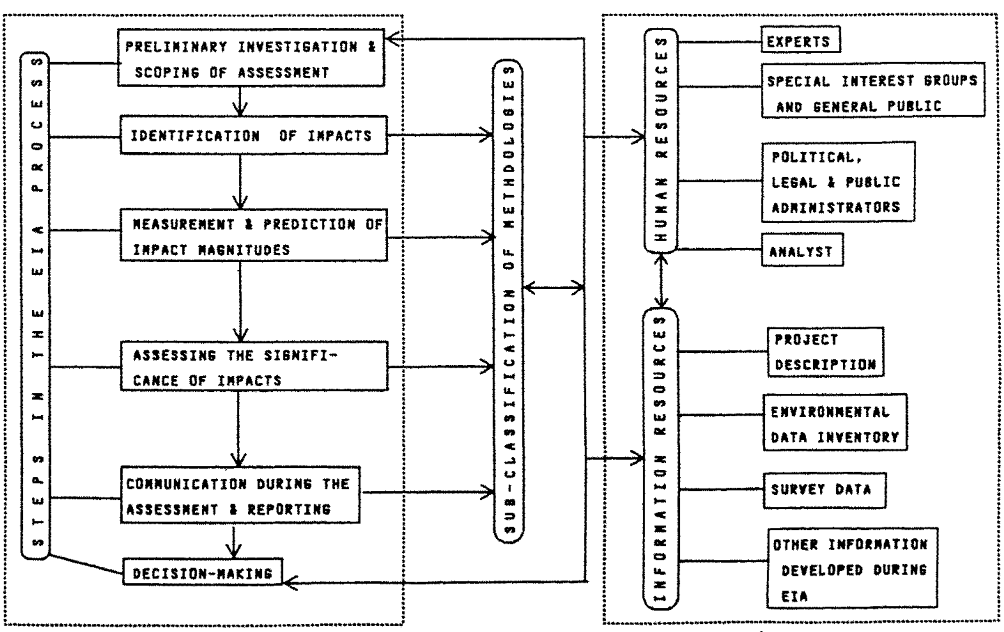


Figure 3. CLASSIFICATION OF METHODOLOGIES BASED ON THE STEPS IN EIA



not still solve the problem of air pollution. Whereas, traffic control measures are more efficient to alleviate both air and noise pollution over a wider area.

Finally, based on the level and plan period of the urban transportation planning, the importance of each link between the elements varies. At the master plan level, all the links are important to be considered. At the project plan level, the interaction between Transportation and Environment and the link from Landuse to Environment are more important than the others. At the detailed design level, only the direct impacts from Landuse and Transport on the Environment are necessary to be considered. Further, to comprehensively evaluate the environmental impacts of urban transportation policies an integrated approach is essential.

3. ENVIRONMENTAL IMPACT ASSESSMENT

The various steps in the preparation of an EIA are
1) identifying the impacts
2) measurement and prediction of impacts
3) assessing the significance of impacts
4) communication with concerned parties and reporting.

There is interaction with both human and information resources at all these steps in the EIA procedure as shown in Figure 3. The existing approaches for EIA can be considered as systems which are combination of methods classified into categories based on the steps in EIA. Using a list of 22 criteria the application of the system for EIA in urban transportation planning can be evaluated. (Seetharam et al, 1988).

Present approaches for EIA urban transportation planning deal with mainly the detailed design level, where only the direct environmental impacts of road traffic are considered. As discussed earlier, the policies that can be tested at this level are limited in number and effectivity. Although there are a few applications of EIA at the higher levels, the uncertainties in the realization and location of the project and the alternatives result in inaccuracies and arbitrariness in those evlauations. So, in order to consider the alternatives at higher level as shown in Figure 4, it is necessary to develop comprehensive procedures for the EIA, so that it can address these levels. This is impossible without considering the interaction among Landuse, Transport and Environment.

4. THE INTEGRATION OF EIA IN URBAN TRANSPORTATION PLANNING

In this paper, the integration of EIA with urban transportation planning is presented. The integrated system addresses the different requirements of the macro as well as micro aspects of the analysis involved in the various levels of planning. Figure 5 demonstrates the interaction among the different elements of urban transportation and the role of

FIGURE 4. EXISTING EIA APPROCHES IN URBAN TRANSPORTATION PLANNING

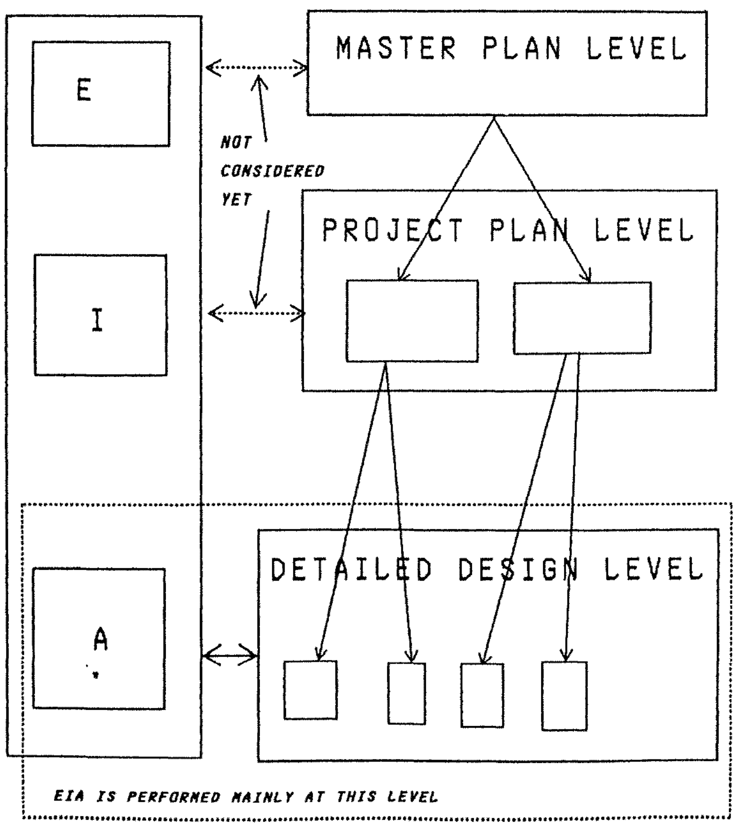
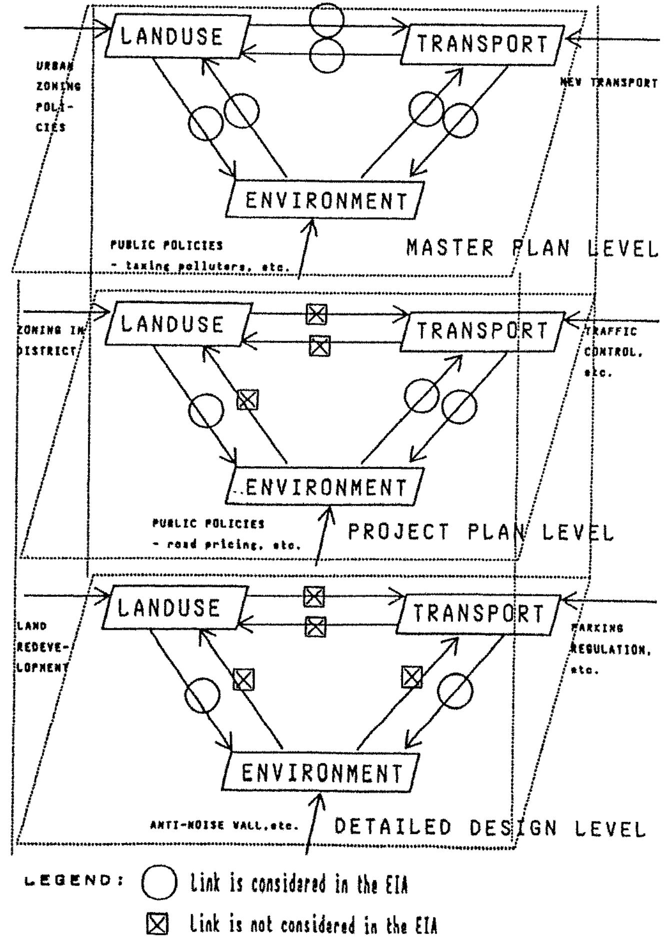


Figure 5. EIA AT THE DIFFERENT LEVELS OF URBAN TRANSPORTATION PLANNING



EIA in selecting the appropriate policies for improving the environment.

For example, at the detailed design level, only the direct environmental impacts from landuse and transport are considered in the EIA. Here only counter measures such as anti-noise walls can be tested.

At the project plan level, the environmental conservation policies include traffic control measures such as removing through traffic by road design, which are effective over a wider area. They can often be combined with schemes which improve the environment, like designating pedestrian-only areas or simply restricting the movement of heavy vehicles in residential zones. There are also other options such as road pricing, etc. All these in turn affect the road traffic and change the congestion levels, which affect the pollution in many related areas. To really test these policies, the environmental impacts must be simulated after the traffic assignment is done. Hence, here the Transport-Environment interaction will be the main focus.

At the master plan level, long term policies such as improving the network structure,·not only change the travel demand, but also affect the locational desire of firms and households. Similarly, zoning policies or taxing for pollution, affect the location of firms and households, which then affect the travel demands. So, the EIA at this level must focus on all the interactions.

Thus, the contents of EIA at the different levels of planning is different as shown in Table 2. The type of analysis required at the detailed design level are more microscopic, while at the master plan the macroscopic analysis is required for evaluating the alternatives.

Data Requirements

In order to efficiently analyze the alternatives at the master plan level, for example, a new ring road project, it is important to use a large scale map to avoid the uncertainties in the location of the road and the estimation of the environmental impacts, although the final evaluation will have to be done with a small scale map. Such spatial analyses demand large volumes, different types and details of data required for those spatial analyses, which cannot be efficiently handled without a Geographical Information System (GIS). With the choice of such analyses involving simulation and detailed evaluation of results, the application of computer graphics and systems becomes inevitable.

5. GIS INTEGRATED SYSTEM FOR EIA

A system has been designed for the integrated EIA. This Computer Aided Landuse Transport Environment Analysis System

Table 2 ELEMENTS OF THE INTEGRATED EIA FOR THE DIFFERENT LEVELS IN THE URBAN TRANSPORTATION PLANNING

	Levels in Urban Transportation Planning		
Steps in EIA	Master Plan	Project Plan	Detailed Design
Scope of Project	Network Planning New Infrastructure Planning	Route Planning	Road Design
Identification of Impacts & Project Alternatives	Environmental damage for the entire area Major alternatives like new modes, roads taxing, etc.	Environmental Problems in a local area Alternatives like rerouting, capacity control, etc.	Pollution in the immediate surrounding Alternatives like anti-noise walls, etc.
Measurement and Prediction of Impacts	Long term impacts Impacts from changes in land use Landuse-Transport-Environment Interaction	Short term impacts Impacts from changes in traffic volume Transport-Environment Interaction	Immediate impacts Effects of anti-noise walls, etc. Impact of Transport on the Environment
Assessing the Significance of Impacts	Consider total emission of pollutants in the area	Consider exposed population in the area	consider actual values of noise and air pollution at each location
Communication & Reporting	Use Expert opinions	Use Public hearings	Use home interview

(CALTEAS) consists of a GIS based database and several user-interactive modules for performing input display and analysis, which are essential for the EIA. These modules can be classified into three sub systems namely map display, simulation and evaluation. An outline of the system is shown in Figure 6. CALTEAS is being developed on the Sun3 workstation.

The Map Display Sub system

The map features are stored in the database as points, lines and polygons, which have unique identifiers and are linked through relational files. The socio-economic and environmental attributes based on the polygons and the traffic data based on the links are stored in indexed files using the polygon and link identifiers are keys respectively.

The map consisting of polygons and links can be displayed conveniently with any scale between 1:1000 and 1:50000. With the use of scroll bars the different parts of a map that extends to four times the size of the screen can be viewed conveniently.

The socio-economic attributes can be displayed with colors using the legends that classify them into different intervals between the minimum and maximum values. The extreme values are chosen automatically from the map currently displayed while the length of the interval can be interactively chosen. It is also possibly to overlay two attribute features to see impacts such as population affected by different noise levels. Such easily understanble visuals are very effective to demonstrate to results of EIA to the concerned groups.

The Simulation Sub system

This sub system consists of modules for simulating the air and noise pollution due to the traffic on the neighboring environment. The impact of all roads within a 400m radius from a location is considered in the estimation of air and noise pollution. The noise pollution can be estimated approximately at the macroscopic level, with the estimate at the centroid of a block representing the average pollution in the block, considering only the average height of buildings in that block. At a microscopic level, more accurate estimation is done, for each building in a block, considering the heights of individual buildings. In the estimation of air pollution the effects of wind can be either included or excluded depending on the scale of simulation. Similar modules are being for estimating the environmental pollution from factories.

Presently the system can also simulate the traffic volumes using the zonal trip distribution and network data by performing the traffic assignment. Now, policies such as removing a certain link, reducing the capacity of some roads to reduce environmental pollution can be tested. The models for trip generation, modal split and trip distribution, and the location models are being developed.

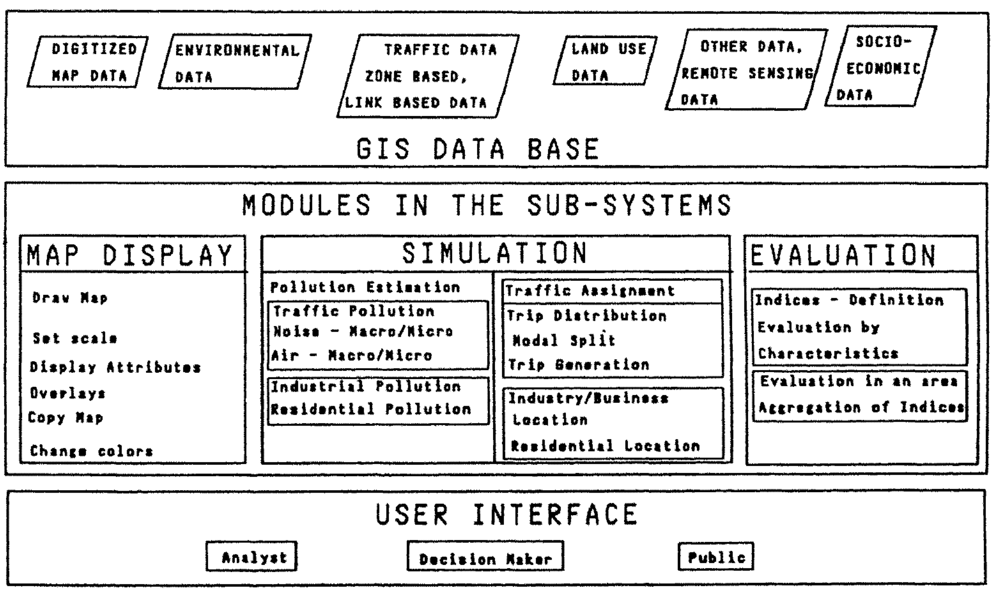
Evaluation Sub system

The evaluation subsystem has three major functions. First, the definition of indices representing the environmental impacts can be performed interactively. With these indices, then the second function, is to define a way to combine them based on other factors such landuse, population density, etc. Finally, the display of the indices and the results of the final evaluation in terms of graphs is the last function. The second function, requires input from experts and it is proposed to develop an expert system for this purpose later.

6. APPLICATION OF CALTEAS

In order to test the first version of CALTEAS which includes modules to represent the Transport-Environment interaction in the integrated model, the socio-economic and traffic data available in Metro Manila in Philippines before the construction of the Light Rail Transit (LRT) were input into the system. The environmental situation before the LRT was estimated. Then, forecasts were for the traffic situation and the resulting environmental pollution after the LRT. The evaluation based on number of persons affected by different noise and air pollution levels showed that the environmental situation improved in many areas after the introduction of the LRT. The following two pictures are shown to give an idea of the some of the results in the application.

FIGURE 6. FRAMEWORK OF CALTEAS



7. CONCLUDING REMARKS

CALTEAS is a very useful system for the comprehensive EIA in urban transportation planning. The ability to evaluate indirect impacts considering the interaction among Landuse, Transport and Environment, makes it possible to apply EIA at the higher levels in the planning. The integration of GIS is very advantagous to analyze comprehensive policies for environmental conservation with more accuracies in the evaluation. The capability of the system to present the results of EIA through easily understandable visuals makes CALTEAS a useful tool for the planner to communicate with concerned groups. The authors will report in future on further development and application of CALTEAS.

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Seetharam K.E., Miyamoto K. & Nakamura H., 1988, A review and classification of the existing methodologies for environmental impact assessment, Proceedings of the infrastructure planning, Japan, Vol 11, pp 325-332.

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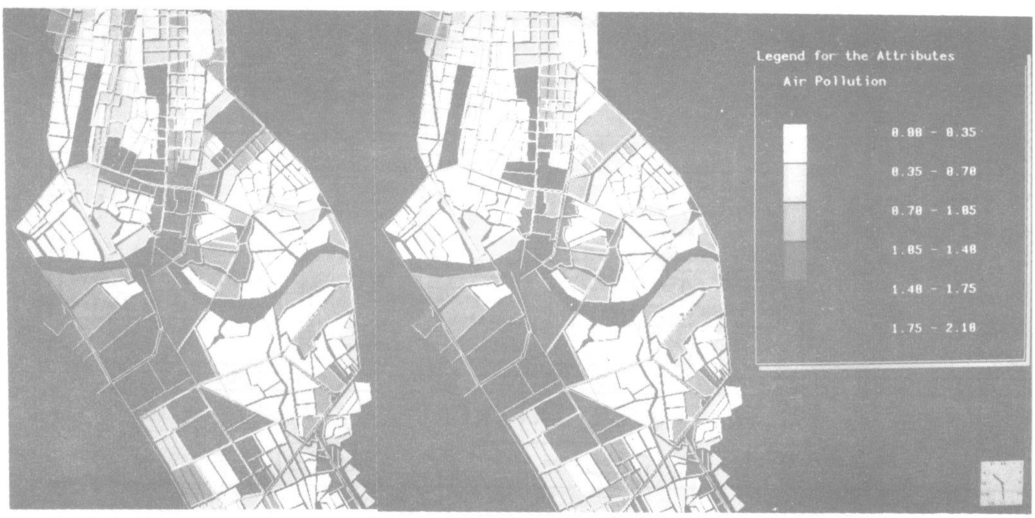
RESULTS OF THE APPLICATION OF CALTEAS

Picture 1. Before LRT **Picture 2. After LRT**



LAND-USE AND TRANSPORT MODELLING IN THE PERTH METROPOLITAN REGION : AN INTEGRATED APPROACH

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ABSTRACT

In 1988, the Western Australian State Planning Commission (SPC) in conjunction with three other government agencies commissioned a major land-use - transport study of the Perth Metropolitan Region. The study - known as the Road Reserves Review (RRR) - has two principal themes. The first is to review the procedures involved in reserving land for future transport requirements. And the second, to determine whether existing road reservations can be rationalised under the SPC's preferred strategy for the future development of Perth.

The only way to test the viability of the preferred strategy is to measure its performance against some alternatives. Accordingly, three additional land-use scenarios have been developed. The scenarios are sufficiently different from each other and from the preferred strategy - while remaining within the bounds of possibility - to generate quite different transport modes and networks.

This study represents a notable achievement in land-use and transport planning in Australia. It is the first time that four computer based models have been integrated to evaluate the merits of alternative forms of urban growth.

The first of these models - the Interactive Spatial Planning system provides social, economic and land-use data for the Perth Region, over a 30 year forecasting horizon, based on a system of 65 data collection zones. The second is a custom built disaggregation model (CADAS) which disaggregates the land-use data to Main Roads Department (MRD) traffic zones.

The RRR model (based on 179 traffic zones) is a hybrid model incorporating elements of the MRD model (based on 606 traffic zones, and the Department of Transport model. At the more detailed level it is used for highway assignments, while at the more aggregated level, for trip estimates and distributions, and for modal split analysis.

Following a general introduction, the discussion will focus on the land-use stage of the study.

The ISP system will be introduced and the base year (1986) variables identified. This will be followed by a discussion of the modelling process, including: the development of a set of externally generated regional parameters which are and common to all scenarios, scenario generation and quantification, special purpose policies, scenario evaluation and the computer aided disaggregation system.

The paper will conclude with an appraisal of the land-use models, highlighting their strengths and weaknesses and identifying directions for future research.

'DEVELOPMENTS IN COMPUTER-AIDED TEACHING OF LAND-USE AND TRANSPORT PLANNING TECHNIQUES'

by

J A Black and T T Ton

Abstract

Land-use and transport planning has been taught formally both as a post graduate subject and as a component of a professional education course in transport at the University of New South Wales since 1957. This paper reflects on the innovations over the last 15 years in the educational philosophy and methods of teaching land-use and transport planning models at the undergraduate and postgraduate levels to engineers and town planners. It describes developments of computer programs running on both main-frame and on micro-computers.

The material presented in the paper is based on experience with software developed specifically for educational purposes at the University of New South Wales. In order to emphasise practical applications, a computer program named MLUTRAN, was based on models, equations and parameters developed by consultants in their advice to the National Capital Development Commission on the long-term strategic planning of land-use and transport in Canberra, Australia's capital city. The program may be run in one of three modes: as a suite of land-use and transport planning models; as a Lowry model of land-use and transport interaction; or as a multiple objective optimisation model. A critical appraisal of computer-aided teaching, including student views, is offered and some directions for future developments are indicated.

1. Introduction

In 1955, when the Prime Minister of Australia, Mr R G Menzies, announced that a graduate School of Traffic Engineering would be established at the University of New South Wales, the Chair of Traffic Engineering became the first professorial position of its kind anywhere in the British Commonwealth. A subject on land-use and transport planning was soon established in the curriculum of the coursework masters programme, and as part of a semester-long, full-time graduate special short course on traffic planning and control. The underpining philosophy of these courses - the fundamentals of land-use and transport interaction and the application of mathematical analysis and operation research techniques - can easily be distiled from the publications of the Foundation Professor of Traffic Engineering (Blunden, 1967, 1971).

When the senior co-author of this paper joined the School of Transportation and Traffic in 1975, he was responsible primarily for lectures on local area, urban and regional transport planning. Students frequently asked about the practical applications of theory, and this was one factor in the inclusion of chapters on Canberra as a case study of land-use and transport planning in a text-book Urban Transport Planning: Theory and Practice (Black 1971, 1987T). During these "number crunching days" of the mainframe computer, practical applications were not taught with the aid of commercially-available software packages, such as UTPS, but with specially written programs. These programs, have subsequently evolved as teaching experience accumulated and as the technology of main-frame computer hardware and peripherals has changes, and have been subsequently revised in response to the commercial breakthrough in 1978 that transformed the micro-computer from the kit form into a mass produced, ready-to-run, personalised computer.

This paper reflects on the changing technology of computers and its impact on the teaching of transport planning at the University of New South Wales from 1975 to the present. Three historical phases are identified: the "pencil and paper" days (Section 2); the transition from "number crunching" on the mainframe to more man-machine interaction (Section 3); and the micro-computer revolution (Section 4). In each phase, the influence of computers on the educational process are indicated and discussed and then reviewed, finally, in Section 5. Principles in designing such computer programs are formulated, and experiences in teaching undergraduate, graduate and continuing professional education courses - to both civil engineers and to town planners - are assessed from a lecturer's perspective and from student feedback, through formal subject evaluations and assignments. The philosophical approach that has emerged is of course subject to educational debate and challenge. However, its significance, in terms of student numbers alone, are that from 1981, when a Foundation Chair of Transport Engineering was established in the School of Civil Engineering, and additional transport subjects were taught as part of the BE (Civil) curriculum, a total of about 600 undergraduate students, 100 graduate students and 250 transport professionals (including delegates from the People's Republic of China) have been exposed to some of the ideas presented in this paper.

2. Pencil and Paper Approaches

A conceptual model of the educational process set out in schematic form (Figure 1). This figure shows typical steps of the conventional process using the blackboard in the lecture room and tutorial support. The lecturer starts with definitions, equations and a discussion of static diagrams. Typically,the analysis method would be presented, a simple worked example is set out, and how to cope with variations in the analysis would be indicated. These are predominantly "passive" learning experiences for the student. It is only in the tutorial that the students become "active", but, due to time constraints, simple, and not necessarily realistic, problems are set. A good example of this would be the calibration of a trip distribution model where an even 3 x 2 zone matrix requires tedious, repetitious calculations. Student assignments are designed to make any calculations feasible in the time allocated, and so simplification of the problems faced in later professional practice is again necessary. In fact, many engineers and planners would subscribe to the view that students learn in the "real world".

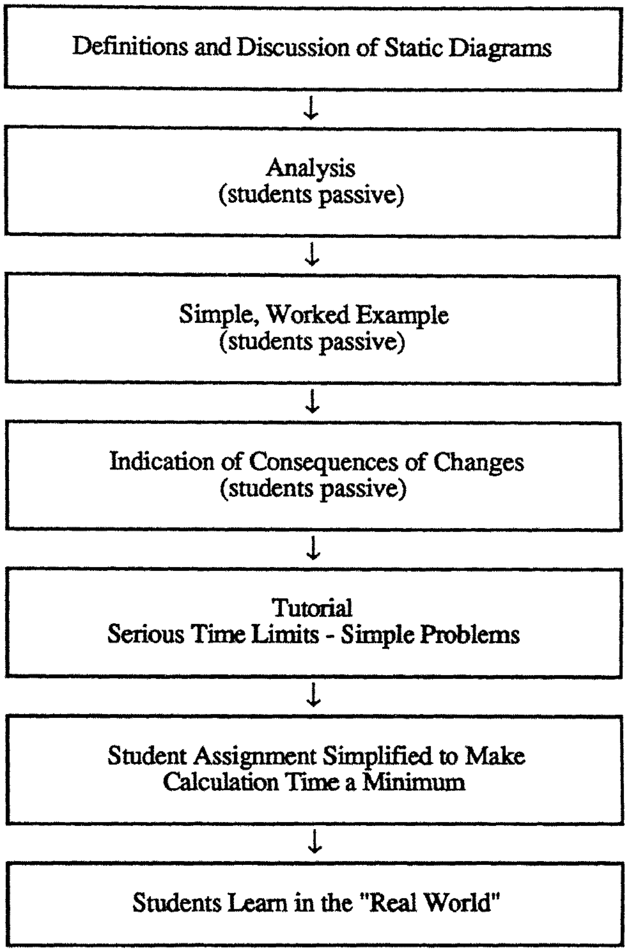

Figure 1: Schematic Diagram Showing the Conventional Learning Process in a Curriculum

When this educational model is applied to the teaching of land use and transport planning techniques - for example, the calibration of the model parameters for trip generation, trip distribution, modal split and traffic assignments - only simple worked examples (restricted in the number of zones, number of explanatory variables, or number of routes) can be given. In the mid 1970s, the School of Transportation and Traffic had an IBM 1620 Computer with a card reader and such a computer environment was not very suitable for teaching purposes. To augment lectures on transport planning practice, where Canberra was used as an example (see Black, 1981, Part II), an elementary program had been written to calculate, for a user specified input of zonal land use, vehicular trip generation and vehicular trip distribution. The printed output was in the form of an 16 x 16 zone origin-destination matrix. Students selected origin zones and completed manual traffic assignments. In hindsight, this early exploration into computer-based instruction was of limited value but it did pave the way for subsequent developments with computer graphics.

3. Main Frame Computers

MLUTRAN is a computer program developed on the University of New South Wales Cyber computer and used in the multiple objective evaluation of land-use transport plans with specific reference to Canberra, the capital city of Australia. The formal mathematical technique of multi-objective programming (Blunden and Black, 1984) provides a framework for grappling with conflicting objectives and trade-off situations. When the decision maker is unaware, or unsure, of the relative importance (weighting) of each objective, appropriate trade-offs between the number of objectives must be determined. The program was designed specifically as a man-machine interactive system with computer graphics to assist decision makers in their search for better strategic land use and transport plans. The program requires approximately 180 kilo octal cp words of core memory (60 bits to a cp word on the Cyber 171).

By varying a single control instruction, the same program can be run as a conventional aggregate 4-step land-use and transport planning model. Most of the traffic forecasting equations embedded in the program are those used by engineering consultants in their work for the National Capital Development Commission in the planning of Canberra. These studies are described fully in Black (1981, pp 154 - 158). The models used by the consultants were all standard models, and their structure and calibration parameters require no elaboration for the purpose of this paper. However, the main features of the models are:

(a) linear regression models of mode-specific trip generation;
(b) fully constrained gravity models with a power functions of distance for trip distribution; and
(c) highway and public transport traffic assignment based on the all-or-nothing method.

In the actual planning of Canberra, and the formulation of the Concept Plan, the evaluation of land-use and transport alternatives used average travel times by trip purpose, travel costs and vehicle-kilometres of travel as the main quantitative criteria (see, Black, 1981, pp. 160-165). However, in addition, MLUTRAN includes a broader range of performance measures: travel time/flow relationships for 6 road designs; accident and fatality rates; estimates of pollution; road and land-use development capital costs; and zonal indices of accessibility to employment (summarised as a gini-coefficient).

After transport planning practice in Canberra as a case study has been described in the lectures , students then tackle a workshop using MLUTRAN running as a conventional transport planning package. In designing this program for educational purposes, the amount of input data required on the part of the students was deliberately limited. Sixteen "macro zones" in the Canberra region were defined, where 1 million people 360,000 basic and service sector jobs must be allocated (to some, or all, of the zones). Superimposed over the land- use zones is a road network of 27 links, where a choice of 6 geometric designs and road capacities (from a 6-lane freeway to a 2-lane arterial) must be made for each of the 27 links (the network configuration is deliberately fixed and links cannot be added or deleted). Students are provided with the Concept Plan (which was adopted as policy by the NCDC to guide the long-term development of Canberra) and the results of this plan provide a means of judging the performance of their individual designs.

All of the workshops have had common features summarised below.

(a) A lecture of about two hours describing the real-world context for applying the models (Canberra in this case).
(b) An overview of the inputs and outputs for MLUTRAN (one hour tutorial).

(c) How to run the program and obtain the output (the time required depends on whether the participants are familiar with editing commands).
(d) The specification of the problem set to students.
(e) Sufficient time (typically of two-weeks duration) for participants to undertake the designs, analyse the results and prepare a report.
(f) Presentation of key results by a few selected participants, discussion of individual approaches and solutions.
(g) General questions and comments on MLUTRAN (about one hour for (f) and (g)).

It is worth noting that "problem" set can be either an open-ended one where participants have to define the objectives of their plan, or plans, or can be specific with constraints, such as "develop a land-use plan that minimises residential development cost and has a budget for roads not exceeding $250 million" or "develop a land-use and road plan that minimises environmental costs."

Although the amount of data entry and editing for the user of MLUTRAN is restricted to only several lines on the terminal, the amount of output is comprehensive. This includes results of the land-use and transport models: the land-use plan arranged by zone; estimates of zonal vehicular trip generation; a matrix of inter-zonal origin-destination traffic estimates; and road line related information (design standards selected, construction cost, speeds, travel times, volume/capacity ratios and accident rates). An important educational feature of MLUTRAN is the representation of the output of these models is graphical form. The line printer is used to produce maps of zonal accessibility level with three levels of shading. A specifically written program interprets the results into graphical form that can be previewed on a graphics display terminal (such as a Tektronix Plot - 10) before hard copies are obtained. Examples of the graphics capability are given in Figure 2, which shows the zonal distribution of basic and service sector employment, the zonal distribution of basic and service sector employment, the zonal distribution of basic and service sector employment, the zonal distribution of population, the daily vehicular traffic derive line pattern, and the assignment of this traffic to the road network.

The overall performance of each land-use and transport design is summarised in a table containing economic, social and environmental indices. These embrace total road development costs, total residential land development costs, accessibility measures (using the gini coefficient), mean trip lengths and travel times, accident rates, vehicular emissions and the potential market for introducing a mass rapid transit system. This is the most informative part of the exercise for students because they are confronted with multiple evaluation criteria, and realise that it is impossible to optimise all objectives and that there are conflicts and trade offs. It sheets home the link between defining planning objectives and plan evaluation. Many students, at his point, are motivated to re-think their objectives and redesign another land-use and transport plan to satisfy themselves of the implications of different design philosophies.

In 1987, the University of New South Wales replaced its Cyber Mainframe with an IBM 3090 and the machine-specific graphics for MLUTRAN was lost. The program can still be run on the School of Civil Engineering's VAX computer but without the graphical plotting capability. MLUTRAN is now being developed as a micro-computer program to meet the challenges of the micro-computer revolution of the 1980s and the expectations raised by knowledge-based systems.

4. Microcomputer Revolution

It is important to recall that, world-wide, the application of microcomputers in transport planning spans less than one decade. One early response was formalised in the summer of 1981 when the Institute of Transportation Engineers Technical Council formed

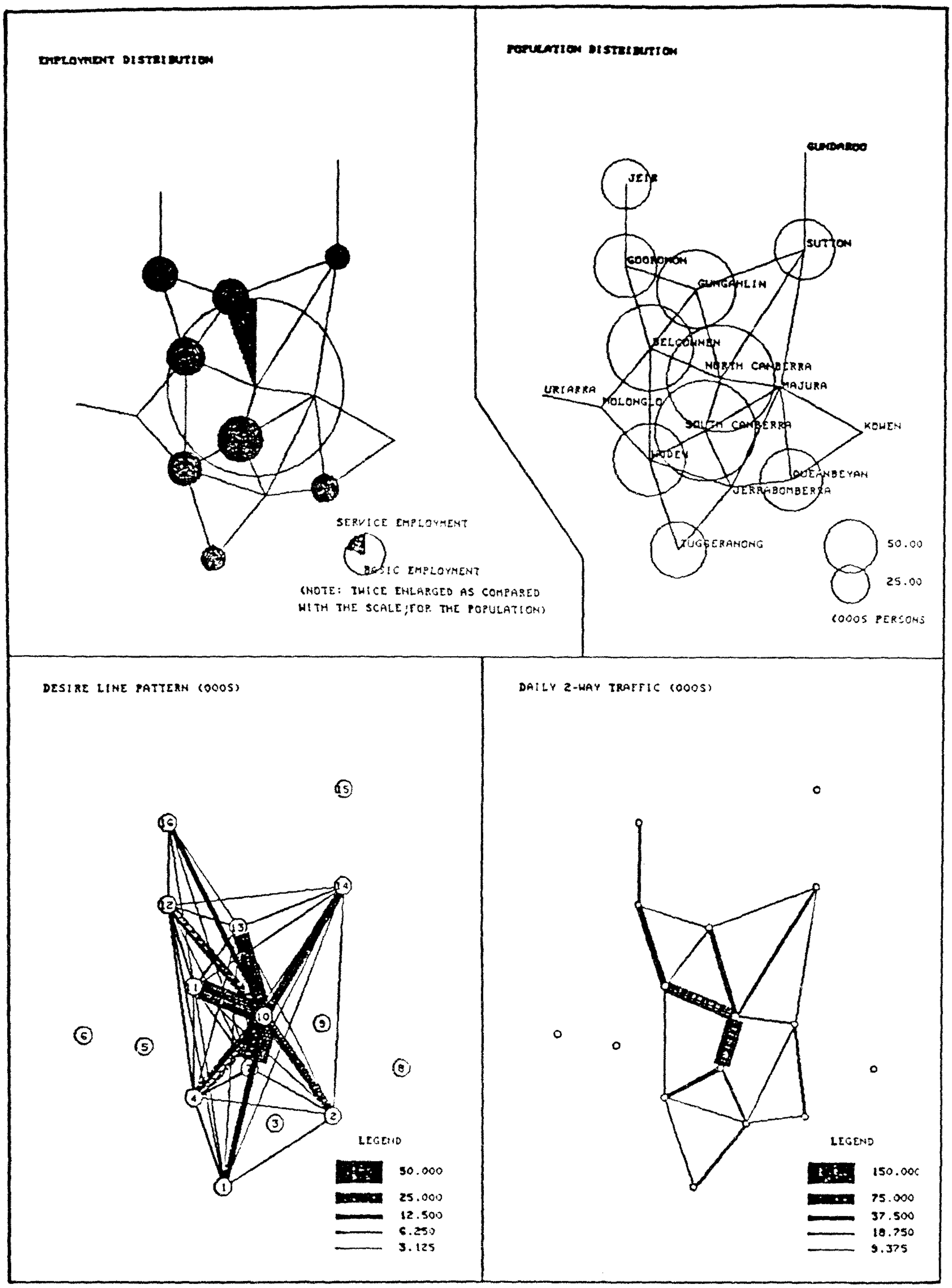

Figure 2: Examples of Graphical Output of MLUTRAN for a Design that Minimises the Cost of Residential Land Development in Canberra at a Projected Population of One Million.

Committee 6E-29 'Microcomputer Applications in Transportation Engineering'. Initially, this committee concentrated on making an inventory of micro-computer application (hardware and software) and on investigating the feasibility of technical workshops (Institute of Transportation Engineers, 1982; Weinstock, 1982). Following the Institute's first workshop at their 1982 Annual Meeting, the U.S. Transportation Research Board's Task Force on Microcomputers in Transportation sponsored a workshop in conjunction with the Board's 62nd Annual Meeting in January, 1983, that covered the areas of planning, public transport, traffic engineering and railway engineering (Manheim and Simkowitz, 1983).

In Australia, at Monash University, the Department of Civil Engineering reviewed some of the developments in micro-computers and computer graphics applied to transport planning and design and identified some suitable commercial software packages (Richardson, et al, 1983, Young and Taylor, 1984). In 1982, a University of New South Wales Special Research Grant allocation to the Department of Transport Engineering lead to literature searches, appraisal of suitable hardware and software, program development, testing and documentation of a number of transport programs, including an educational package explaining the theory of land-use and transport interaction. As a basic tenet of the engineering profession is responsibility for the calculations, transport planning students must be exposed to the basic methodology, assumptions, formulae and equations, factors and constants and limits on the data that are embedded into computer-aided analysis. This led to design principles in guiding the development of appropriate programs for the micro-computer. They were:

(a) the program should eliminate repetitious calculations from analysis work and so facilitate sensitivity analyses to be undertaken;

(b) the program should be interactive with the user;

(c) both tabulated and graphical results of calculations should be produced;

(d) contextual information may be displayed on the screen but no instruction manuals should be supplied because they become misplaced, and are rarely up-to-date; and

(e) a demonstration example must be included in the program.

In formulating these design principles we had in mind the educational purpose to provide advice to graduate students who were undertaking Master of Engineering Science research projects (on quarter of the coursework masters programme) using micro-computers. Projects included floppy diskettes appended to the inside cover of the project report. Portability of the programs for demonstration and teaching purposes is an obvious advantage of micro-computers. One example is traffic analysis for road planning. The sections following on traffic system analysis outline the menu-driven computer program and then describe their component parts. the explanation of these sub-programs are kept to a minimum - technical references are indicted where appropriate. These chains of sub-program have been used both in the civil engineering graduate and undergraduate curriculum at the University of New South Wales, in special graduate short courses organised by the School of Civil Engineering, and in technical training seminars as part of the United Nations Development Programme (UNDP) - Urban Highway Planning for Indonesia.

In the planning of either new transport , or transport system management schemes, macro-behavioural laws of land-use and transport interaction are used to calculate the equilibrium between travel demand and transport supply. Traffic and travel-time equilibrium solutions are examined, and the dynamic nature of the land-use and transport system is evaluated by conducting sensitivity analyses of land-use activity levels and transport capability - the analytical core of the land-use and transport planning process.

system is evaluated by conducting sensitivity analyses of land-use activity levels and transport capability - the analytical core of the land-use and transport planning process.

A simple numerical example of this process, simplified to the case of two land-use zones and two roads connecting the zone centroids is set out in Black (1981, pp. 33-34) and this problem formed the basis of a program written in Basic for the Apple IIe microcomputer, that demonstrates the fundamental concepts and equations, and then calculates equilibrium solutions for user-specified parameters and other data inputs of planning kind. The menu that drives this program is reproduced as Figure 3.

Assignment problem menu

0 ⟨⟨exit⟩⟩

1 ⟨demo⟩ concept of equilibrium

2 ⟨demo⟩ concept of two route equal-time assignment

3 ⟨demo⟩ concept of two route equilibrium assignment

4 Analysis of two route equilibrium assignment

5 Analysis of two route equilibrium assignment (with printing capability).

Select by number ⇒

Figure 3: Menu for Traffic Analysis for Road Planning Microcomputer Program

These sub-programmes, arranged in increasing order of complexity, have been described elsewhere (ten Brummelaar and Black, 1985) and are only summarised here.

⟨demo⟩ <u>concept of equilibrium</u>

This is a simple graphical display of the well known concept of the intersection of a demand and a supply curve. Travel demand from one place to another is calculated from the unconstrained form of the gravity model. Transport supply - the travel-time/traffic flow relationship - is calculated from Davidson's formula (with the implicit zonal subscripts dropped):

$$T = T_0 \frac{[1 - (1 - J)Y]}{1 - Y}$$

where,

T = travel time from zone 1 to zone 2;

T_0 = 'zero flow' travel time from zone 1 to zone 2 (ie the reciprocal of the free speed);

J = level-of-service parameter that characterises different road designs and their driving environments; and

Y = ratio of traffic flow, Q, to the saturation flow, or capacity of the road, S.

The sub-program draws the graph, labelling the horizontal abscissa 'traffic volume' and the vertical abscissa 'travel time'. In drawing the above non-linear functions for and appropriate range of numerical inputs the pitch of the programme reminds the users of two important conditions: as traffic volume increases so too does the travel time to make the journey; and as the travel time increases the travel demand decreases. Equilibrium is the intersection of the two curves and the numerical values for traffic volume and travel time are indicated respectively on the abscissae by the vertical and horizontal lines drawn through the equilibrium point.

⟨demo⟩ <u>concept of two route equal-time assignment</u>

When there are two (or more) roads, traffic assignment theory to tow (or more) alternative routes in a corridor (or to a complex network of facilities) is founded on Wardrop's principle which postulates that no individual traveller can become better off by finding a route with travel times lower than those defined by an equilibrium, or an equal travel-time assignment. The problem posed to the student on the terminal screen is to make an initial guess of route traffic assignments then to adjust them interactively. A graphical display shows the numerical values of the travel times as a bar chart for the user specified inputs. The objective of this sub-program is to obtain bars of equal height and so effect an equilibrium assignment by trial-and-error.

⟨demo⟩ <u>concept of two route equilibrium assignment</u>

This sub-program draws the formal graphical solution, together with a printed explanation of the steps involved, to the two zone, two route problem explained in Black (1981, p.33-43). Figure 4 is a reproduction of a hard-copy of the solution which appears on the screen. It shows the input data, the graphical solution and the equilibrium results for the route traffic assignments and the travel time. The traffic units are in thousands of vehicles per hour and the time units are in minutes. In the design of this sub-program, delay loops. as suggested by Leith and O'Shea (1980) have been included to allow the student to properly assimilate the build-up of the methodology that produces the final display shown on the screen.

<u>Analysis of Two Route Equilibrium Assignment</u>

This sub-program is identical to that described previously except that the user is prompted to specify the parameters and variables of the demand and supply equations. This feature allows sensitivity analyses to be conducted that produce a new equilibrium situation and thus simulate the traffic implications of various land-use and transport policies. At the conclusion of each analysis a prompt appears on the screen as to whether a repetition of the analysis with revised input data is required.

Readers familiar with the equations of land-use and transport interaction for simple problems will realise that there are algebraic methods to solve explicitly equilibrium solution. In the problem presented in Figure 3 one of the J values has been deliberately set to unity to ensure that Q_1 or Q_2 is obtained by solving the roots of a quadratic equation. However, in this sub-section, Newton's approximation for solving the roots of a cubic equation has been used, and this allows the equilibrium solution to problems where either J1 or J2 are not equal to unity.

<u>Analysis of Two Route Equilibrium Assignment</u>

This is identical to the previous sub-program with the addition of a hard-copy output. This feature is specific to a hardware system and requires an IDS Paper Tiger Printer because the graphics are machine dependent on the Apple IIe Microcomputer.

Summary of the Input

Route 1:	S1	=	3
	J1	=	3
	T01	=	24
Route 2:	S2	=	2
	J2	=	1
	T02	=	38

Demand Characteristic

Q = Q1 + Q2 = 120/T

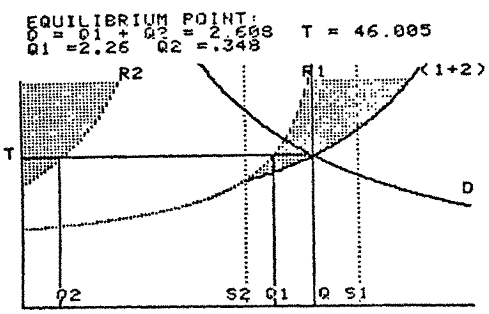

Figure 4: Equilibrium Solution to a Two Route, Two Zone Problem of Travel Demand and Transport Supply as Presented by the Apple IIe Microcomputer

The traffic systems analysis program described above forms the basis of a micro-computer laboratory session for graduate students in the Theory of Land-Use and Transport Interaction (8.403G) where the assignment is for the student to devise their own problem (that is, specify the equations and planning inputs) for a "base case" and then to test the implications of various planning policies. One weakness in the program that has been exposed in the laboratory environment is that any numerical values radically different from those specified in the lectures are outside the computation bounds of the program algorithms. However, with ingenuity on the part of the student this weakness has been overcome by introducing scaling factors for traffic volumes and travel times. Figure 5 sets out the equivalent educational process to that given earlier in Figure 2 when computer-aided analysis is used in teaching. Initially, the power of computer graphics allows the lecturer to give the definitions supported by demonstrations with dynamic diagrams. This has an important function enthusing the students who recognise that analysis and design can be creative and imaginative, not soley tedious and repetitious. The students become "active" with hands-on trials with the program, they can verify the results of more complex examples and investigate the consequences of variations to the problem. The power of the computer allows more realistic assignments to be formulated and this equips the student more adequately for the challenges of the professional world.

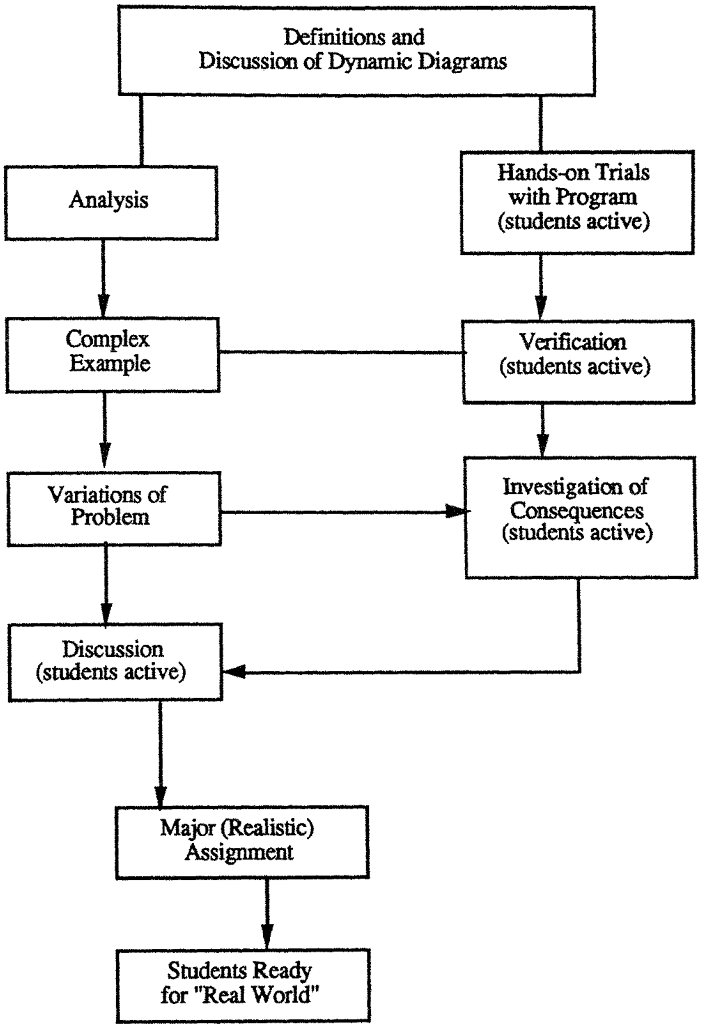

Figure 5: Schematic Diagram Showing Computer-Aided Instruction in a Curriculum

5. Summary

Teaching methods in civil engineering and planning still involve extensive use of the blackboard. Complex diagrams such as those reproduced as Figures 2 and 4 are difficult to draw with any degree of accuracy and any pre-prepared illustrations for the overhead projector suffer from a static presentation inherent in that medium of visual aids. Computer displays are dynamic and also repeatable. Seldom would a complicated diagram in chalk on a blackboard be erased and redrawn in order to reiterate a point to the class. The pencil and paper days allowed the essential theory, structure and calibration of simple land-use and transport models to be taught but would arguably not prepare students for the "real world."

Computer graphics are accurate and so can be used to not only emphasise points but also show in rapid succession a large number of different pictures all showing subtle variations around the point being made. Computer-assisted learning was slow to gain acceptance, primarily due to the high cost of mainframe computer facilities. The relative low cost of personal computers now provides an impetus to this form of learning - a technique made even more powerful by the graphic capabilities that are being developed. An obvious development for both the MLUTRAN and the traffic system analysis programs, for example, is to make them explicitly computer-assisted learning programs with dual capabilities, and for use after class by the students themselves to reinforce the ideas presented in the lecture. The latter capability could be readily implemented as a knowledge-based system with the text on the screen (in any language) and direct linking with a video monitor that has film or real-world traffic conditions represented by the analytical equations of the travel time/traffic flow conditions.

In an article on educating tomorrow's transportation planners, Meyer (1985, p. 85) emphasised the importance of strategic planning and two areas that warranted special attention. The first area is that planning is a continuous process of setting broad objectives, devising appropriate policies, and communicating decisions. The second area is that the management of the flow of information and the communication of information are central elements of the planning process. The structure of MLUTRAN - where the emphasis is on the user specifying the objectives and evaluating, and communicating, the results of different plans - is especially suitable to meet Meyer's educational challenge. To quote a professional engineer participating on a special short course: "Initially, my first run was a dud... The model overall is interesting and the complexities it is able to process are little short of incredible. A real eye opener."

During the past fifteen years, the technology available to support teaching has changed dramatically leading to new opportunities. With this "revolution" in mind, we have developed programs for the teaching of transport planning. Having described the main feature of our programs we have shared our educational experiences in undergraduate and graduate teaching and in professional short courses by formulating conceptual models of the educational process before and after the introduction of computers.

We are confident that an appropriate sequence of presenting the teaching material is: (a) to explain the theory and principles with traditional, blackboard lectures and pencil and paper analysis, (b) to reinforce the theory of land-use and transport interaction with the traffic analysis micro-computer program described in Section 4, (c) to demonstrate the application of the theory to a case study (here, in Canberra), (d) to explain how MLUTRAN has been developed from real-world planning problems, and (e) to conduct a workshop using MLUTRAN (see Section 3). In the hours available to undergraduate or graduate subjects there is unlikely to be sufficient time to use commercially available software. However, in special short courses that we have conducted we have followed the above sequence to prepare participants for understanding TRANSTEP, a program developed by R J Nairn and Partners in Canberra, and applying this package to consultancy briefs issued by Fairfield City Council, in 1986, and Gosford Council, in 1988. A copy of the briefing notes for the latter project are given as Appendix A.

In the future, when many engineers will have access to a personal computer, the distribution by mail of self-educating programs (without expensive printed manuals) may provide a suitable vehicle for continuing professional education. This capability for continuing education, together with the likely impact of computer-aided draughting may allow developing countries to shorten the length of study when there are economic pressures for more engineers but when resources are restricted. The development of knowledge-based teaching programs will facilitate individual study of complex topics and systems.

Acknowledgements

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Officers, and their assistance in literature searches, appraisal of suitable hardware and software, program development, testing and documentation is gratefully acknowledged. Dr Kuranami is the sole author of the traffic system analysis program and Mr Roger Hall (formerly Professional Officer, Department of Transport Engineering) modified it slightly to run on the School's Apple II micro-computer laboratory system. An early version of MLUTRAN was written for an IBM 1650 computer by Mr Colin Wingrove (Professional Officer, School of Transportation and Traffic) in 1975. The second version, which exploited computer graphics and ran off the Dual Processor Cyber 171, was written by Dr Chiaki Kuranami. A micro-computer version for IBM - PC compatibles is being written by Mr Tu That Ton and Mr Youzhen Cheng. The transport planning package TRANSTEP has been kindly made available to the Department by Mr R J Nairn and is used for educational purposes. The consultancy briefs are to UTE Consultants - a "mock consultancy" company in the Department of Transport and Engineering - and we acknowledge the generous support in time and in resources by Mr Nairn.

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Appendix A

The Brief

Gosford City Council has engaged UTE Consultant Services in a strategic planning study of land use and transport in a local government area. The objectives are:

(a) to review previous transport studies in Gosford and to indicate directions for further work;

(b) to make an appraisal of the suitability of the TRANSTEP model in the context of local government planning objectives;

(c) to run the calibrated model and interpret the results for alternative land-use/transport strategies of interest to the client; and

(d) to produce a written report and to report the main findings at a seminar.

Educational Objectives

(a) To understand the technical features of a commercially-available computer program package thereby extending information from lectures on the Fundamentals of Land-Use/Transport Planning into a practical situation.

(b) To gain hands-on experience in applying the model to specific strategies.

(c) To make a critical assessment of working with computer-based models at this sub-regional scale of analysis.

(d) To organise and manage the activity tasks and to communicate effectively with other members of the consulting team in the execution of the study and in the production of the final report.

(e) To develop skills in seminar presentations.

Alternatives to be Tested

(i) The development of new industrial estate

(ii) An east-west by-pass

(iii) Public transport access to the town centre

(iv) Commuter park-and-ride

A COMPUTERIZED PASSENGER INFORMATION SYSTEM FOR MELBOURNE'S RAILWAY NETWORK

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ABSTRACT

This paper describes the development of a computerized passenger information system for Melbourne's railway network. The system operates on a microcomputer and can generate an optimal travel itinerary when given the origin, destination and either the desired starting or arrival time. The origin and destination can be specified either as railway stations or points defined by grid coordinates.

PART I INTRODUCTION

1.1 What is a Computerized Passenger Information System

There are many ways that people can obtain information on how to use a public transport system:-

a) they can learn from route maps and timetables;

b) they can enquire at a travel information centre; and

c) they can learn from previous experience of public transport usage.

A computerized passenger information system (CPIS) is a recent invention to provide information on how to travel by public transport. The concept of a CPIS is illustrated on Figure 1. For example, a person wishes to go from place A to place B at a certain time and date. He inputs his travel requirements to the system, the system processes the enquiry and outputs travel information.

There are several ways that the system could be used. It could be placed at public transport stations for use by the public; it could be installed at a travel information centre for use by authorized staff when answering travel enquiries; it could also be made accessible to home computers through computer networking.

The advantages of a CPIS are:-

a) it replaces manual judgement of how to use a public transport system by computer processing;

b) it retrieves route information from a centralized source;

c) it provides more accurate information;

d) it reduces the staffing costs required to handle passenger enquiries.

Advancement of computer technology and communication systems has made it possible for information to be processed and transmitted in various forms, such as through computer networking, portable telephones and fax machines. CPIS is an example of using modern technology to facilitate the dissemination of information on public transport systems.

1.2 Different Types of Computerized Passenger Information Systems

Whilst Figure 1 shows the basic elements of a CPIS, each element of the system could exist in various forms thus resulting in different types of CPIS. This section discusses the various possible ways in which each of these elements could be developed.

a) Route information

The most basic type of route information is the route maps and route timetables coded as a computer database. Supplementary information, such as the physical location (co-ordinates) of stops could also be included. Ease of coding and updating of information are important considerations in the establishment of the database.

Instead of using preset timetables, an on-line route information system could be established. The system makes use of a vehicle monitoring system to provide real-time route information.

b) Travel enquiries

Apart from the origin, destination, starting time or arrival time of a journey, travel enquiries could be made in various forms.

The origin and destination could be specified in terms of names of transit stops, street names or a grid coordinate derived from a street map.

The time of a journey could be specified in various ways. A person may wish to arrive at a certain place before a certain time; or wish to start the journey at a certain time.

A person may wish to know of alternative routes of travel so as to choose the one which suits his preference.

c) Computer and computer software

Computer requirements would depend on the following design aspects of CPIS:-

- input/output devices,
- memory capacity,
- processing speed.

The computer software required would depend on the type of travel enquiry which can be processed by the system. If the software can deal with a wide range of travel enquiries, the response time is also likely to be longer. Hence a suitable balance should be struck between the flexibility of the software and the response time.

d) Travel information

The most commonly required travel information is a best itinerary from origin to destination. This information could be presented in a tabular form; in a narrative form; or in a pictorial form. Other information, such as the fare; alternative itineraries; route timetables or route maps could also be generated.

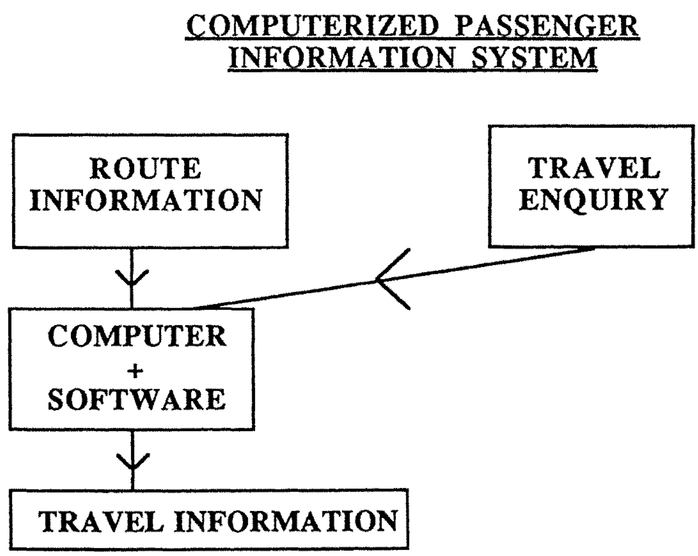

Figure 1 Basic elements of a computerized passenger information system

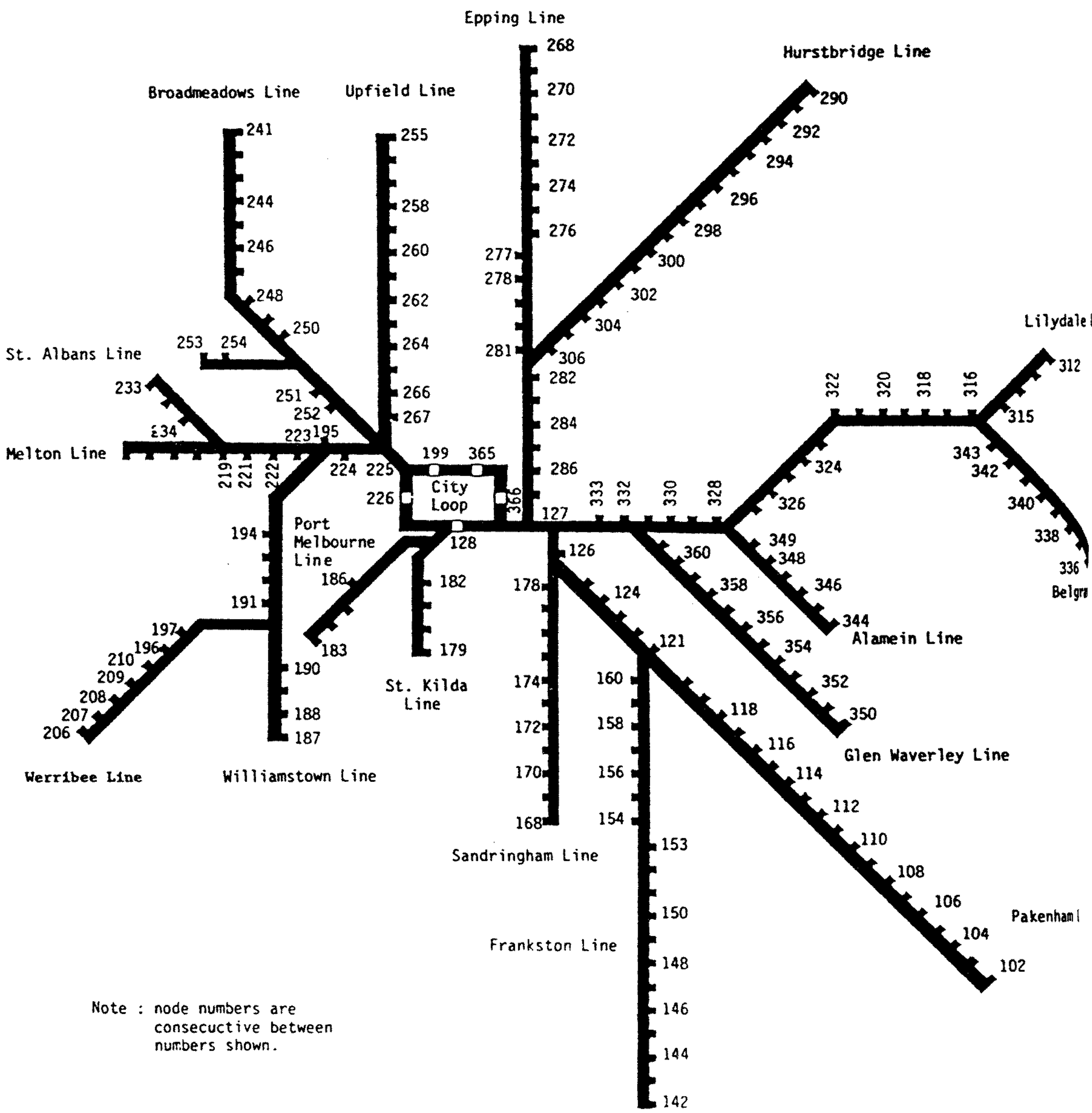

Figure 2 Melbourne's Railway Network

PART II SYSTEM DEVELOPMENT

2.1 Background

This project was initiated in 1983 as a Ph.D. project at Monash University. It was partly funded by the Ministry of Transport, Victoria, Australia.

2.2 Objective

The objective of the project is to develop a CPIS for Melbourne's railway network. The project also serves as a pilot study of a more comprehensive CPIS covering different public transport services operating in the city of Melbourne.

2.3 System Specifications

As the aim of the project is to investigate the feasibility of building a CPIS, only the most basic functions are specified for the system. The following system specifications were stipulated:-

a) It includes all rail services operating in the metropolitan area of Melbourne.

b) It is based on published information on rail services.

c) It generates an optimal travel itinerary when given the origin, the destination and either the starting time or arrival time. The origin and destination can either be stations or point specified by grid coordinates (based on a 1:20,000 scale street map published by Melway).

d) In determining the optimal travel itinerary, a weighted combination of various travel components such as in-vehicle time, waiting time, walking time and route change penalty is used.

e) Second best itineraries are not generated, however, alternative itineraries could be obtained by modifying the travel enquiry.

f) The system can be operated on a stand-alone microcomputer.

2.4 Melbourne's Railway Network

Melbourne's railway network is shown on Figure 2. It consists of 17 radial lines converging towards the city centre. There is an underground loop line circling the city centre. This is an extensive railway network with over 200 stations.

2.5 Coding of Route Information

Although the coding of route information is a straight forward task, the data should be coded in a format that facilities information updating and retrieval.

Each railway station is represented by a node number. A file containing the station name, station number and station location (in the form of a grid coordinate) is coded.

The information on each railway timetable in coded and stored on a separate file. On each file is coded the station number list and the time schedules arranged in a matrix format. Each timetable is given a route number which corresponds to the file name. There is also a route information file which shows the full route name assigned to each timetable and the day of week in which the timetable is operational.

An example is used to illustrate the coding of route information. Part of a railway timetable for the Glen Waverley line is shown on Figure 3. In this timetable, stations are represented by node numbers and their grid coordinates are coded as shown on Table 1. The station number list and time schedules are coded in a format as shown on Table 2.

Node	Map	Grid		Station name
350	71	C	2	GLEN WAVERLEY
351	70	K	1	SYNDAL
352	70	E	1	MOUNT WAVERLEY
353	61	A	12	JORDANVILLE
354	69	F	1	HOLMESGLEN
355	69	B	1	EAST MALVERN
356	59	K	11	DARLING
357	59	J	8	GLEN IRIS
358	59	H	7	GARDINER
359	59	E	6	TOORONGA
360	59	C	3	KOOYONG
361	59	A	2	HEYINGTON
332	2H	E	11	BURNLEY
333	2G	K	10	EAST RICHMOND
127	2G	F	9	RICHMOND
366	2F	J	2	PARLIAMENT
365	2F	E	1	MUSEUM
199	2F	B	2	FLAGSTAFF
226	2F	A	6	SPENSER STREET
128	2F	G	5	FLINDER'S STREET
160	68	E	5	GLENHUNTLY

Table 1. Station node numbers and map grids

GLEN WAVERLEY LINE

TO MELBOURNE — Monday to Friday

	a.m.	a.m.	a.m.	a.m.	a.m.	a.m.	a.m.	a.m.	a.m.	a.m.	a.m.	a.m.	a.m.	a.m.	a.m.	a.m.	a.m.	a.m.	a.m.	a.m.	a.m.	a.m.	a.m.	a.m.	a.m.	a.m.	a.m.
GLEN WAVERLEY Dep	4 57	5 35	6 09	6 31	6 52	7 04	7 14	7 25	7 34	7 38	7 46	7 49	7 58	8 03	8 11	8 16	8 24	8 37	8 51	9 04	9 20	9 35	9 50	10 05	10 20	10 35	10 50
SYNDAL	4 59	5 37	6 11	6 33	6 54	7 06	7 16	7 27	7 36	7 40	7 48	7 51	8 00	8 05	8 13	8 18	8 26	8 39	8 53	9 06	9 22	9 37	9 52	10 07	10 22	10 37	10 52
MOUNT WAVERLEY	5 02	5 40	6 14	6 36	6 57	7 09	7 19	7 30	7 39	7 43	7 51	7 54	8 03	8 08	8 16	8 21	8 29	8 42	8 56	9 09	9 25	9 40	9 55	10 10	10 25	10 40	10 55
JORDANVILLE	5 04	5 42	6 16	6 38	6 59	7 11	7 21	7 32	7 41	7 45	7 53	7 56	8 05	8 10	8 18	8 23	8 31	8 44	8 58	9 11	9 27	9 42	9 57	10 12	10 27	10 42	10 57
HOLMESGLEN	5 06	5 44	6 18	6 40	7 01	7 13	7 23	7 34	7 43	7 47	7 55	7 58	8 07	8 12	8 20	8 25	8 33	8 46	9 00	9 13	9 29	9 44	9 59	10 14	10 29	10 44	10 59
EAST MALVERN	5 09	5 47	6 21	6 43	7 04	7 16	7 26	7 37	7 46	7 50	7 58	8 01	8 10	8 15	8 23	8 28	8 36	8 49	9 03	9 16	9 32	9 47	10 02	10 17	10 32	10 47	11 02
DARLING	5 11	5 49	6 23	6 45	7 06	7 18	7 28	7 39	7 48	7 52	8 00	8 03	8 12	8 17	8 25	8 30	8 38	8 51	9 05	9 18	9 34	9 49	10 04	10 19	10 34	10 49	11 04
GLEN IRIS	5 13	5 51	6 25	6 47	7 08	7 20	7 30	7 41	*	7 54	*	8 05	*	8 19	*	8 32	8 40	8 53	9 07	9 20	9 36	9 51	10 06	10 21	10 36	10 51	11 06
GARDINER	5 15	5 53	6 27	6 49	7 10	7 22	7 32	7 43	*	7 56	*	8 07	*	8 21	*	8 34	8 42	8 55	9 09	9 22	9 38	9 53	10 08	10 23	10 38	10 53	11 08
TOORONGA	5 17	5 55	6 29	6 51	7 12	7 24	7 34	7 45	*	7 58	*	8 09	*	8 23	*	8 36	8 44	8 57	9 11	9 24	9 40	9 55	10 10	10 25	10 40	10 55	11 10
KOOYONG	5 19	5 57	6 31	6 53	7 14	7 26	7 36	7 47	*	8 00	*	8 11	*	8 25	*	8 38	8 46	8 59	9 13	9 26	9 42	9 57	10 12	10 27	10 42	10 57	11 12
HEYINGTON	5 21	5 59	6 33	6 55	7 16	7 28	7 38	7 49	*	8 02	*	8 13	*	8 27	*	8 40	8 48	9 01	9 15	9 28	9 44	9 59	10 14	10 29	10 44	10 59	11 14
BURNLEY	5 24	6 02	6 36	6 58	7 19	7 31	7 41	7 53	*	8 06	*	8 17	*	8 31	*	8 43	8 51	9 04	9 18	9 31	9 47	10 02	10 17	10 32	10 47	11 02	11 17
EAST RICHMOND	5 26	6 04	6 38	7 00	7 21	7 33	7 43	7 55	*	8 08	*	8 19	*	8 33	*	8 45	8 53	9 06	9 20	9 33	9 49	10 04	10 19	10 34	10 49	11 04	11 19
RICHMOND	5 28	6 06	6 40	7 02	7 23	7 35	7 45	7 57	8 01	8 10	8 14	8 21	8 25	8 35	8 39	8 47	8 55	9 08	9 22	9 35	9 51	10 06	10 21	10 36	10 51	11 06	11 21
PARLIAMENT Arr	..	..	..	..	7 26	..	7 48	..	8 04	..	8 17	..	8 28	..	8 42	..	8 58	9 11	9 25	9 38	9 54	10 09	10 24	10 39	10 54	11 09	11 24
MUSEUM	..	..	..	..	7 28	..	7 50	..	8 06	..	8 19	..	8 30	..	8 44	..	9 00	9 13	9 27	9 40	9 56	10 11	10 26	10 41	10 56	11 11	11 26
FLAGSTAFF	..	..	..	..	7 29	..	7 51	..	8 07	..	8 20	..	8 31	..	8 45	..	9 01	9 14	9 28	9 41	9 57	10 12	10 27	10 42	10 57	11 12	11 27
SPENCER STREET	..	..	..	..	7 31	..	7 53	..	8 09	..	8 22	..	8 33	..	8 47	..	9 03	9 16	9 30	9 43	9 59	10 14	10 29	10 44	10 59	11 14	11 29
FLINDERS STREET	5 33	6 11	6 45	7 07	7 35	7 40	7 57	8 02	8 14	8 15	8 26	8 26	8 37	8 40	8 51	8 52	9 07	9 20	9 34	9 47	10 03	10 18	10 33	10 48	11 03	11 18	11 32

	a.m.	a.m.	a.m.	a.m.	p.m.	p.m.	p.m.	p.m.	p.m.	p.m.	p.m.	p.m.	p.m.	p.m.	p.m.	p.m.	p.m.	p.m.	p.m.	p.m.	p.m.	p.m.	p.m.	p.m.	p.m.	p.m.	p.m.
GLEN WAVERLEY Dep	11 05	11 20	11 35	11 50	12 05	12 20	12 35	12 50	1 05	1 20	1 35	1 50	2 05	2 20	2 35	2 50	3 05	3 20	3 35	3 48	4 00	4 12	4 20	4 29	4 40	4 52	5 02
SYNDAL	11 07	11 22	11 37	11 52	12 07	12 22	12 37	12 52	1 07	1 22	1 37	1 52	2 07	2 22	2 37	2 52	3 07	3 22	3 37	3 50	4 02	4 14	4 22	4 31	4 42	4 54	5 04
MOUNT WAVERLEY	11 10	11 25	11 40	11 55	12 10	12 25	12 40	12 55	1 10	1 25	1 40	1 55	2 10	2 25	2 40	2 55	3 10	3 25	3 40	3 53	4 05	4 17	4 25	4 34	4 45	4 57	5 07
JORDANVILLE	11 12	11 27	11 42	11 57	12 12	12 27	12 42	12 57	1 12	1 27	1 42	1 57	2 12	2 27	2 42	2 57	3 12	3 27	3 42	3 55	4 07	4 19	4 27	4 36	4 47	4 59	5 09
HOLMESGLEN	11 14	11 29	11 44	11 59	12 14	12 29	12 44	12 59	1 14	1 29	1 44	1 59	2 14	2 29	2 44	2 59	3 14	3 29	3 44	3 57	4 09	4 21	4 29	4 38	4 49	5 01	5 11
EAST MALVERN	11 17	11 32	11 47	12 02	12 17	12 32	12 47	1 02	1 17	1 32	1 47	2 02	2 17	2 32	2 47	3 02	3 17	3 32	3 47	4 00	4 12	4 24	4 32	4 41	4 52	5 04	5 14
DARLING	11 19	11 34	11 49	12 04	12 19	12 34	12 49	1 04	1 19	1 34	1 49	2 04	2 19	2 34	2 49	3 04	3 19	3 34	3 49	4 02	4 14	4 26	4 34	4 43	4 54	5 06	5 16
GLEN IRIS	11 21	11 36	11 51	12 06	12 21	12 36	12 51	1 06	1 21	1 36	1 51	2 06	2 21	2 36	2 51	3 06	3 21	3 36	3 51	4 04	4 16	4 28	*	4 45	4 56	5 08	5 18
GARDINER	11 23	11 38	11 53	12 08	12 23	12 38	12 53	1 08	1 23	1 38	1 53	2 08	2 23	2 38	2 53	3 08	3 23	3 38	3 53	4 06	4 18	4 30	*	4 47	4 58	5 10	5 20
TOORONGA	11 25	11 40	11 55	12 10	12 25	12 40	12 55	1 10	1 25	1 40	1 55	2 10	2 25	2 40	2 55	3 10	3 25	3 40	3 55	4 08	4 20	4 32	*	4 49	5 00	5 12	5 22
KOOYONG	11 27	11 42	11 57	12 12	12 27	12 42	12 57	1 12	1 27	1 42	1 57	2 12	2 27	2 42	2 57	3 12	3 27	3 42	3 57	4 10	4 22	4 34	*	4 51	5 02	5 14	5 24
HEYINGTON	11 29	11 44	11 59	12 14	12 29	12 44	12 59	1 14	1 29	1 44	1 59	2 14	2 29	2 44	2 59	3 14	3 29	3 44	3 59	4 12	4 24	4 36	*	4 53	5 04	5 16	5 26
BURNLEY	11 32	11 47	12 02	12 17	12 32	12 47	1 02	1 17	1 32	1 47	2 02	2 17	2 32	2 47	3 02	3 17	3 32	3 47	4 02	4 15	4 27	4 39	*	4 56	5 07	5 19	5 29
EAST RICHMOND	11 34	11 49	12 04	12 19	12 34	12 49	1 04	1 19	1 34	1 49	2 04	2 19	2 34	2 49	3 04	3 19	3 34	3 49	4 04	4 17	4 29	4 41	*	4 58	5 09	5 21	5 31
RICHMOND	11 36	11 51	12 06	12 21	12 36	12 51	1 06	1 21	1 36	1 51	2 06	2 21	2 36	2 51	3 06	3 21	3 36	3 51	4 06	4 19	4 31	4 43	4 47	5 00	5 11	5 23	5 33
FLINDERS STREET Arr	11 41	11 56	12 11	12 26	12 41	12 56	1 11	1 26	1 41	1 56	2 11	2 26	2 41	2 56	3 11	3 26	3 41	3 56	4 11	4 24	4 37	4 48	4 52	5 05	5 16	5 28	5 38
SPENCER STREET	..	..	12 15	12 30	12 45	1 00	1 15	1 30	1 45	..	2 15	2 30	2 48	3 00	3 17	3 36	3 47	4 06	4 17	..	4 41	4 54	..	..	..	..	5 42
FLAGSTAFF	..	..	12 17	12 32	12 47	1 02	1 17	1 32	1 47	..	2 17	2 32	2 50	3 02	3 19	3 38	3 49	4 08	4 19	..	4 43	4 56	..	..	..	..	5 44
MUSEUM	..	..	12 18	12 33	12 48	1 03	1 18	1 33	1 48	..	2 18	2 33	2 51	3 03	3 20	3 39	3 50	4 09	4 20	..	4 44	4 57	..	..	..	..	5 45
PARLIAMENT	..	..	12 20	12 35	12 50	1 05	1 20	1 35	1 50	..	2 20	2 35	2 53	3 05	3 22	3 41	3 52	4 11	4 22	..	4 46	4 59	..	..	..	..	5 47

	p.m.	p.m.	p.m.	p.m.	p.m.	p.m.	p.m.	p.m.	p.m.	p.m.	p.m.	p.m.	p.m.	p.m.	p.m.	p.m.
GLEN WAVERLEY Dep.	5 24	5 41	6 00	6 18	6 35	6 46	7 06	7 26	7 56	8 26	8 56	9 26	9 56	10 26	10 56	11 26
SYNDAL	5 26	5 43	6 02	6 20	6 37	6 48	7 08	7 28	7 58	8 28	8 58	9 28	9 58	10 28	10 58	11 28
MOUNT WAVERLEY	5 29	5 46	6 05	6 23	6 40	6 51	7 11	7 31	8 01	8 31	9 01	9 31	10 01	10 31	11 01	11 31
JORDANVILLE	5 31	5 48	6 07	6 25	6 42	6 53	7 13	7 33	8 03	8 33	9 03	9 33	10 03	10 33	11 03	11 33
HOLMESGLEN	5 33	5 50	6 09	6 27	6 44	6 55	7 15	7 35	8 05	8 35	9 05	9 35	10 05	10 35	11 05	11 35
EAST MALVERN	5 36	5 53	6 12	6 30	6 47	6 58	7 18	7 38	8 08	8 38	9 08	9 38	10 08	10 38	11 08	11 38
DARLING	5 38	5 55	6 14	6 32	6 49	7 00	7 20	7 40	8 10	8 40	9 10	9 40	10 10	10 40	11 10	11 40
GLEN IRIS	5 40	5 57	6 16	6 34	*	7 02	7 22	7 42	8 12	8 42	9 12	9 42	10 12	10 42	11 12	11 42
GARDINER	5 42	5 59	6 18	6 36	*	7 04	7 24	7 44	8 14	8 44	9 14	9 44	10 14	10 44	11 14	11 44
TOORONGA	5 44	6 01	6 20	6 38	*	7 06	7 26	7 46	8 16	8 46	9 16	9 46	10 16	10 46	11 16	11 46
KOOYONG	5 46	6 03	6 22	6 40	*	7 08	7 28	7 48	8 18	8 48	9 18	9 48	10 18	10 48	11 18	11 48
HEYINGTON	5 48	6 05	6 24	6 42	*	7 10	7 30	7 50	8 20	8 50	9 20	9 50	10 20	10 50	11 20	11 50
BURNLEY	5 51	6 08	6 27	6 45	*	7 13	7 33	7 53	8 23	8 53	9 23	9 53	10 23	10 53	11 23	11 53
EAST RICHMOND	5 53	6 10	6 29	6 47	*	7 15	7 35	7 55	8 25	8 55	9 25	9 55	10 25	10 55	11 25	11 55
RICHMOND	5 55	6 12	6 31	6 49	7 02	7 17	7 37	7 57	8 27	8 57	9 27	9 57	10 27	10 57	11 27	11 57
FLINDERS STREET Arr.	6 00	6 17	6 36	6 54	7 07	7 22	7 42	8 02	8 32	9 02	9 32	10 02	10 32	11 02	11 32	12 02
SPENCER STREET	6 04	6 21	6 42	..	..	..	..	..	8 37	9 07	9 37	10 07	10 37	11 07	11 37	12 07
FLAGSTAFF	6 06	6 23	6 44	..	..	..	..	..	8 39	9 09	9 39	10 09	10 39	11 09	11 39	12 09
MUSEUM	6 07	6 24	6 45	..	..	..	..	..	8 40	9 10	9 40	10 10	10 40	11 10	11 40	12 10
PARLIAMENT	6 09	6 26	6 47	..	..	..	..	..	8 42	9 12	9 42	10 12	10 42	11 12	11 42	12 12

Figure 3. Part of a typical railway timetable.

T GLEN WAVERLEY LINE TO MELBOURNE WEEKDAY

STOP=		20								
A	350	351	352	353	354	355	356	357	358	359
A	360	361	332	333	127	336	365	101	226	128
COLM=		10								
1	457	535	609	631	652	704	725	734	738	746
1	459	537	611	633	654	706	727	736	740	748
1	502	540	614	636	657	709	730	739	743	751
1	504	542	616	638	659	711	732	741	745	753
1	506	544	618	640	701	713	734	743	747	755
1	509	547	621	643	704	716	737	746	750	758
1	511	549	623	645	706	718	739	748	752	800
1	513	551	625	647	708	720	741		754	
1	515	553	627	649	710	722	743		756	
1	517	555	629	651	712	724	745		758	
1	519	557	631	653	714	726	747		800	
1	521	559	633	655	716	728	749		802	
1	524	602	636	658	719	731	753		806	
1	526	604	638	700	721	733	755		808	
1	528	606	640	702	723	735	757	801	810	814
1					726			804		817
1					728			806		819
1					729			807		820
1					731			809		822
1	533	611	645	707	735	740	802	814	815	826
COLM=		10								
1	758	803	811	816	824	837	851	904	920	935
1	800	805	813	818	826	839	853	906	922	937
1	803	808	816	821	829	842	856	909	925	940
1	805	810	818	823	831	844	858	911	927	942
1	807	812	820	825	833	846	900	913	929	944
1	810	815	823	828	836	849	903	916	932	947
1	812	817	825	830	838	851	905	918	934	949
1		819		832	840	853	907	920	936	951
1		821		834	842	855	909	922	938	953
1		823		836	844	857	911	924	940	955
1		825		838	846	859	913	926	942	957
1		827		840	848	901	915	928	944	959
1		831		843	851	904	918	931	947	1002
1		833		845	853	906	920	933	949	1004
1	812	835	839	847	855	908	922	935	951	1006
1	828		842		858	911	925	938	954	1009
1	830		844		900	913	927	940	956	1011
1	831		845		901	914	928	941	957	1012
1	833		847		903	916	930	943	959	1014
1	837	840	851	852	907	920	934	947	1003	1018

Table 2. Timetable coding format

2.6 Network Building

Network building converts the coded route information into a network file that can be used by the computer for generating optimal travel itineraries. A network is a combination of nodes and links. It is described by a network file which is a collection of link records. Each link record contains the following information:-

A-NODE - start node number

B-NODE - end node number

LTIME - time difference between departure time at A-NODE and departure time at B-NODE

RTNO - route number

R - number of times a vehicle runs through the link as recorded

ST(1) - departure time of vehicle from A-NODE in first run

.
.

ST(J) - departure time of vehicle from A-NODE in Jth run

.
.

ST(R) - departure time of vehicle from A-NODE in Rth run

As shown on Figure 3, each column of the timetable represent a complete run of a train from the starting station to the end station. However, not every column in the timetable has the same route profile. (The space-time trajectory of a vehicle when it is operating along a route is called its route profile.) Columns with identical route profile are grouped together and given a unique route number. Within each group of columns are generated a number of link records.

2.7 Pathfinding Algorithm

The pathfinding algorithm is a set of procedures for generating an optimal itinerary in response to a travel enquiry. A path generating procedure is adopted. Different alternative paths are generated from origin to destination, however, in order to restrict the number of paths various rules are set to guide the path generation procedure. After all feasible paths are generated, the optimal one is selected. A more detailed description of the algorithm can be found in Tong and Richardson (1984).

Weighted travel time is used as the criterion for determining the optimal itinerary. In determining the weighted travel time, the effort spent in travelling is broken up into a number of components, with weighting factors attached to various components of a trip as shown on Table 3 below:-

	Travel Component	Weighting Factor
a)	Access time to the origin station or from the destination station	1.5
b)	Waiting time at the origin station or at the destination	1.0
c)	In-vehicle time	1.0
d)	Walking time during route change	2.0
e)	Waiting time at station during route change	1.5
f)	Penalty for a route change	5 minutes

Table 3. Weighting factors used for determining the weighted travel time of a trip.

The weighting factors shown on Table 3 are used because they are found to result in logical itineraries. Other weighting factors could be used if these are found to model more accurately the preference of travellers.

2.8 Generation of Door-to-Door Paths

Apart from station-to-station paths, the pathfinding algorithm can also generate door-to-door paths. The basic requirement of this extended capability of the algorithm is a map grid system for defining the position of railway stations. A street map directory of Melbourne published by Melway Publishing Pty. Ltd. is used. The street maps are of scale 1:20,000 and have grids each covering an area of 390 m by 410 m.

In generating a door-to-door path, the grid coordinates of the origin and destination are input. A searching procedure is then used for finding suitable origin and destination stations. Access/egress links are then generated to connect to these stations. However, the search is limited to a maximum area bounded by a rectangle of 4.29 km by 4.51 km with either the origin or destination as the centroid. An access/egress speed of 5.5 kph is assumed.

2.9 User/Machine Communication

There are different ways that a travel enquiry could be input to the system. The method adopted is by successive questions appearing on the computer screen prompting for answers to be input from a keyboard. In response to the input enquiry, an optimal itinerary is generated and is presented in a tabular form. An example of the input and output format is shown on Table 4.

```
ENTER NETWORK IDENTIFICATION NUMBER ?  3
DO YOU WISH TO USE MAP CODES (Y/N) ? N
ENTER ORIGIN NODE NUMBER ?  353
ENTER DESTINATION NODE NUMBER ? 328
START TIME (1); ARRIVAL TIME (2) ? 1
ENTER START TIME (HR,MIN) ? 7,30

 NODE  ARRIVE  DEPART  WAIT  ROUTE USED
       TIME    TIME    TIME  TO DEPART
-------------------------------------------
 353           7:32            G1
 354    7:34   7:34      0     G1
 355    7:37   7:37      0     G1
 356    7:39   7:39      0     G1
 357    7:41   7:41      0     G1
 358    7:43   7:43      0     G1
 359    7:45   7:45      0     G1
 360    7:47   7:47      0     G1
 361    7:49   7:49      0     G1
 332    7:52   7:54      2     L15
 331    7:56   7:56      0     L15
 330    7:58   7:58      0     L15
 329    8: 0   8: 0      0     L15
 328    8: 3
 IN-VEH TIME= 29MIN, WALK TIME=  0MIN, WAIT TIME=  2I
 ROUTE CHANGES= 1.  TOTAL TRIP TIME=  31 MIN.

TO CONTINUE PROGRAM, ENTER:1 FOR NEW ORIGIN AND OR DI
                           2 FOR NEW START TIME
                           3 TO STOP ? 2
START TIME? (1); ARRIVAL TIME (2) ? 2
ENTER ARRIVAL TIME (HR,MIN) ? 8,0

 NODE  ARRIVE  DEPART  WAIT  ROUTE USED
       TIME    TIME    TIME  TO ARRIVE
-------------------------------------------
 353           7:24
 354    7:26   7:26      0    G1
 355    7:29   7:29      0    G1
 356    7:31   7:31      0    G1
 357    7:33   7:33      0    G1
 358    7:35   7:35      0    G1
 359    7:37   7:37      0    G1
 360    7:39   7:39      0    G1
 361    7:41   7:41      0    G1
 332    7:44   7:45      1    G1
 331    7:47   7:47      0    L17
 330    7:49   7:49      0    L17
 329    7:51   7:51      0    L17
 328    7:55                  L17
IN-VEH TIME= 30MIN, WALK TIME=  0MIN, WAIT TIME=  1MI
ROUTE CHANGES= 1.  TOTAL TRIP TIME=  31MIN.

TO CONTINUE PROGRAM, ENTER:1 FOR NEW ORIGIN AND OR DI
                           2 FOR NEW START TIME
                           3 TO STOP ? 3      PROGRAM
```

Table 4. Generation of optimal itineraries, a sample

2.10 Other System Characteristics

The software is written in Fortran 77 and should be easily transportable between different computers. When operating the system on an IBM compatible AT machine, the program requires a core memory of 300 KB. With a processing speed of 12 Mhz, the maximum system response time to an enquiry is about 2 minutes. However, for most enquiries, the response time ranges from 3-15 seconds.

2.11 Conclusion

The development work undertaken has demonstrated a possible method for establishing a CPIS for Melbourne's railway network. The system can generate optimal itineraries in response to travel enquiries. It can be operated on IBM AT computers. The major cost required for establishing the system is the manpower for coding of railway timetables. This task can easily be undertaken by data punching agencies.

2.12 Further Work

Research is currently being undertaken to extend the system so that it could include other public transport networks (tram and bus) operating in Melbourne. Hence optimal itineraries could be generated within a multimodal transit network.

REFERENCES

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COMPUTER BASED PARKING SYSTEM FOR LOCAL AUTHORITIES IN MALAYSIA

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Abstract

Transport, one of the major urban systems somehow give rise to a varying degree of problems in many different cities. Malaysia being among the developing nations is no exception to such problems. When urban development takes place, infrastructure has to be provided adequately. The needs of efficient parking system have to be at par with the development itself. Parking, for example plays a similar role and it is indeed vital for every motorist. This paper outlines the general problems related to parking in urban areas and a generalised software suitable for micro computer system is developed. The rationale is to help local authorities improve their financial management besides assisting them in physical planning.

This paper is based on the actual research carried out by the writer and fully funded by the Universiti Sains Malaysia.

Parking Problems

The demand for parking space is enormous when a motorist arrives at the destination. It serves the task of providing a space to define a halt for a vehicle. It is required to fullfill one's desire of purpose of travelling (at that point) of arrival.

Parking is made up of several forms or types. One, is the form of on street parking whereas the other would be off street parking. The latter is commonly located in buildings or large areas, off the street. Any of these plays the same role providing the required parking facilities. With the outlook of Malaysian parking in urban areas it can be concluded that the on street parking is most generally found. And on top of it, publicly owned is the dominant form of parking compared to the other which is less prominent.

The local authorities who are related to the parking are empowered to certain-by-laws. These by-laws are to look into the supply of parking facilities and at the same time take care of the maintenance as well. All these are largely done within the respective jurisdiction. Currently, the increase in vehicle ownership and changing sosio-economic structure have injected an increase in demand for travel, particularly by car. Furthermore, this activity is more highlighted in areas such as the city centre. They are likely to be well in excess of the capacity of the road system in some places.

Out of the traffic management measures, parking is one of the factors which contributes to the improvement of the system and hence its technique. Parking problems grow corresponding to the high percentage of urban travel. The situation is not likely to be resolved as the movement of vehicle is on the rise. The increase in vehicular traffic is due to the continued attraction of city centres which in some places have the capacity to facilitate the inflow of vehicles. Most local authorities in Malaysia are now facing serious problems particularly in parking fee collection.

This is followed by the problem of detecting non paying parkers and lately the problems of detecting and predicting the parking demand. Parking problems vary in character and extent but generally the problem can be classified into two :

1) Physical

2) Management

From the surveys carried out by the writer it was found out that all local authorities, particularly the municipal councils have more than 2000 parking bays each. So far, on street parking and especially publicly owned constituted the most.

Despite this, there are inadequate supply of parking spaces in some areas. Sometimes the demand in the city centres are extremely high exceeding the capacity and as a result, causing parking problems. Some places, the demand is from 8 a.m to 5 p.m but with further increase in volume of vehicles, the peak demand time is sometimes extends from 8 a.m to 10 p.m . This is the time when charges could have been imposed in most of the city centres in Malaysia.

The study carried out by the writer also indicated that the demand for parking spaces in these areas are still high despite of higher fees. However, some areas are under utilised with occupancy as low as 10% per day or per hour. Thus, such a situation could be uneconomical for the local authority to manage.

Problems of planning related to the provisions of a reasonable amount of bays may arise. Such provisions are normally in great need at strategic locations to meet the demand which lately has brought great concern to local authorities.

With exceeding demand, additional parking spaces have provided and located quite far from the destinations. In this situation, it requires the parkers to walk longer distance than they should do and difficulty arises as they have to consume longer time. This is inconvenient to users.

The major problem lies in the understanding of the actual problems. It is therefore neccessary to have a clear definition of the subject matter. However, problems could also be analysed by computers and availability of the data over certain period of time and various parking zones.

Another serious problem is poor collection and storage of data. Thus, to uncover the actual problems and demand in terms of travel characteristics, occupancy by road, area, day and time is not possible. Even if possible, it is time consuming and requires thorough survey work.

However, if the data is properly collected and stored, the problems could be greatly reduced. As we consider the problems, fee collection is the most serious problems. So far, it has been done with the help of parking attendants who are employed by the respective local authorities.

The process of the fee collection done manually is the common phenomenon in Malaysian urban areas. Despite common use, the technique is tedious, unreliable and most of the time it causes delay, including the backlog of work such as the delay in sorting out the issued and paid tickets. To sort out and determine the unsettled bills as well as the irresponsible parkers are also affected as some local authorities take several years to settle these problems. By the time they manage to sort out this issue, the car in question has been sold. The change in ownership always further increase the difficulties to the authorities in getting the bills settled or bring the right person to court.

Some of the accounts are always closed at a later date due to the manual process. This will further aggravate the management problem as it is hardly able to determine the financial structure in terms of revenue and expenditure daily, weekly and month on time. Therefore, effective decisions making is greatly affected because facts on these aspects could not be obtained or retrieved immediately for analysing purposes. In view of this, what they managed to analyse now are facts base on previous years. Besides, the data could not be properly updated. Even if data are extracted from the present storage system, they do not provide a reliable basis for effective analysis. Due to poor management control as a result of manual process, some local authorities in Malaysia experienced deficits. Even if they are making profit, it is at a declining rate.

Why Computerise

On the basis of existing characteristics outlined in the preceeding sections, the problems could be greatly minimised if the local authorities computerise the parking system. With regard to storing data and retrieving information, computerising can overcome it in seconds. In line with such a proclamation, computerised parking system is known to be cost effective as it increases not only productivity but also profitability.

As the problems become crucial, plan to call for productivity improvement as well as cost saving measures should be given a high priority in local authorities. However, the benefits of the system cannot be easily quantified. Nevertheless, computation in terms of total percentage can be done effectively.

On the basis of information already computerised, one can employ flexibility as they can retrieve information from the system themselves rather than wasting time waiting for their clerical staffs to pull out files in their search for informations.

Computerised system also helps to reduce time and minimising errors in the process of gathering and storing data. The performance which is affected by inadequate inventory of parking data as well as poor management decision related to finance can be avoided with the help of computer. The computer system can be used as an information management system for effective decision making in terms of :-

1) Physical planning related to structure and local plans

2) Financial management

The computer is recommended to be used for providing faster and improved customer services apart from providing a good basis for effective planning which involves decision making.

Parking Software

It is important to realise that an area or town is divided into zones and it can be coded accordingly. To ascertain the divisions, the name of zones with specific codes are registered initially. It is done by registering the parking characteristics such as code and name of road, town centre or otherwise.

In line with the objective as indicated in the abstract of this paper and to enable effective planning and financial decisions be made, a parking software is developed.

The data related to parking characteristics such as issued tickets that need to be categorised before keying in are : -

1 - zone
2 - lot/bay
3 - duration
4 - registration plate number
5 - road tax number
6 - amount to be paid
7 - date

The main idea and reason in doing so is to store and record the parking data for eventual use. Simultaneously (if local area network is developed) , data related to paid tickets could also be keyed in. Though this process, merely by keying in of issued and paid tickets, an agency is also able to ascertain the unpaid bills and eventually determine the errant parkers.

Further actions relating to issuing notices, compounds and summons could also be done more effectively. This process is done after determining the rightful owner and address of the irresponsible parker.

In anticipation of continued favourable circumstances, the process of developing the software is mechanised. This is outlined in Figure 1 indicating the steps covering the system analysis, design, programming and implementation. Based on the design concept, the software was dessigned using dBase III programming language. A menu driven approach was developed so that it can be easily handled by the users, largely clerical staffs who usually have low computer knowledge.

To support the data base system package, data base files have to be created. In this case, 5 dBase files are created as shown in Figure 2. These data basefiles show the parking data structures such as ticket, road tax, address, bay, time, registration number, payment and many others as shown in Figure 2. The data are actually stuctured as stipulated in the menu driven screen.

To maintain the quality, consistency and to enable it to be used easily, the main menu was designed to comprise of 4 major choices (Figure 3) namely :-

1 - SET UP   3 - BROWSE DATA

2 - DATA ENTRY   4 - ADMINISTRATION

All of these play very important role in the choices.

The SET UP choice is concerned mainly with the name of agency, data directory and colour setting.

The DATA ENTRY choice (Figure 4) has been designed to enable the data to be keyed in and stored for further uses. This can be classified into :-

1 - issued tickets

2 - paid tickets

3 - parking data (location, bay, occupancy characteristics)

4 - MAIN MENU

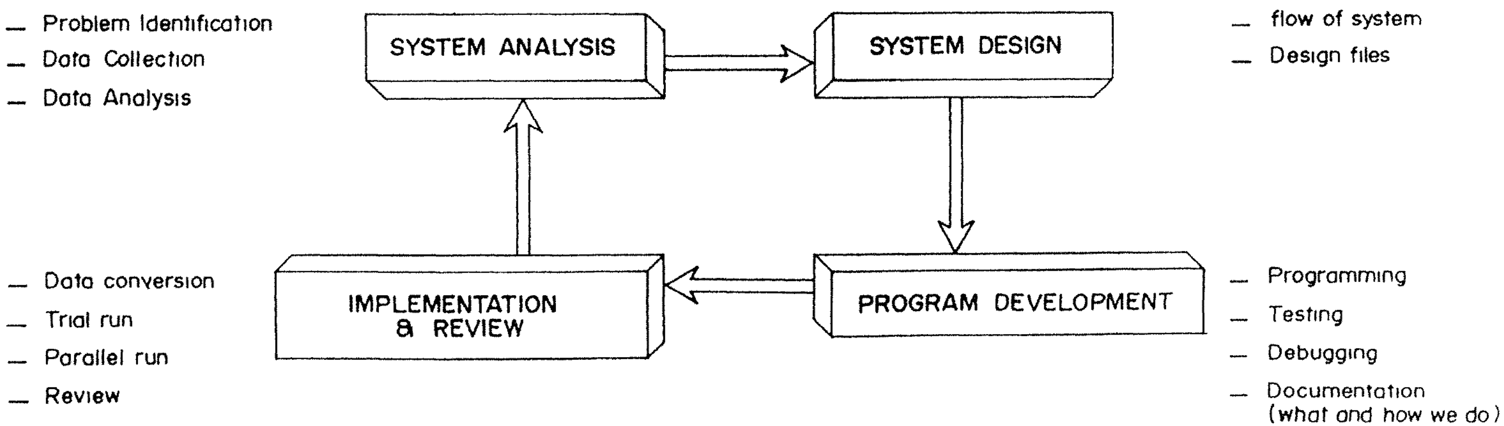

FIGURE 1 - SYSTEM DEVELOPMENT PROCESS

FIGURE 2 - EXAMPLES OF DATABASE FILES

Structure for database B \ parksys \ PARKSYS CFG
Number of data records 1
Date of last update 01/01/80

Field	Field name	Type	Width	Dec
1	DAT	Character	20	
2	NAME	Character	70	
3	COLOR1	Character	20	
4	COLOR2	Character	20	
5	COLOR3	Character	20	
Total			151	

Structure for database B \ parksys tkt
Number of data records 33
Date of last update 01/01/80

Field	Field name	Type	Width	Dec
1	TICKET	Numeric	7	
2	CODE	Character	4	
3	LOT	Numeric	4	
4	DATE	Date	8	
5	TIME-IN	Numeric	4	
6	TIME-OUT	Numeric	4	
7	PAYMENT	Numeric	5	2
8	REG-NO	Character	10	
9	PAID	Logical	1	
Total			48	

Structure for database : B :\parksys loc
Number of data records : 2
Date of last update : 01/01/80

Field	Field name	Type	Width	Dec
1	CODE	Character	4	
2	NAME	Character	40	
3	TOWN-CENTR	Logical	1	
4	OFF-ROAD	Logical	1	
Total			47	

Structure for database . B \parksys pnt
Number of data records : 2
Date of last update · 01/01/80

Field	Field name	Type	Width	Dec
1	CODE	Character	4	
2	YEAR	Numeric	4	
3	FIRST	Numeric	5	2
4	SECOND	Numeric	5	2
5	THIRD	Numeric	5	2
6	NEXT	Numeric	5	2
7	UNIT	Numeric	5	2
Total			34	

Structure for database . B : \parksys uns
Number of data records · 28
Date of last update 01/01/80

Field	Field name	Type	Width	Dec
1	TICKET	Numeric	7	
2	ROADTAX	Character	12	
3	OWN-NAME	Character	70	
4	OWN-ADD1	Character	70	
5	OWN-ADD2	Character	70	
6	OWN-DATE	Date	8	
7	P-OWN-NAME	Character	70	
8	P-OWN-ADD1	Character	70	
9	P-OWN-ADD2	Character	70	
10	P-OWN-DATE	Date	8	
11	TYPE	Character	10	
12	MODEL	Character	10	
13	COLOUR	Character	10	
14	WARNING	Character	1	
15	NOTICE1	Date	8	
16	NOTICE2	Date	8	
17	COMPOUN	Numeric	7	2
18	NOTE	Character	70	
Total			580	

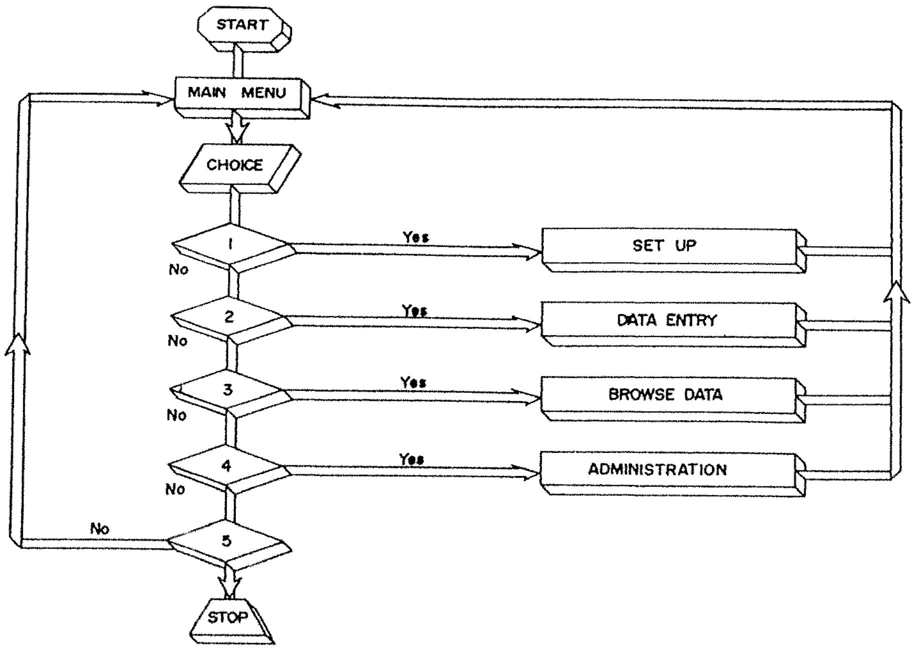

FIGURE 3 : FLOWCHARTING - MAIN MENU

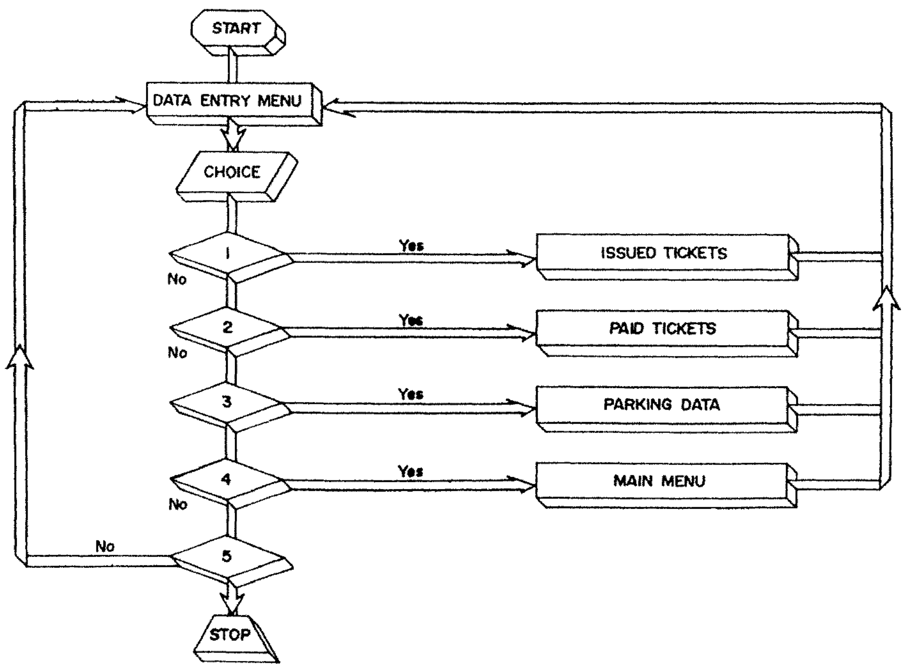

FIGURE 4 : FLOWCHARTING - DATA ENTRY SUBROUTINE

From the choice alternative, an agency is able to key in all particulars related to the DATE, DURATION, CHARGES, REGISTRATION PLATE NUMBER, ROAD TAX NUMBER and TIME. This is done closely to monitor the perfomance. Data relating to the paid tickets could be recorded simultaneously while keying in data on issued tickets.

This choice is supported with the BROWSE facility enabling the users to ascertain what has been keyed in and what to comply with.

The administration subroutine is further classified into : -

1 - parking summary

2 - parking characteristics

3 - parking usage/occupancy

4 - unpaid bills

5 - summons

6 - prints

The output under this classification rely on the DATA ENTRY choice, which also supported by other commands such as DELETE, ADD and MODIFY.

Thus the system is designed on a Menu Driven approach to allow the users to work with easily. The output of this software can be in the following form :-

1 - analysis of parking usage

2 - analysis of summons

3 - analysis of unpaid bills

However, other sophisticated forms of output can be generated depending on one's needs to create a favourable result. Nevertheless, the output indicates some analysis for physical planning as well as financial management out of which both are equally important and cannot be avoided. Although problems relating to storage, retrieval and data analysis and deficits cannot be overcome, they could definitely be minimised.

Hence, it would be helpful if it is designed for time sharing or sharing the system in the local authorities to meet the contemporary needs. However, the local area network (LAN) in this context, is confined to this system. It serves as an important system within the same local authorities or agencies. Since this is a small system it does not require massive modification to the software as well as hardware installation. In this case, high cost could be greatly reduced.

Time sharing using the same programmes and data for parallel processing requires initial configuration. This is neccessary as some local authorities do have certain specific requirements and constraints. The varying needs of various authorities in Malaysia necessitate the software to be slightly configured to meet the specific requirements of the agencies.

Furthermore, the present software is not yet reconfigured and it is designed based on the STAND ALONE philosophy. Since it is developed for micro computer including personal computers, with hard disk of over 20 megabytes, it certainly has to be reconfigured to enable the system to recognise the local area network facilities. For this purpose, two or more terminals could be installed and link to the hard disk.

The parking software developed for local authorities in Malaysia could also be converted to be used in other systems such as the mainframe and mini computers which are comparatively capable of processing enormous amount of data. If a particular system other than micro computer is to be used, then the parking software can be converted into other appropriate languages that can be handled effectively using the adopted computer systems including mainframe and mini computers.

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COMPUTERIZED SCHOOL BUSSING (CSB) SYSTEM IN ISRAEL

Shmuel MANDEL
Enosh systems

Ahuva FINEMESSER
Ministry of Education

1. Background

CSB system consists of 100,000 pupils, 10,000 paths in 220 local authorities.
The system includes various groups of pupils (retarded, handicapped etc:), means of transprtation and vehicles.
Total annual expense 70 million USD.

2. Goals of CSB system

- Control of validity and efficency of paths and indication of exceptions.
- Checking of execution reports and authorizing payment.
- Presenting global data and what-if analysis for descision making in national level.
- Detailed planning of optimal paths.

3 The target function is: minimal cost for a givem level of service.

4. Efficency criteria

- Seats occupied, cost per km, cost per pupil, cost per pupil/km.

5 Optimization

3 different approachs have been tried:

- Linear and Integer programming.
- Branch and bound.
- Decision support system.

6. Further extension

- Connection with G.I.S.
- Expert system.

THE APPLICATION OF GIS FOR URBAN LAND USE PLANNING AND MONITORING: A CASE STUDY OF LOW INCOME HOUSING DEVELOPMENT IN KUALA LUMPUR, MALAYSIA

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The most notable problems of rapid urbanization in Malaysia today include the need for land, housing and provision of services. The link with day-to-day planning problems however remains a critical factor. The quality of the planning and decision making process can be substantially improved when available and valid data are appropriately and efficiently handled. The aim of this paper is to demonstrate how the application of GIS can aid urban land use planning and monitoring at the local authority level in Kuala Lumpur, with particular reference to a case study of low income housing development. Data requirements, problems of data availability and the appropriateness of different analytical tools are examined, followed by discussion of the feedback between the information system and the planning/decision making process which is necessary for the successful implementation of new GIS technology.

HYPERMEDIA-ASSISTED CREATIVITY IN IDENTIFYING WAYS TO SHELTER THE HOMELESS

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ABSTRACT

The main purposes of this paper are (1) to describe a system for computer-assisted innovation support, known as CyberQuest (CQ) and (2) to highlight a case study application of CQ in which the aim was to provide more and better housing for the poor, worldwide.

CQ was applied to a situation involving, hypothetically, the UN Centre for Human Settlement as a client. Ten ideas were generated in the case. While some have been employed before, several are unique and of some benefit, especially if combined together in a "package."

INTRODUCTION

Computers and ideas are a logical combination that have in many ways caused a subtle revolution in urban areas. Penzias, in Ideas and Information: Managing in a High Tech World (Penzias, 1989) points out that automobile designers have created petroleum out of pure information. Relatively less fuel is needed today because automobiles are much more efficient than before. This is due in great measure to the ideas which designers have had for lightweight structures; efficient drive trains; microprocessors used for a variety of purposes; and computer-aided design to help bring these about.

This paper focuses on a hypermedia hardware/software system for creativity and innovation support known as CyberQuest (CQ). This will be described in some detail as will a case dealing with the problem of shelter for the homeless. It should be noted from the start that CQ does not generate ideas itself. The users do. But CQ does provide conceptual stimuli from which users can generate ideas and ways to help users screen, package, and evaluate their ideas to bring them to a more complete and usable form.

CYBERQUEST

CyberQuest (CQ) is a hypermedia-assisted approach for generating and evaluating ideas to help solve a particular problem or achieve a particular opportunity. CQ contains databases of diverse concepts drawn from management, engineering, physics, sociology, science fiction, art, religion, and many other fields. The main section of CQ software allows the user to define an "aim" and search databases for concepts that relate to this aim. These concepts help the user to generate ideas, which in turn can be screened, packaged, and evaluated.

Brief Description

The six basic steps in CQ are:
1. Problem Description and Analysis
2. Word Selection
3. Generation of Ideas
4. Idea Screening
5. Idea Packaging and Evaluation
6. Reporting

As a brief and highly simplified introduction, in step one the user is asked for a short (50 character) description of the aim to be achieved through any ideas generated via CQ. Subsequently, the user selects four key words, from a list provided by CQ, that best relate to that aim description.

Once the appropriate key words have been chosen, CQ employs them in step 3 to match against concepts in the databases. These concepts come from several sources and cover a variety of topical areas. They, too, have four words describing them, again taken from CQ's list. If a match is found between a word describing the aim and one associated with a concept, the assumption is made that there is some similarity. The matching concept is displayed on the screen and the user asked to try to draw an analogy to obtain an idea to help achieve that aim.

In step 4 the ideas are screened. This involves assigning a "status" to each, depending on whether the idea has been done before or not and its implementability. Packaging and evaluation, in step 5, require that the user look for combinations of ideas that are more productive, beneficial, cost-effective, etc. than any idea individually. The resultant packages are then evaluated for completeness, and decisions made among them. In the final step, reports are generated showing the ideas, associated concepts, screening results, and packages.

Another feature of CQ is that the idea sets can be put back into the system's data bases and employed by succeeding users with a similar type of problem.

More Detailed Example

The illustration below draws on the case to be described later on providing more and better housing worldwide. Two points should be noted:

(1) CQ is a much "richer" system and process than is demonstrated here. It would take a much longer paper to describe all of its features. We also have found from

experience that most péople cannot fully grasp its potential unless they actually try it.

(2) The current version of CQ is much richer than that employed at the time the case was done (about 1½ years ago). In particular, the screening, packaging, and evaluation steps are much more elaborate now. The emphasis in the cases thus is on idea generation, although the example below also touches on the later steps.

Step 1: Problem Description and Analysis. The aim to be achieved is identified as finding a new way to "provide more and better housing for the poor." The client is hypothesized to be "the UNCHS" and a time horizon for the implementation of any resultant ideas is taken as ten years.

Step 2: Word Selection. CQ contains about 190 base words. Approximately 130 of these are "subjects" (nouns), divided into the categories of Groups of People, Bodily Functions, Natural Environment, Manmade Environment, and Abstractions (such as "Love" and "Quality").

The remaining base words are "descriptor (adjective) pairs", like "new - old," "large - small," and "accessible-inaccessible." The user selects two words from the first set and two pairs from the second. The chosen words must approximate those in the aim as closely as possible.

To illustrate, for the aim of providing more and better housing for the poor, the words selected were:

Housing (for "housing")
Quality (for "better")
Wealthy - Poor (to make the "poor" more "wealthy")
Numerous - Scare (to go from "scarce" to "numerous" houses)

It is important that most of the selected words NOT be the same as those in the aim, since a modest difference usually will lead to concepts somewhat outside, but close enough to, the normal experience of the user.

Step 3: Idea Generation. There currently are 18 sources of concepts in CQ. Some of these are listed and described briefly in Table 1. Each concept in these sources has four words selected from the same CQ list.[1] After the user picks one of the sources, CQ attempts to match one or more of the concept key words with those describing the aim. If such a match is found, the concept is displayed, and the user tries to come up with an idea for the aim.

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[1]Except for the CD-ROM's. On these the user can search for CQ (or any other) words in the text.

The process is illustrated in Table 2. In the top part, the user has picked the General Concepts source. This has about 200 concepts in it.

TABLE 1
SOURCES OF CONCEPTS AVAILABLE IN CQ

Examples:	Illustrations of particular base words.
Previous Ideas:	Idea sets from previous CQ applications
General Concepts:	Broad-based phrases involving general action
Definitional Concepts:	Terms with defined properties or characteristics.
Relational Concepts:	A conclusion and one or more premises affecting or leading to it.
Electronic Encyclopedia:	Compact Disc Read Only Memory (CD-ROM) with 30,000 articles (9 million words).
Music:	Descriptions of about 250 pieces of music, which can be searched and then played.
Video Discs:	Descriptions of frames (slides) on six video discs.
Unique Facts:	Derived from Ripley, Asimov, and others.

When matching is attempted, CQ finds the concept "Turn Something Upside Down" (the ninth concept in the file). The match is on the descriptor pair "numerous - scarce" (presumedly because turning something upside down might make something "numerous" seem "scarce", or vice versa).

The user now is asked to come up with ideas based on this concept. We cannot imagine what associations might go through his mind, but let us guess that he had been thinking about money, then "turned that thought upside down" to get taxes, which in turn brought to mind the idea of a tax on the rich -- perhaps a value added tax on luxury goods. A similar process might link the concept of "Mercantilism" (matching on "wealthy - poor") and the idea of having a "origination fee" for a country depending on the amount of its exports and per capita GNP.

TABLE 2
AN ILLUSTRATION OF IDEA GENERATION

Source:	General Concepts
Concept:	"Turn Something Upside Down"
Matching Words:	Numerous - Scarce
Idea 1:	Have a value-added tax on luxury goods.
Source:	Relational Concepts
Concept:	Mercantilism
Matching Words:	Wealthy - Poor
Idea 2:	Have an origination fee depending on exports and GNP.

Step 4: Idea Screening. Many ideas can be generated in a short period of time. Not all can or should be considered for implementation. The set of ideas thus needs to be screened. Each idea is given a status[2] per the categories in Table 3.

For instance:
Idea 1: Value-Added Tax (should be implemented)
Idea 2: Origination Fee needs to be thought out more.

TABLE 3
SCREENING STATUS CATEGORIES

It really is a goal to be achieved. (Goal)
- It has been done before:
  - Successfully. (Successful)
  - Unsuccessfully. (Unsuccessful)
- It has not been done before:
  - It needs to be thought our more. (Muse)
  - More information is needed. (More Info)
  - It would not be feasible under current conditions. (Infeasible)
  - It could be useful given contingencies. (Contingency)
  - It should be implemented. (Implement)

Step 5: Packaging and Evaluation.
The screened ideas can be put into "packages" according to similarity, complementarity, mutual benefits, time sequencing, and/or resource limits.

[2]In the current version of CQ
, the user also can enter evaluative comments for each idea and give it ratings both for importance and effort (resources) required for implementation.

These packages then can be assessed considering the aim and other factors, such as: (1) revenues, (2) benefits, (3) costs, (4) profitability, (5) innovativeness, and/or (6) completeness.

To illustrate, we might combine ideas 1 and 2 into a single package:

Have a value-added tax on luxury goods exported, with the tax rate depending on the export levels and per capita GNP.

This package might then be evaluated as being useful in meeting the aim of providing more and better housing for the poor. It also seems to be relatively inexpensive and perhaps not subject to overwhelming political rejection.[3]

Step 6: Reporting. CQ can produce a variety of reports -- for idea generation, screening, and packaging as well as a final summary of the three.

Additional Feature: The ideas produced in this case can be put back into the system as "Previous Ideas" files, accessible by future users in the Idea Generation step.

<u>The Case</u>

The case chosen for demonstration in this paper is a small one. This is intentional since most of the others with which we have dealt[4] have involved 40 to 80 ideas and thus are simply too large to present in sufficient detail here.

The focus of this case, as brought out in the preceding example, is the provision of more and better housing for the poor (with a more specific center point being those people, primarily in the third world, without any shelter). The case was undertaken in a two hour period about a year ago at Virginia Tech with the assistance of two people:

Dr. Gyorgy Kunszt, former Director, Hungarian Institute of Building Science, and one time consultant to the UN Center for Human Settlements

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[3]The current version of CQ has several sets of checklists to help the user make a more complete package by considering, for example, financial, legal, organizational, personnel, and "sales" concepts that may be applicable. The user also can employ a variety of analytic tools -- like spreadsheets -- to do cost and other analyses.

[4]There have been at least four others dealing with housing in one form or the other.

Mr. David Goodsell, middle-aged Ph.D. student in the Center for Public Administration and Policy, with a broad background in policy matters.

Thus there was one person with direct knowledge of the problem; one with more general project experience in a number of developing countries (myself), and one particularly creative person. In addition, Dr. Kunszt brought the perspective of an Eastern-block socialist country.

The ten ideas that were generated in the short session are presented in Table 4. Along with these are various notes which help to clarify and give examples to the respective ideas.

As can be seen, the first two ideas are the same as in the preceding example. They are based on the concepts presented there. The others evolved from just two other concepts, both of which came from a conceptual data base dealing with economics and finance. It thus is not surprising that most of the ideas deal with taxes and other economic incentives.

TABLE 4

SUMMARY OF IDEAS

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1. Have a worldwide, value added tax on luxury goods to be used for housing in poor countries.

   Notes: Since much gold and diamonds come from South Africa, there may be sympathy among both Eastern and Western-block countries for such a tax.

   Have the UNDP, World Bank, or regional banks collect the tax as part of their on-going programs.

2. Have each country pay an "origination fee" depending on the amount of their exports and per capita GNP of the country.

3. Have a tax which, by agreement, would come into effect any time the world price of a special factor increases above a certain, prespecified level.
   Note: An example may be for oil.

4. Have a tax imposed on any country whose monetary exchange rate with the rest of the world rises at some "exorbitant" speed.

5. An international bank found guilty of being an accomplice to an illegal transaction would be required to set up a loan fund for housing for the poor.

Note: For example, Pres. Noriega's use of Panamanian banks for laundering of drug money.

6. As part of military treaties, have a portion of the money saved from arms reductions dedicated to housing for the poor.

   Note: The interrelationships between domestic, foreign, and military policies (called "intermestics" by Bayliss Manning) should be considered here.

7. Develop an international insurance program for poor people who lost their housing due to natural disasters.

   Note: More wealthy people may be willing to support an insurance program rather than a "giveaway" program.

8. Mesh the overall government support for housing with individual participation within the population.

   Notes: East Germany is an example of strong governmental support for housing, although with relatively poor quality and a low level of participation from the population.

   An example of individual participation is in Mondragon area in Spain, where cooperatives are employed beneficially.

9. Get a better understanding of the relationships between the rigidities within the financing, technology, and architectural systems.

   Note: An example may be the historic development of housing policy in Hungary and China, where the reduction in rigidities is in progress.

10. Have an insurance program whereby high-income house buyers or renters would pay for payment default insurance.

    Note: This would help low income buyers/renters whose incomes (and therefore ability to pay) would be more likely to vary with the economy.

Some of the ideas have actually been tried before (e.g., the insurance program in Idea 10) and most of the others suggested at one time or the other. Still, according to Dr. Kunszt, one or two are new and unique, at least as far as his experience goes.

No attempt was made in this case to screen, package, or evaluate any of the ideas. Yet it is easy to imagine, say, various packages that might be suggested. For instance, in the current era of interest in arms reduction, idea 6 (Use Arms Reductions Savings) might have some appeal and possibly could be combined with Idea 8 (Mesh with Individual Participation) in many countries.

We harbor no illusions that any of these ideas would be easy to implement. The UNCHS is known primarily for identifying problem areas and carrying out small scale studies. It, like most UN agencies, has very little in the way of funds to spread around. On the other hand, it could try to encourage individual and groups of countries to enact laws and regulations that might help achieve some of the ideas listed in Table 4. Screening, packaging, and evaluation thus are difficult tasks here because they may involve different countries and different circumstances.

COMMENTS

Because CQ is new and unique, there are a great many more questions that can be asked about than can be answered in the space here. We will attempt, nevertheless, to address two broad, central issues, then discuss the main focus of this paper... the use of computers in innovation support in urban planning and management.

The two general issues reduce to the questions: "Are any of the ideas really new?" and "Are not all the ideas just common sense that anybody could generate?" The answer to both is a clear "it depends." On the first, we have found that perhaps only 20% of the ideas are "new." But we are not sure. Perhaps if an intense, expensive worldwide survey were undertaken, the percentage would be much less. That may not be the point, however. The comparison perhaps should be to an equivalent use of time and resources by the people involved. Would they, in the limited time available, find something new and beneficial <u>to them</u>, even if it existed elsewhere?

A second point is that it usually is not any one idea that is "new" but a combination (package) of them. The two ideas in the example case of a "value-added tax" and "origination fee" are not new individually but are new in combination (we think).

These two points show that the overall issue of "newness" and "uniqueness" is a complicated one, which has only been explored briefly. A more in-depth analysis will have to come in another paper.

The second issue is that of "common sense." We have found such only partially common. We usually find that several of the ideas suggested, particularly in the beginning of a session, are well known by most people who have studied or given thought to the problem at hand. Moreover, some clever person (or group) might easily come up with a lot of the ideas simply by spending more time thinking about the problem. Still, there can be a big difference between knowing you <u>could have</u> come up with the idea and actually doing it.

Once you are exposed to a new idea, it often becomes "obvious" and very much "common sense." The point is that many times it is not easy to come up with the ideas that immediately thereafter appear as "common sense."

<u>The Role of the Computer</u>

The major advantage of the computer (as well as the audio-video equipment) in CyberQuest is the vast number of concepts that can be searched and brought to bear on a problem. Particularly with the CD-ROM's, there are literally millions of concepts available. This makes the system much richer than any individual or group of individuals, at least in terms of general knowledge (like that found in a large encyclopedia). This, combined with people's "local" knowledge (like that of their own organization, which usually cannot be found in an encyclopedia), provides almost all of the ingredients and information needed to develop beneficial, relevant ideas.

CQ also has the advantage that it can be employed by an individual as well as a group. This can be compared to, say, a brainstorming session, which requires six to eight people to be effective. Moreover, with CQ the ideas can be screened, packaged, evaluated, and put in a printed report all in one sitting.

Curiously, one possible disadvantage of CQ is that it may be <u>too rich</u>. In the cases reported here only four concepts, out of the millions, were employed to generate ideas. Obviously there are a lot more that possibly could have provided an even better base for ideas.

It also happens that, as here, a CQ session usually stops after the idea generation step. The first three steps can be done with one group at one setting, whereas screening, packaging, and evaluation generally require an extended period of time for formal information gathering, conversations with varied groups, and general interpersonal interaction. The number of actors involved usually increases substantially in these steps, which is difficult to coordinate via CQ.

Currently our interest is in identifying circumstances for the proper use of CQ in the on-going, real-world process when alternatives are generated and evaluated and decisions made. Since these activities occur at varying times and places and with varying actors, it is not clear how CQ can be employed to best advantage. In the above case, for instance, CQ was employed for a total of about 2 hours. Considering how long the problem has existed, and the large number of person-hours invested by a wide spectrum of groups in searching for solutions, the CQ time was miniscule. It thus is surprising that anything worthwhile could emerge in such a comparatively small time. It also is obvious that greater doses of CQ, at the proper points and with the proper people, could have comparatively worthwhile payoffs.

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COMPUTERS, TELECOMMUNICATIONS AND PLANNING

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ABSTRACT

This paper details analysis undertaken in planning the provision of new telecommunications infrastructure in Australia. A bundle of new technologies (optical fibres, ISDN and fast packet switching) await installation as the new telematic infrastructure for cities in the 1990s. GIS and microcomputer-based planning tools are employed to identify those areas requiring early installation of telecommunications hardware, based on an examination of information - intensive industries, their modes of operation and their forecast demand for new services linked to the new telecommunications infrastructure.

INTEGRATING URBAN INFORMATION SYSTEMS AND SPATIAL MODELS

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ABSTRACT

Recent developments in urban information systems and regional modeling in the United States have created the basis for an integrated approach to urban problem-solving. Urban and regional information systems are finally delivering on the promises of two decades. Spatial modeling of locational decisions has had renewed interests and substantial resources committed. The evolution of geographic information systems, and corollary digital encoding of all types of spatial information, has been impressive. The U.S. Census will produce TIGER geo-referenced files as output from the 1990 census, and information will be widely available in optical media in the form of CD-ROM disks. This paper will outline these developments broadly, focusing on the current development of urban information systems and utilization of spatial models.

Urban Information Systems

The General Concept

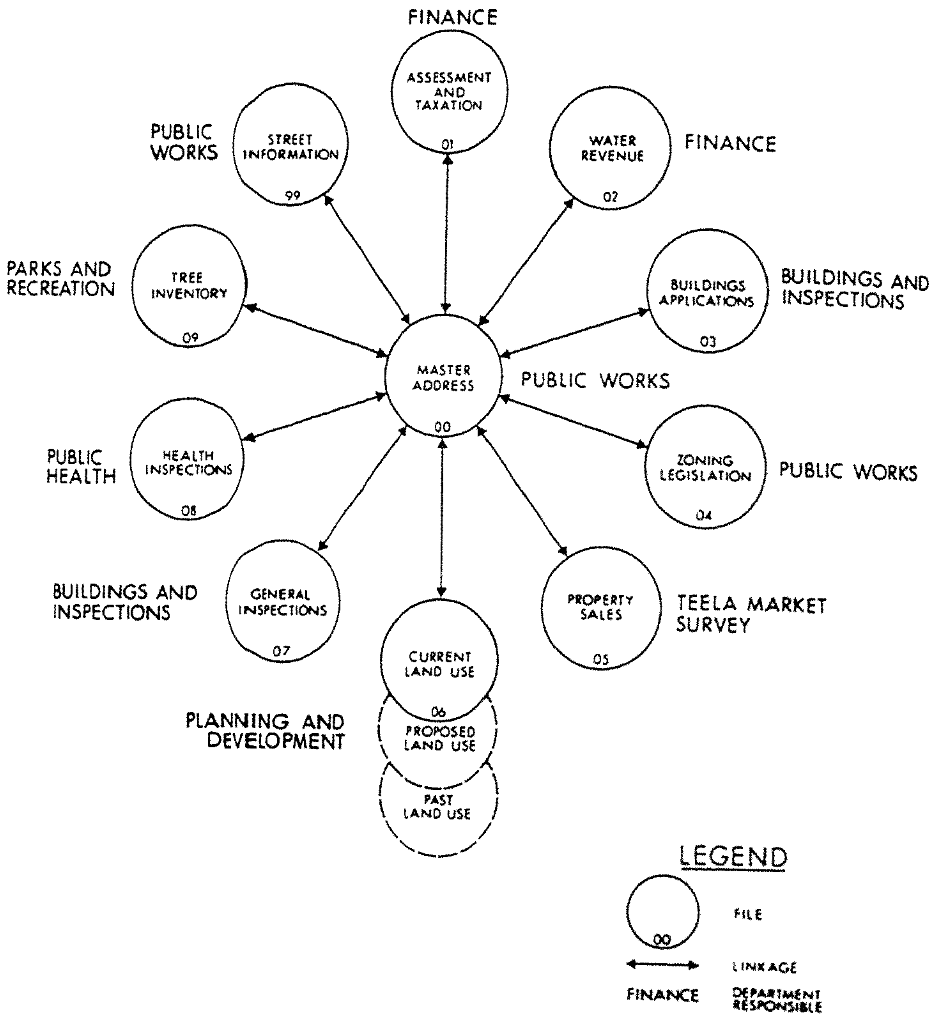
Broadly conceived, urban information systems contain structured databases, projective models, and query methodologies useful to problem-solving in city and region. The databases range across the wide set of administrative and planning activities. We shall focus on one easily understandable system as an illustration of the kinds of files which can be maintained. We shall use the database design of this system as a counterpoint to a more powerful alternative. This comprehensive system, The Central Property Register in Toronto, Canada contains files which cover the areas shown in Figure 1 (Mitchell, 1985). Designed as a hierarchical data model, there is a "parent-child" relationship among the files in the database. The center of the wheel is the Master Address file, which is the primary identifier for the records stored in the system. Each record identifies a particular parcel address in Toronto. All other files, the ones on the rim of the wheel, are keyed to this Master Address file.

An examination of these files shows the extent of the Toronto information system. There are the obvious administrative ones -- water billing and tax assessments. The system contains current land use information on each parcel, a complete record of all permits issued for building activities, the inspections carried out on the buildings, and

FIGURE 1

CENTRAL PROPERTY REGISTER DISPLAY ACCESS SYSTEM

FILE ORGANIZATION



property sales data. This land use information provides necessary information for the planner, and is accessible through on-line computer terminals.

The Toronto information system also contains two files which are interesting examples of what can be included. One is the Tree Inventory file, where all trees located in public rights-of-way are recorded. Trees are an important urban resource, and such information can be useful to keeping track of the number, species and location of trees. Such information proves particularly useful when street reconstruction is required. The other interesting case is the Streets Information file, which contains a history of street maintenance activities by block segment. It seems that the harsh Canadian winters make systematic street maintenance essential. This roadway information permits the city to more optimally schedule repaving, thereby saving considerably public monies.

Urban information systems, such as Toronto, provide one piece of an integrated approach to better public decision-making. Bills can be sent, land use inventories calculated, and streets repaved on schedule. However, the kind of system described for Toronto is only one element in a comprehensive decision support approach. One of the obvious elements of better decision support is the ability to do queries. For example, one might want to know how many building permits were issued in a particular zone of the city during the past year, or the relationship between tax delinquency and land use category. The hierarchical structure of the Toronto system makes some questions impossible to answer, and all queries difficult to do. Other data models, especially the relational database design, provide a more flexible approach to query operations (Brail, 1987, 1988; Smith, Stanton and MacKenzie, 1988). An integrated approach using a relational model framework will be discussed subsequently.

Permit Tracking and Development Monitoring

One special element of the Toronto information system is the building permit file. This file and its use as an administrative tool represent what has been labeled "permit tracking." There are a large number of governments which have moved to computerized permit tracking systems.[1] The development of permit tracking systems within local governments is an useful addition to public management and planning. In a general sense, permit tracking is a element of development monitoring. We must be careful to distinguish between the two terms. Formally, development monitoring consists of 3 elements -- a permit tracking process which is able to document permanent changes in land use patterns, an information system which can store these changes in a database, and an analysis system which can assess the meaning of development changes for current planning efforts as well as forecast to the future.

There are a wide variety of ways in which permit tracking systems have been set up by municipalities in the United States and elsewhere. Only few can be categorized as full-blown development monitoring systems. While these development monitoring systems exist, the larger integration of monitoring systems with modeling efforts and alternative scenario building is just now emerging.

Development monitoring is a variation of the urban guidance system approach. Rather than attempting to shape future land use, development monitoring attempts to assess current patterns of development. Development hotspots can be spatially pinpointed and trends determined. Such monitoring would be useful for infrastructure planning and for assessing the need for new regulatory directions.

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[1] There are a number of recent pieces on permit tracking and monitoring. See, for example, Arbeit, Heald, and Skotzak (1987) on a system in Austin, Texas or Tryggvi (1986) on utilizing development tracking as a tool to assist capital improvement programming and land use planning. Other interesting papers are by Qureshi (1985) on a basic design, Routsala (1985) on microcomputer-based systems, Hester and Reed (1986) and Eidal (1985) on geographic information systems and tracking, and Held (1986) on an overview of a system in Wayne County, Michigan. Zwart and Williamson (1988) is an excellent piece on a system embedded within a GIS framework.

Godschalk, et al. (1986) and Bollens and Godschalk (1986, 1987) surveyed land supply monitoring systems These are not permit tracking systems as we have outlined them; however, the overview and survey data provided are useful as an introduction to an information systems approach. The report by Kops (1986) is a basic introduction.

Two existing tracking systems are particularly interesting in terms of their design and use. San Diego has developed a "Development Monitoring System" which tracks permits and provides updated community monitoring information. For example, the results of the analyzing current permits can be incorporated into distributed reports on community impacts. Existing development and permits for new construction, rezonings, and the like in the "pipeline" can be compared with calculated community "build out" estimates (Godschalk, 1986).

Montgomery County, Maryland has developed an information system which also monitors land use development through a permit tracking approach (Godschalk, 1986). Policy areas within the county are assigned a "threshold" level, or carrying capacity, beyond which additional development would require additional infrastructure expenditures. Once a threshold is established for an area, a simple calculation can be performed to determine the amount of development capacity left. The existing development at any point in time is added to the pipeline. Such a system requires a close relationship between permit tracking administration and land use planning. The basic equation is shown below:

Remaining development potential = Threshold - (Existing + Pipeline)

The development of such a system permits the planner to assess the kinds of changes which are being made in the built environment and develop some handle on where infrastructure problem are likely to occur. The concept is straightforward and powerful, but does require the integration of an urban information system with a land use plan which sets capacity limits. As Krueckeberg and Silvers (1974) pointed out over a decade ago, there are two highly general models of how planners can view community change. The "planned requirements" approach develops the urban future in terms of a master plan, while the "market simulation" approach attempts to simulate locational decisions through various model frameworks. To a degree, the development potential approach outlined for Montgomery County sets out development goals, but does not tell us when they will be reached or the likelihood that they will be exceeded. This system is a variant on the planned requirements concept, except that only the total development potential is mandated. The question then: is there not a need to examine the market simulation concept? We shall do so by exploring current efforts at urban spatial modeling in the United States.

Urban and Regional Spatial Modeling

An Overview

Urban spatial models are designed to allocate future population and employment projections to sub-areas within a region. They are also called urban development or intra-urban allocation models. Unfortunately, the future which is predicted by these models is often based on data from the distant historical records. Thus, in 1989 an analyst might dutifully predict year 2000 development patterns using 1980 data, the most recently available base year data from U. S. Census, as the beginning point. Model calibration might involve using the 1970 to 1980 period, the most recent period for which data were available. Or, the model parameters will be derived from previous studies and other places. Any reasonable projection effort using such models will occur in spite of the data, not because of it. Emerging technology and practice may now permit a stronger link between past and future -- the present. The growth and maturation of urban information systems, such as discussed above, with monitoring of current development trends, may well contribute to better spatial models.

In spite of data deficiencies, urban development models have had a resurgence in the United States in the past decade. The current interest in spatial modeling in the United States to a great degree is the result of the efforts of one individual, Steven Putman at the University of Pennsylvania. The ITLUP (Integrated Transportation and land Package) has been in development under the direction of Putman since 1971. The package is currently in operation in a number of U.S. regions. The models are being used in the Puget Sound Council of Governments (Seattle), Mid-America Regional Council (Kansas City), the Pike's Peak Area Council of Governments (Colorado Springs), and the North Central Texas Council of Governments (Dallas-Fort Worth). Of particular interest is the current work in the Los Angeles region done by the Southern California Association of Governments (SCAG). The study area is large and the region very dynamic in terms of demographic change and urban development.

Beyond the ITLUP modeling effort the other major approach has been based on derivatives of the Lowry model heritage (Webber, 1984). One of the interesting current efforts is occurring in the San Diego region, where they are using a version of PLUM, the Projective Land Use Model (Kunkel, 1988; San Diego Association of Governments, 1988a, 1988b). The whole system consists of four models -- DEFM (Demographic and Economic Forecasting), BEM (Basic Employment Model) and PLUM. The DEFM model produces regional forecasts of population, housing and employment, while BEM allocates basic employment to zones. Following the Lowry approach, PLUM allocates population and local-serving employment to 161 zones in the San Diego region. The final model, SOAP (Sophisticated Allocation Process), further allocates population, housing, and employment to a highly disaggregated level of grid cells 2,000 feet square. There are approximately 25,000 grid cells in the study area, a very high level of detail.

We will focus on the DRAM/EMPAL models of the ITLUP system in outlining the current status of spatial modeling in the United States. There are two reasons for this decision. First, the DRAM/EMPAL set of models appears to have momentum in terms of new applications. Douglas, Whitmore and Jacob (1987) have done a nationwide survey of 105 planning agencies, private consultants, and universities. They conclude that:

> The survey analysis suggests a possible trend in the development and application of small area forecasting models. The general trend seems to be moving from the land use allocation techniques of the early 1970's, to the more complex statistical models such as DRAM/EMPAL. (Douglas, Whitmore and Jacob, 1987)

Second, there is a growing body of empirical work on DRAM/EMPAL which permits us to examine exactly how well such models do in both calibration and prediction.

The Structure of ITLUP

The ITLUP system currently consists of five models (Putman, 1989). The earlier work is chronicled in *Integrated Urban Models: Policy Analysis of Transportation and Land Use* (Putman, 1983). The current structure contains five models (Putman, 1989):

1. EMPAL -- An employment location model
2. DRAM -- Residential location and trip distribution
3. LANCON -- Land consumption sub-model (inside DRAM)
4. MSPLT -- Modal split
5. NETWRK -- Trip assignment

The ITLUP model system addresses the interactions between land use and transportation which occur over time. One contribution of the Putman approach has been the development of an integrated land use and transportation approach. The sequence of this recursive general equilibrium design is intuitive. First, EMPAL is run, projecting zonal employment by type for time period t+1. Next DRAM is run, projecting t+1 households by type. ITLUP defines types of households in terms of income. LANCON is the third step, calculating the amount of land consumed. DRAM produces both future residential location and three trip matrices -- home-to-work, work-to-shop, and home-to-shop. These trip matrices then feed the transportation side of this integrated approach. MSPLT does a modal split, separating auto and transit trips. Finally, NETWRK then assigns automobile trips to a highway network. The network assignment model produces a zonal travel time matrix which can be used as input to EMPAL and DRAM on the next iteration, demonstrating the recursive equilibrium approach.

In point of fact, the idealized version of ITLUP with land use and transportation elements feeding each other has not been used widely. More typically, only EMPAL and DRAM are run, projecting employees and households. Putman (1989) discusses the results of four case study results using DRAM for the Houston-Galveston, Washington, Los Angeles, and Colorado Springs, Colorado regions. The independent variables in DRAM currently include :

1. Travel time
2. Vacant acres
3. Percent developed acres
4. Residential acres
5. Percent low-income households
6. Percent lower-middle income households
7. Percent upper-middle income households
8. Percent upper income household

The variables reflect different classes of predictors. Travel time is a standard **spatial interaction** predictor. Vacant land, percent developed acres, and residential acres are all **land suitability** variables. The income predictors are what Putman (1983, p.216) calls **household composition** variables, meaning that new residential locators of a particular income class will seek nearness to others of similar income levels. Some of these predictors, such as travel time and land suitability variables, find their roots in earlier spatial models. The household composition variables are an interesting addition.

The DRAM model contains embedded theoretic concepts which are not as well specified as would be desired. For example, Lenk (1988) has pointed to the instability in the vacant land variable. In some applications the sign of the variable is positive, meaning that more vacant land means more residential development. In other studies, the sign is **negative.** The vacant land variable was dropped in the Puget Sound study because of collinearity (Watterson, 1988).

Calibration and Prediction with Spatial Models

The relative newness of spatial models and lack of available data has pushed model builders to calibration on relatively few data points. For example, DRAM/EMPAL has often been calibrated on zonal data for a single year (Putman, 1989). There are relatively few cases when the calibrated model has been used to predict to some future point with model results compared to actual numbers. There are continuing questions about the ability of existing spatial models to predict the future, rather than calibrate the past. Much energy has been spent on the calibration phase, and considerably less on checking how well models predict. Since the behavioral bases of these models tend to be weak, this focus on statistical fitting to known facts raises questions. The DRAM/EMPAL model environment is reasonably mature by current standards, yet the appropriate balance between calibration and prediction is unclear.

The DRAM/EMPAL combination is currently being applied to the Los Angeles region (Putman, 1989). Both calibration and real-world validation are being done. The preliminary results add to our understanding of the current situation in spatial modeling. Efforts to produce creditable calibration results in DRAM/EMPAL environments have lead to the use of K-factors. These individual zonal adjustment values are used to account for differences between actual and predicted values during the calibration phase. These differences, or residuals, are assumed to be the result of unexplained behavioral factors.

It may be recalled that one of the criticisms of the gravity models used for trip distribution is the ubiquitous use of similar "socioeconomic" adjustments factors. The DRAM/EMPAL implementation in Los Angeles follows transportation planning practice in that it is assumed that K-factors will remain constant into the future. Clearly, the use of K-factors make some sense: simple models have difficulty with complex non-deterministic systems. For example, the DRAM model would over-predict development in a forest preserve located in a highly developable suburban area. A K-factor adjustment would be appropriate in sterilizing the zone for development.

However, what is simple in concept is harder in implementation. In the Los Angeles case, DRAM and EMPAL were calibrated on 1980 data with reasonable fit.[2] Comparative data was available for 1987. This real-world data was scaled back to 1985 and DRAM and EMPAL run against them. Both DRAM and EMPAL were run with and without K-factor adjustments. Without K-factors the correlation for total households was .51 The correlation increased to .91 using K-factors carried forward from the 1980 calibration run. Clearly, the inclusion of K-factors helped prediction in this short-run case. However, the inclusion of K-factors in the EMPAL model lowered the correlation over the case where they were not used. While the results reported by Putman are preliminary, they suggest that prediction is an inexact science at best.

The difficulties which the DRAM/EMPAL models face in calibration and prediction are inevitable given the complexity of urban spatial systems. These problems extend beyond DRAM/EMPAL to other modeling frameworks. The Lowry model has faced similar difficulties. In reviewing the results of a number of applications Webber says:

> The results which have been described in this chapter are disappointing. Despite such improvements to Lowry's model as explicit spatial interaction equations for journeys to work and shop, formally defined submodels of the supply of housing and developed land, and disaggregation into social groups, the model still performs erratically and can only infrequently allocate service jobs and populations with errors of less than 15-20%. (Webber, 1984, p.128)

Integrating Information Systems and Spatial Models

There is a large gap between the avowed purposes of model builders and the needs of planners and policy makers for decision support tools. The planner would like to be able to use models to test alternative futures. Lenk (1988) and Watterson (1988) both discuss actual planning applications to which DRAM/EMPAL was put in their regions. Lenk is particularly critical of DRAM/EMPAL in terms of model specification and calibration results. Watterson claims reasonable results in various policy tests, although he cautions that the models must be run by experienced modelers. He states that: " success in modelling is fundamentally dependent on human expertise, not on the models themselves" (Watterson, 1988, p.92). If spatial models are left to model builders, then we cannot expect their wide use as decision support tools for planning future urban environments.

There are a number of propositions which can be stated at this point. First, we need to recognize the inherent weaknesses of using models to predict the future. Complex urban systems cannot be easily understood, and the suspicion with which

[2] The DRAM and EMPAL models are non-linear in design. Instead of using the linear coefficient of determination (R^2) Putman (1983) uses the maximum likelihood criterion. The likelihood criterion was run to test the calibration results on DRAM in Los Angeles, and ranged from .55 to .76 across four income groupings for 772 zones. Interestingly, the R^2 values are also reported and are uniformly 5 to 7 points below the likelihood criterion values. For all practical purposes, these two measures run together in three case studies reported (Putman, 1989).

analysts such as Lenk and Watterson have viewed model outcomes suggests that this feeling is shared.

Second, there needs to be better integration between models and data. There is very little discussion of data as a resource in the spatial model-building literature, and even less discussion of models as analytic tools for urban information systems. There is some absurdity in a model builder in 1989 predicting 1990 from 1980 data. Even if the prediction year is 2000, or thereabouts, the question remains: should we not use current data to correct the path of longer-term projections? Real-time monitoring of development trends could greatly assist the projection process. Access to an disaggregated socio-economic database can assist the modeling process in other ways. For example, should we attempt to relate K-factors in models like DRAM to identifiable social areas within a region? Current modeling appears generally oblivious to the concept of community. The K-factor represents that unexplainable "something," although we have not identified exactly what the something is. Would it be possible to introduce ethnographic elements into the analysis? In other words, modelers might be able to explore the use of cultural factors as explanatory devices.

Third, both models and data, must be conceptualized within an integrated framework. Such framework would place a variety of data sources and models within a common environment. The relational data model has been proposed as one element of a larger conceptual effort which has been labeled the "structured urban model system" (SUMS) (Brail, 1988). The core of SUMS is simplicity in database design and the use of modularity concepts in model design. SUMS can work at many levels, but does require a methodological approach to how data and models are handled. The basic idea, while simple, requires the development of a "data management system," akin to ones proposed by Ezigbalike and others (1987) for the Province of New Brunswick land information network, and by Smith, Stanton and MacKenzie (1988) for a graphics-oriented database environment. This management system would operate as a "shell" to connect data with planning and policy models.

Ideally, we should be able to do "plug-and-play" with a variety of models. Perhaps, DRAM/EMPAL works in some parts of the study area, and PLUM in others. A shift-share projection may be appropriate for one scenario and not another. It may be possible to design expert systems which "learn" from the results of model applications by storing the results of model runs and using rule-based searches to suggest a particular analytic track for a new problem. There is increasing focus on developing expert systems for planning applications (Kim and Wiggins, forthcoming; Davis, et al, 1988; Han and Kim, 1988). We are proposing an expert system to assist the local planner is making reasonable choices in model selection and data manipulation.

In summary, urban information systems and spatial models need to be to brought into a common framework. Obviously, the development of GIS systems using the relational model are also important in developing this shell environment. Planner simply must come to terms with the vast quantities of data which are increasingly available describing the past and present, while not forgetting the future-oriented models which are our heritage.

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THE STUDY OF MICROCOMPUTER-BASED URBAN PLANNING AND MANAGEMENT INFORMATION SYSTEM

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ABSTRACT

Urban plannig and management information system is very useful in P. R. China today. But there are many difficulties to apply this system to actul work. Besides collection of data and coordination of orgnizations amd geocoding, the difficulty includes the expansiveness of system, the spatial analysis function of software and the unstability of usr's information flow. The Study of Suzhou Uban Planning and Management Information System was just in view of above problems. The result of study shows that urban planning and mamagement information system, although which is based on Su zhou's case, is acceptable to other cities even on personal computers.

Since 1987, urban planning has been resumed all over P.R.China. After ten years of work, master planning has been prepared and varies detailed planning has been doing in more than 400 cities. But tranditional planning dose not fit the needs of objective situation. First, on the concepts and patterns, it dose not fit the economic system transformation from planned economy to mixed planned and commodity economy. Second, on the methods and techniques, it dose not fit the construction need at quality and depth of work. Urban planning and management information system (UPMIS) is the foundmantal work to fit the tranditional planning to the actual situation. Although, using information system means changing of the methods and techniques, the improvement of analysis and efficiency will promote change of concepts and pattens of urban planning.

After 1980's, the situation of computer technology is favorable to spread computers. But even in the cities of developped country, only a small percentage actully has UPMIS. If UPMIS is often restricted by collection of data and coordination of orgnizations and geocoding in developed countries, the hardware and suppoting software are other restrictions in China. Because China is a developping country, many planning institutes even have not personal computers by now. This is the first problem for us in research of UPMIS. That is to say, the cost of system must be low.

Second, much of information about planning has spatial character. The system not only has large amount of alpha/numeric data but more graphic data and it can be useful only when two type of data associated together. In China, by now, there has been no commocialized software package that has spatial analysis function and can run on microcomputers.

Third, user's information flow of UPMIS is unstable. So, the user needanalysis is difficult.

In view of above promblems, the tactics of The Study of Suzhou Urban Planning and Management Information System are followiing:

1. The main members of research group is exprienced both in planning and in computer. So, it is easier to suitably seperate and analysis the complex system and to make the system's function simpler, of course, which can meet the user's essential needs.

2. After detailed comparion of many commocialized software packages that can be buoght with RMB alpha/numeric data base management system INFORMIX and graphic data edit system AUTOCAD were selected. The graphic and non-graphic data bases are read and written directly through program of C language. The function of these programs includes:

(1) Polygon topological data structure generation and checking;
(2) Area statistics of polygon overlay;
(3) Query graphic information associated with some attribute data;
(4) Query attribute information associated with some geographic area.

So, the system essentially has spatial analysis functions.

3. Some flexible modules, including mathematical statistics and common report writting have been made. These modules or programs can be served for prediction, evaluation, optimization or decision making of many planning problems at all time.

According to Suzhou's circumstance, the main contents of alpha/numeric data base are concerned with population, industry, education, hospital and health service, office, commercial facility, park and historic site, road traffic, land use and building. The main contents of graphic data are concerned with land use, building, infrastructure and administrative area. Most of statistical figures and maps was gotten from census bureau and sector of serveying and mapping of local gevernment. These were input by keyboad and tablate digitizer.

Now, Suzhou's UPMIS is the first one used by local gevernment in P. R. China and the data processing speed is acceptable even on IBM PC/XT computer.

With the help of Suzhou's UPMIS, large ammount of quantitative analysis have been done for the study of capacity of Suzhou old town. The study conclusion and analysis of background have been given to the gevernment as an important basis in the preservation and renewal of the old town.

Some software of the system was used in Shanghai south area planning, the Xinshikou area rebuilding planning of Wuhu, Anhui province and the master planning of Quzhou, Zhejiang province. Using the software improved the quality and efficiency of these planning works. Some planning institutes of other cities hope to use this system and to develop it further at their cities.

The result of study shows that UPMIS, although which is based on Suzhou's case, is acceptable to other cities even on personal computers.

Autthors' note

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URBAN PLANNING PROCESSES AND STRATEGIC INFORMATION SYSTEMS

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ABSTRACT

The paper is based on a project (Telford Urban Policy Information System Project or TUPIS) which is currently being developed in the Urban Research Laboratory at Liverpool University in conjuction with Wrekin Council and Prism Research (Telford). The aim of the project is to produce a prototype urban management (decision support) system in which three key elements (an **urban planning and management process**, a suite of **integrated stategic information systems** and the **technological and methodological environment** are developed simultaneously and to complement each other.

INTRODUCTION

The main task of this paper is to examine the role of strategic information systems in the process of managing urban change. This is mainly in response to a concern that current developments in GIS are being technologically-driven and are taking place in isolation from, and faster than, developments in other aspects of the policy making processes. Insufficient attention is being placed upon developing planning processes, data models of urban systems and data collection processes. The pace of technological development is far exceeding the pace of development in the data and policy-making infrastructures needed to manage urban change. This is compounded by the fact that developing primary data collection systems and enhancing the integratability of existing data systems is accorded far too low a priority by central and local government in the UK.

Unless there is a more even pace of development in the policy making processes which provide the context for GIS development and the data collection systems which underpin GIS development, the usefulness of GIS technology to urban policy making will be limited, decision makers will lose faith and the GIS bandwagon will grind to a halt. I argue that a managerialist urban planning process can be used to provide a framework the the more harmonious development of statistical systems, GIS technology, resource allocation techniques, expert systems and for the specification of research projects needed to enhance the knowledge base which informs urban policy making.

While many claims are being made about the potential of GIS in public policy-making, their role is basically to assist in the efficient storage of data, to enhance its ability to be interrogated, to assist in integrating disparate data sets and to provide an effective medium for presenting intelligence to decision-makers to support them in their attempt to make more informed and effective decisions. GIS are a means to effective decision making and not and end in themselves.

I will try to achieve three tasks. First, to describe a managerialist urban planning process; second, to describe a practical attempt to develop a suite of integrated urban information systems in Telford (though I will refer to other locally designed and managed systems in the UK) and, finally, to explore the policy-analytical potential of the Telford system and to examine how the system is to be developed.

TOWARDS A MANAGERIALIST URBAN PLANNING PROCESS

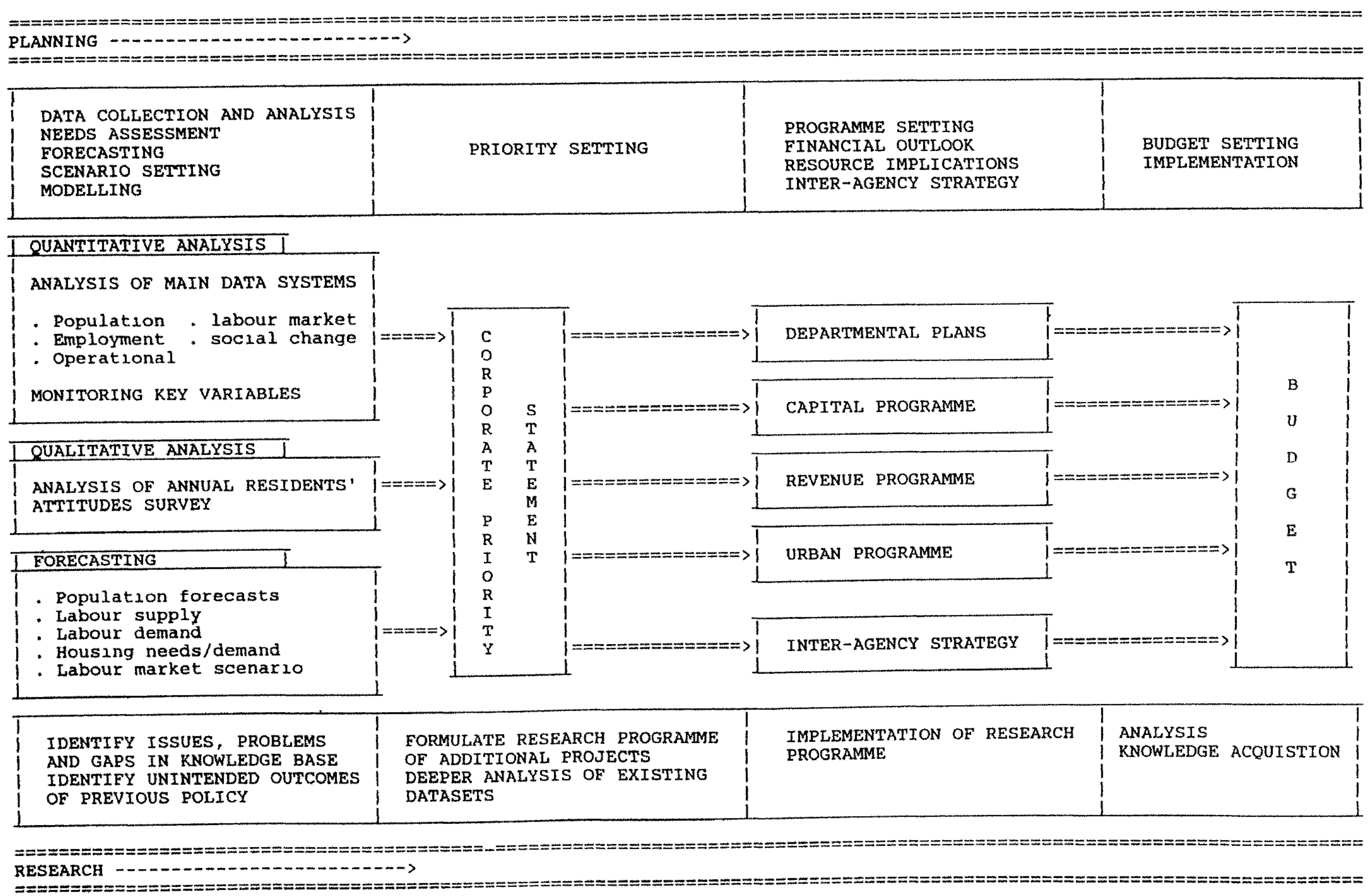
Even though urban systems are highly complex, dynamic and difficult to manage, this has not prevented some planning agencies in the UK from developing interventionist approaches to urban management. While many authorities have espoused such approaches, few have made explicit the planning processes they have developed to achieve their objectives in the urban system. The task here is to describe such a process.

A concern with urban systems is an active and not a passive concern and so GIS must be designed in the context of the planning process they support. The planning mode alluded to here is a continuous process of strategic choice based upon an emerging understanding of the causal structure of the urban system, an ability to identify nascent problems, an ability to anticipate the future, an ability to learn from intervention and an ability to adapt to the unforeseen. A managerialist approach to urban planning process is thus interventionist, analytically based, recursive, adaptive, problem-orientated, anticipatory and information-intensive.

The characteristics of this mode of planning place major demands on the strategic information systems ~~required~~ required to support it and the technological and methodological devices needed to assist informed and effective decision-making. It is in these two areas, information system development and the development of decision support techniques, that many UK local authorities have been particularly weak.

An outline of an annual policy planning process (similar to that used in Telford) is shown in Figure 1. The process begins with a scan of a suite of strategic information systems (which are described below) and a set of key indicators. A major feature of the planning process is its strong empirical basis. The objective in this first stage is to examine annual

Figure 1 A strategic planning process for the management of urban change



change and longer term trends in population growth and composition, household structures, labour demand, labour supply, commuting and social structure. The base data and assumptions derived from the trend analysis are then fitted into various forecasting models to produce consistent estimates of population growth, labour demand, labour supply and housing demand.

The "hard" data derived from the various information systems is augmented by "soft" data from an annual research project to assess residents' attitudes, values and preferences. Each year a survey of around 1000 households is undertaken in which residents are asked to state what they perceive to be the key issues and problems facing the area. In the selection of the sample of households, care is taken to obtain wide geographic coverage and to obtain a social class and housing tenure profile which reflects the composition of the area as a whole. By so doing it is possible to weight the preferences of certain social groups to reflect prevailing political values.

The second phase of the planning process is concerned with corporate priority setting based upon the empirical foundation provided by the first phase of the process. In this phase, the resident's attitude survey has been used to identify profound opinion shifts in the area (mainly away from labour market concerns to housing market concerns) and these have been used to re-orientate corporate priorities. The corporate strategy statement is then used as a contextual device for the development of departmental plans and various spending and implementation programmes which are reified in the annual budget. A major output of the third stage in the process is the development of an inter-agency strategy which provides the planning authority with a framework for the management of influence across other agencies active in the area.

A major feature of the annual process is that the planning and research functions are seen as parallel activities: while planning is seen as a process of preparing a set of logically consistent decisions for action, research is seen as a process for acquiring knowledge both about the structure of urban problems and about identifying effective means of bringing about politically determined ends. Many previous definitions of planning processes seem to have ignored the activity of knowledge acquisition as an integral part of the planning process. It is this commitment to knowledge acquisition and knowledge management which opens up the planning process shown in Figure 1 to the application of expert systems techniques. The area of knowledge management is an area where it is proposed to develop the planning process.

THE DEVELOPMENT OF AN URBAN DATA MODEL

The greatest impediment to improving our knowledge of how urban systems work and to the development of more effective public policy is the lack of data. More important, is the lack of coherent and integrated frameworks for data collection. Most of the socio-demographic information systems currently used to inform policy making have evolved separately, have been designed for administrative and not analytical purposes, are organised on different principles and cannot be integrated. These deficiencies undermine the ability of the systems to inform policy-making and as a result much urban policy is not empirically grounded and cannot be monitored.

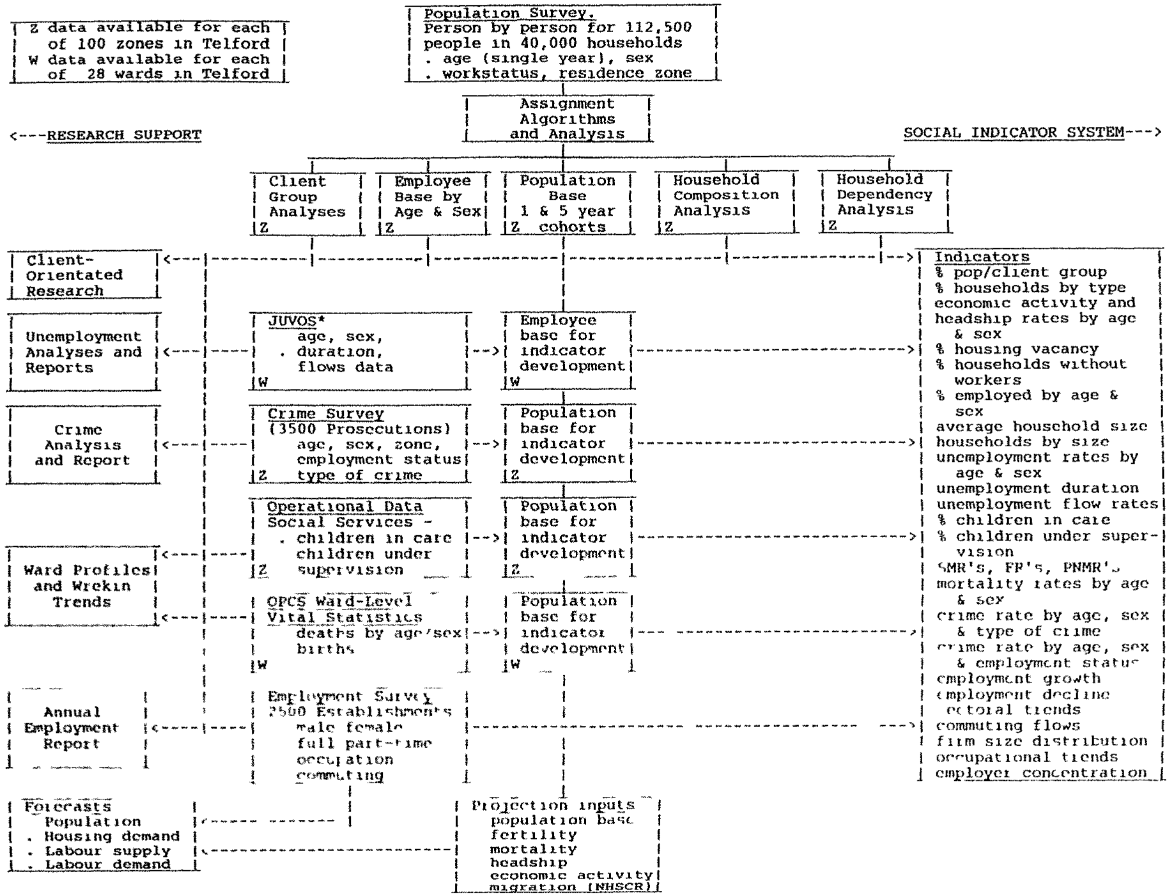
An interventionist planning style places major demands on the nature of the information systems required to support it: design issues such as periodicity, topicality, integratability and sectoral/spatial resolution are immediately apparent (Worrall, 1989c). High quality information is needed to facilitate the more efficient targeting of resources, to lay bare some of the social and economic processes which shape urban systems and to explore the causal structures of urban problems. The fact that Central Government and most local authorities have sought to develop policies without an adequate empirical base raises questions about the wisdom of these policies and more fundamental questions about how the effects of these policies have been monitored and evaluated against objectives.

In the UK, the nationally available statistical systems used to support urban planning are inadequate when evaluated against the above criteria (Worrall, 1988b). It could be expected that the poor quality of the nationally available statistical series should have prompted local government to develop its own systems to support local policy analysis and development: this has generally <u>not</u> been the case even though these authorities are the guardians of goldmine of often inaccessible and unintegratable operationally generated data. An unwillingness to invest in the development of appropriate information systems is due to a cost cutting mentality in many local authorities, the absence of people with the necessary vision and skills and the need to apply resources to coping with Central Government imposed legislative change.

Paradoxically, many local authorities in the UK are toying with GIS technology but the development of elaborate GIS "front ends" without corresponding developments in data quality will work agaianst responsive decision making rather than facilitate it. While research into methods of handling data and presenting information is essential, its value is undermined if equivalent developments do not take place to improve the quality, integratability and periodicity of the data needed to support urban planning and research.

There has been a growing realisation within some, but by no means all, public authorities that strategic information systems are essential to support decision-making in an increasingly managerialist environment. Despite the concerns listed above, some local authorities have made significant advances in the development of local systems: Strathclyde Regional Council and Wrekin Council (Telford) are two examples. The data systems developed in Telford are shown in Figure 2.

Figure 2. An Integrated Urban Information System: The Telford Model



* The nationally available JUVOS system superceded [illegible]

The information systems shown in Figure 2 were designed to monitor the economic, social and demographic development of Telford New Town but have subsequently been enhanced to form the empirical basis of the Wrekin Council's annual policy planning process. The Telford Model comprises a suite of both primary and secondary information systems which use a common geography which sub-divides Telford into 100 data collection zones each of which has a population around 1100. The zones can be aggregated into wards - the smallest politically accountable unit - and to approximate school and other facility catchment areas. The primary systems are an annual population survey, crime survey, employment survey and (until 1982) a six-monthly unemployment survey.

The Population Survey is conducted annually in conjunction with the electoral registration canvass and covers about 52,000 households. The global response is usually around 95% but this varies geographically (zonal response ranged from 79% to 100% with a median value of 96% in 1986, Worrall, 1989b). Three data items are collected on each person in each household (sex, age in single years and workstatus). Detailed household composition tables for zones and wards are produced via a suite of assignment algorithms and it is possible to identify specific household type client groups such as one parent families, pensioner households and households lacking economic support.

The Employment Information System comprises information on all employment-generating establishments in Telford. The data collected includes male and female employment (in full-time and part-time employment), employment in each of ten occupational groups (by sex), journey-to-work origin of employees and a range of sectoral and spatial identifiers. The data system is highly flexible and has been used for components of change analysis, research into occupational labour markets and the analysis of changing labour market structure (for example, changing employer concentration). The individual surveys have been built into two time-series data bases for analysis: one data base refers to the establishment level and the other to the firm level.

The Crime System contains data on all prosecuted Telford residents and is collected from the local police authority. The data items include age (single year), sex, employment status at the time of prosecution, prosecution type and zone of residence. When used with the population survey it is possible to produce a small-area analysis of crime for various age/sex groups. Between March 1981 and October 1982 (on a six monthly basis), the personal characteristics (age, sex, occupation, zone of residence, duration of unemployment) of all Telford's unemployed were collected an built into a time-series data base which was used to produce detailed local profiles of unemployment and to measure the determinants of the unemployed to employed flow.

The secondary inputs used in the model are natio available ward-level unemployment data (from JUVOS) ward-level vital statistics (from OPCS). Data obtained operational sources are also included (from the Social Ser and Education Departments of the County Council). The fulfills three main roles: it provides the empirical basi an annual policy planning process; it provides a bod information to support research and to frame addit research projects (Worrall, 1989a) and it supports a small social indicator system (Worrall, 1988a).

The indicator system has been used to measure dimensions of socio-spatial change: the changing associ between variables (this has comprised a continuous ecolo analysis of the changing strengths of the relationships be small-area indicators as a basis for identifing the dete ants of demand for services); changing spatial concentr (it is well known that social problems tend to be spat concentrated in certain neighbourhoods and an analysis of extent to which identifiable social groups are concentrate certain areas has been used to measure the (uninte outcomes of housing allocation policies), and third, cha variation (the indicators system has been analysed usi regression-based approach to identify whether social space becoming increasingly polarised (divergent social change) to identify specific areas which had suffered rel deterioration).

While the Telford Model has contributed significantly the management of urban change, there are two areas developments are needed. First, there is the need to tran the primary, secondary and operational data systems into a readily interrogatable decision support system geared to production of more responsive, anticipatory and effective policy and, second, there is the need to integrate more e iently operational data with strategic data by developing means of jointly analysing or simulating policy and operat interactions.

There are some deficiencies with the Telford M first, while the accounting of stock phenomena in the mode well developed, flow data on moves between system state largely missing, and, second, the system is not linked "graphics engine" to enable the production of mapped outp this has not proved to be a critical deficiency.

A second example of the development of local inform systems for urban policy development in the UK is provide Strathclyde Regional Council. The Regional Council strategic planning authority with a wide range of function an interventionist approach to social and economic p development. The Council needs a wide range of inform about the region and its population at a variety of sp scales to support its decision-making processes: the sp units range from local authority districts through s catchment areas to enumeration districts (Peutherer, 1988)

As in Telford, the central element of the Strathclyde data base is a local Voluntary Population Survey (Black, 1986). The survey is conducted in conjunction with the annual electoral registration canvass with each dwelling being geographically referenced by unit post-code (of which there are 75,000 in the Region). The availability of a wide range of demographic data on each of 75,000 areas clearly poses problems and so the data are aggregated to post-code sectors (410 in the Region). At the post-code sector level, data from other sources can be integrated within the broader data system. These data sources include JUVOS unemployment data and vital statistics (on births by age of mother, deaths by age, sex and cause) from the GRO(S). In addition, departments in the Regional Council are in the process of geographically referencing client-orientated record systems using unit post-codes.

The great advantage of the Strathclyde approach is that the system has been designed, albeit on a piecemeal basis, to meet the strategic planning needs of the Regional Council. Developments have taken place on three fronts: in developing primary collection systems, by integrating data sets from other agencies and by integrating administrative systems within a broader strategic framework. The data contained within the system are current, (the population base is updated annually) and flexible particularly in terms of geographic coverage.

The Stratchclyde and Telford examples show what can be achieved given the vision and commitment. While the systems have their deficiencies, they have been used to identify emerging problems, to measure need systematically, to analyse the structure of urban problems, to measure the effectiveness of policies, to clarify the situational characteristics of client groups and to improve the targeting of resources.

I have argued that the role of GIS in public policy-making has been inadequately specified, that GIS developments have been technology-driven not planning-led and that there are critical deficiencies in national statistical base which undermine the usefulness of GIS to practical decision making. To counter these points, I have shown that examples exist to show the benefits of a taking a planning-led, data-rich approach to the development of strategic information systems (SIS). In the Strathclyde and Telford cases, the GIS component of the SIS is at a relatively low level of development compared to the level of development of the "underlying" statistical systems and "overlying" planning processes - more succinctly, GIS development works best when it follows and not when it leads.

DIRECTIONS FOR DEVELOPMENT

Information systems in a policy-making environment should be evaluated by their contribution to practical decision making and the extent to which they can be used to explore the latent structure of urban problems. Essentially, this requires information system use to transcend the descriptive and be capable of prescriptive use. It is disappointing to note that many GIS applications have not gone beyond "clever mapping". The main tasks to be pursued in the TUPIS project are to develop the Telford information and research base, to link more effectively the strategic information systems, the operational information systems, the attitudinal data base and the various forecasting models (i.e. to develop a unified decision support system) and to build an effective bridge between the empirical data base for policy analysis and decision makers. How can these tasks be achieved?

The task of developing and linking the various data systems more rigourously could be achieved by the adoption of an accounts-based approach. An accounting framework is a device for organising data to illuminate relationships and facilitate analysis. House (1981) argued that an "integrative accounting system clearly points up the need to either generate new data bases or to make it more possible to link up existing disparate data bases". An accounts-based approach will also assist in identifying missing data sets which can be collected directly or produced synthetically by data estimation procedures (such as RUIN - see Birkin and Clarke 1986). The need to develop a system of policy performance indicators within the accounting framework also remains to be more fully explored (Clarke and Wilson, 1986).

An accounts based approach provides a consistent medium for conducting research, policy analysis, and planning - it will thus facilitiate the better integration of research into the planning process. The benefits of an accounts-based approach was summarised by Willekens (1984) who stated that "demographic accounting may...not only reveal data inconsistencies that may otherwise be covered up, but may also provide a proper approach for integrating the direct measurement, the indirect estimation and the analysis of..... data".

A second area for development the production of micro-simulation models using the raw data as policy testing and evaluation devices. A viable area is to use the raw Population Survey data on a household basis to simulate changing household structure as a preliminary to assessing housing demand, labour supply and migration.

The third area, and perhaps the most critical, is to develop an interrogation gateway between the masses of data which has been collected on Telford and decision makers. The possibility of developing expert systems in this area needs to be explored. The volume of data collected on Telford each year is bewildering and most of this data has been collected annually the late 1970's. In addition, there are the results of the many pieces of survey research which have been conducted in the context of the issues identified from the strategic information systems.

CONCLUSIONS

I have tried to achieve a number of tasks. First, to identify some concerns about the current stage in the development of information systems for public policy making: specifically, a concern that development has been technology driven and that the pace of technological development is far exceeding the pace of development of the planning process and data infrastructures needed to inform public policy-making. Second, I have described an operational planning process and the research and learning processes with have been integrated within it, third, I have described the statistical systems which underpin the process and, fourth, I have identified areas where the processes and systems are to be improved.

There needs to be a change in emphasis in urban analysis: there will need to be an increasing commitment to building models which are "data-rich but theory-poor" (Openshaw and Goddard, 1987). The main implication of this is that data has finally been recognised as the raw material of decision-making: this is a finding that urban researchers and model builders ignore at their peril. The emphasis in the future will need to be directed more towards an approach to urban analysis which is problem and data orientated.

More effort should be made to link information systems development to the needs of the planning processes used in (some) local authorities and to identify their role in practical policy-making environments: information systems cannot be developed in a vacuum and public policy must become more empirically grounded if intervention is to be effective. There is also a need to adopt a more integrated approach to the development of all aspects urban planning from the design of data collection systems through computing developments to the development of more effective planning procedures.

There is a need for closer working arrangements to be developed between policy analysts, model builders, knowledge engineers, GIS technologists and statisticians: hopefully, the Urban and Regional Research Laboratories in the UK and initiatives such as NEXTPRI in the Netherlands will make a significant contribution in this area. The importance of overcoming the problems which occur at the interface of the many activities which comprise the planning process, and in particular between decision-makers and the data models and techniques which support them, is paramount.

GIS will stand or fall by their perceived usefulness in public policy-making and it will only be by improving the quality of the data infrastructure on which these systems are built and making explicit the policy planning processes in which these systems operate which will prevent the GIS bandwagon from trundling down a path to oblivion.

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COMPUTERIZED DEVELOPMENT FEASIBILITY MODELS IN URBAN POLICY DEVELOPMENT AND DENSITY RIGHTS TRANSFER NEGOTIATIONS

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ABSTRACT

This paper focuses on the use of computer based development feasibility models in the evaluation of the economic impacts of density and other planning constraints. Several new micro and mini computer based investment value models are introduced and their potential role in land use policy development and density rights transfer negotiations evaluated. As well, the paper examines data input sources and the significance of yield measures. The use of these kinds of models is illustrated by valuing the impact of downtown density control measures of the type implemented in the central areas of such cities as Toronto, London, San Francisco and Boston. The example of Toronto is examined in some detail both in terms of the overall impact on development economics of the City's containment strategy and in terms of the compromises involved in specific bonusing negotiations.

FEASIBILITY MODELS AND PLANNING POLICY

As Graaskamp has argued, successful planning and development is one in which all of the participants maintain "cash solvency", and where the anachronistic "highest and best use" is replaced by the concept of the "most fitting use" evolving out of reconciliation (Graaskamp, 1981; Graaskamp, 1970). Central to the dialogue is the appropriate balance of costs, benefits and risk among the producing, consuming and infrastructure groups, and central to that dialogue is the ability to estimate, in advance, the nature of the balance and the likely response to planning action of the other participants. Generally, ignorance of such feasibility analysis weakens the process by which the necessary reconciliation comes about (Porter, 1986; Roddewig and Shlaes, 1983).

Negotiations between developers and public agencies over such policies as bonusing are also difficult for planners to negotiate in the public interest without being able to appropriately assess the value of the actions (Canestaro, 1982). Planners often have acquired skill in measuring fiscal, environmental, transportation, employment and other public impacts but have lagged behind in their understanding of the effect of public incentives and regulation on the developer's yield. Thus the planner, as negotiator, often finds himself in a poor position, unable to measure the effect of a specific tax or financial incentive on the feasibility of a development project or the benefits embedded in a given density bonus. Consequentially, incentives may be disproportionately large in comparison to the development's provisions for the public amenity or alternatively too small to induce the desired effect. This is unfortunate, for sophisticated computerized economic feasibility models are beginning to make possible the application of sophisticated development feasibility modeling by planning departments.

THE STRUCTURE OF ECONOMIC FEASIBILITY MODELS

Development feasibility analysis can be addressed to three problems: the site in search of a use, the use in search of a site, and the search for the most suitable investment. A range of economic cost-benefit analyses exist within each problem type ranging from static calculations capable of being determined on the backs of envelopes to complete project investment value models, with repeating cash flow analyses providing a temporal dimension. There are two fundamental strategies in the calculations, the so called "front door" and "back door" analytic approaches (Porter, 1986). The first works from the creation cost to the implied charges for a unit of space for a unit of time. The "back door" approach operates in an inverse manner, proceeding from market rents to establish the capital budged justified by revenues. This is the more common logic for most project cost-benefit analyses.

For policy impact assessment and other forms of research, the relatively complete "project investment analyses" are the most useful if the necessary input parameters are available and they are computerized. The completeness of these models permit greater confidence in the conclusions as well. Moreover, their detail permits the extrapolation of specific unknown inputs for academic investigation. This type of analysis can be undertaken on a before and after tax basis and can be designed to produce a variety of yield indices ranging from "net present value" through "return on equity", "return on investment", to both straight and modified "internal rates of return" (IRR and MIRR).

Open and Closed Financial Feasibility Programs

Computerized models of development feasibility are of two basic types: closed or black box (generally the commercial ones), and open models (typically in spreadsheet languages) whose logic are transparent and more easily adaptable to specific purposes than the closed variety.

Examples of closed programs are the Vax based IDA model developed at the University of Western Ontario as both teaching and research tool (Code, Dal Bello and Opper, 1985) and Jim Canestaro's recent released Refine II (Canestaro, 1988). The better closed models permit entry of a range of data. IDA, for example permits input on: leasable area, building efficiency ratios, unit construction cost, rents, operating expenses, property tax rates, leasing fees, specified vacancy rates per annum, bad debt ratios, construction periods, mortgage specifics, depreciation categories, capital replacement, mortgage, working capital loan, reinvestment and interim financing interest rates, present value factors, capital gain and corporate tax rates, capitalization rates, and a variety of legal, architectural and other fees. For each year until a specified resale date, it generates tables indicating total project costs, net operating income for various uses in the project, mortgage tables, depreciation schedules, taxable income, cash flow, working capital loan balances, and annual rate of return indicators including return on equity ("cash on cash return"), default ratios, and the net operating income yield. It then produces summary tables, giving, along with other data, the net present value of the project, average annual yield on total investment, average annual yield on equity investment, IRR, and modified IRR. Refine II is more flexible still, permitting analysis at a range of levels from the most simple to quite complete financial analyses. However, these models do not provide the flexibility of large multi level spreadsheet based models for addressing some of the specific concerns of planners.

An example of an open-model is the recently developed Subdivide, a large three dimensional spreadsheet model designed to financially evaluate changing circumstances in residentially oriented land development (Code and Taylor, 1988). It permits entry of a complex range of data either in detailed or aggregate form and in either absolute or ratio terms. As well, it permits analysis over a protracted time period and can cascade quarterly data into annual reports for present valuing and the determination of a number of yield measures. The mathematics in the model are transparent and provide a greater range of flexibility than the closed models.

Data Inputs

Once a basic understanding of these model's basically simple cost-benefit logic is attained, the main challenge for the user is acquiring and appreciating the input data. In North America this data is available from sources which are updated on an annual and sometimes monthly basis. In general, the necessary data falls into the broad categories of creation cost, revenue, operation costs, and vacancy rates.

Project cost data for larger cities can often be obtained from local reality boards or from a variety of publications such as the Dodge Construction Systems Cost Guide (Dodge Building Cost Services), Mean's Building System Cost Guide (R.S. Means Co. Inc.), Boeckh Building Valuation Manual (E.H. Boeckh American Appraisal Assoc.), the Marshal Valuation

Service (Marshal and Swift Publication Co.) and, for the specific application of shopping centers, the Urban Land Institute's Dollars and Cents of Shopping Centers (U.L.I.).

The most accurate measures of land value, and rental and vacancy rates can usually be obtained for particular cities from the dominant realty company specializing in particular sectors of the rental markets or from consulting companies specializing in assembling such data and usually widely known among local developers. More general sources, useful for verification of rental rates and for data on operating costs, are, for offices -- the annual Building Owners and Managers Building Experience Exchange Report (Building Owners and Managers Association) and the Institute of Real Estate Management's (IREM) Income/Expense Analysis for Suburban Office Buildings (Institute of Real Estate Management), for apartments -- the IREM Income/Expense Analysis for Apartment Buildings (Institute of Real Estate Management). These general sources are usually inferior to local ones for current vacancy rate data.

SENSITIVITY OF DEVELOPMENTS TO PLANNING INFLUENCED VARIABLE INPUTS

The complexity of the interactions within the model, especially in its after tax form, produce results which might not be expected at first glance but which have significant implications for land use planners in anticipating the consequences of their actions.

There are two important characteristics affecting the degree to which input variables into the economic feasibility model contribute to the overall yield: the volume of cash affected by each input, and secondly the manner in which cash is either added or subtracted to the project. In this latter regard both income and expense input variables can be classified into four basic categories: initial investment, which is a one time addition or subtraction of cash such as construction costs; continuing annuity, which is a fixed income or expense introduced to the project over several years; ratio, a variable what has its value determined each year of the project by a given percentage of another variable, such as is typically the case with taxes; and compounding where the sum of cash or expense compounds yearly at a given percent. In general, the compounding variables have the greatest impact on yield, followed, in turn, by the continuous annuity, ratio, and initial investment variables.

In all but exceptional, usually downtown, cases land value normally comprises a relatively small portion of the total creation costs and produces a linear, unit elastic change in net present value. Construction costs normally have a complex but slightly elastic impact on net present value while the construction period has a minimal linear inelastic effect. Revenue variables have a much greater impact on the yield of a development project. Both rental levels and income growth rate normally account for the largest volumes of cash flow in the model. Moreover, rent has an exponential relationship with net present value; a reduction producing a very elastic effect and an increase a less elastic one. Mortgage interest rates generally have a disproportional elastic effect on net present value while corporate income taxes produce a moderately elastic relationship. The collective effect of these variables is indeed a complex one and one which is often counter intuitive.

APPLICATIONS - TWO CASES:

Property Revaluation as a Result of Downzoning

The downzoning in the core of Toronto provides a good example of the use of financial feasibility modeling in Planning. The extensive research undertaken for the Toronto Central Area Plan, along with the standard sources of the period, enabled reconstruction of the 1975 variables necessary for impact determination. These data were applied to a standard site in the highest land value block in the City's financial community. An office building was developed at the maximum allowable densities under the old and new plans.

Running the financial feasibility model with the 1975 variables showed that if rents remained the same, the yield, as measured by net present value, would have declined by almost 43 percent, disproportionately more than the one-third drop in allocated density. The internal rate of return (IRR), however, would have remained virtually the same. Land, treated as a residual (ie. the model with a zero value for land) would have declined by 29 percent or slightly more than the allocated densities. This was in general what the planners had intuitively anticipated.

However, rents and other variables did not remain the same but were significantly increased by the shortage of space generated by the plan. By 1985, the developer's "pro formas" begin to look substantially different than what was anticipated by Toronto's planners. Toronto's Central Area Plan was premised on the assumption that demand for office space could be relatively easily transferred to the suburbs without creating significant increases in the rent differential between the core and the outlying centers. This has traditionally been the case with manufacturing, wholesaling and mass retailing and some kinds of back office, local market oriented, or adjunctive office space. They ignored the possibility that, among the intensively information linked functions in and around Toronto's financial community, resistance to decentralization could be encountered and that the resultant demand pressure would increase rent levels relative to the rest of the metropolitan office space.

They appear to have been wrong. Time series rental data suggested that the difference in rents in newer office buildings of comparable quality between the core and the suburbs increased from the pre-plan to the post-plan period. In the pre plan period the downtown rents average 157 percent of suburban rents while in the period from 1980 they average slightly over 190 percent. While there is no way of confirming whether there is a causal relationship between the core plan and this divergence the implication of a relationship is strong; vacancy rates reached extremely low levels in the core by 1979 at the same time that suburban vacancy rates remained elevated. This corresponded to the upward ratcheting of downtown rents which occurred in the early eighty's.

Working from the assumption that, in the absence of the containment effects of the new plan, rental increases in the core and the suburbs would be similar I calculated shadow rents for the core. These were derived by applying the average 1971 to 1976 ratio of core to suburban rents to the 1985 suburban figure. These implied rents are of interest as a means to approximate the combined effect on development economics of density reduction and revenue increases. Development feasibility models were used to examine the aggregate impact of the central area downzoning and the induced rent increases. We looked at the effect of the plan over the 1975 to 1985 period by comparing the difference between development sites in Toronto assuming a 12 times density development in 1975 and a 8 times density development with 1985 market rents, with what would have been the case without the plan (the difference between the same 1975 development and a 12 times development, using the 1985 shadow rents). Here, the actual change produces a 125 percent constant dollar increase in net present value. The hypothetical situation of no plan change would have produced a 223 percent constant dollar increase in net present value. Thus in this case the plan decreased the yield on new core buildings (even if it enhanced those of existing ones).

The Valuation of Bonusing and Linkage Provisions

An important element of Toronto's Central Area Plan were provisions to transfer development rights to immediately adjacent property in return for the saving of structures of historical and architectural merit on the adjacent property. Subsequently these provisions have been interpreted liberally and development rights transfers have been allowed from non adjacent landmark sites. As well, various negotiations have allowed the transfer of commercial development rights from more distant properties in return for residential development on those other properties. The preeminent example in Toronto of these transfers is Scotia Plaza, a 66 story bank headquarters development at the nexus of the city's financial community. Through a variety of density rights transfers onto its large 140,000 square foot site, the developer changed its density allocation from 8 times commercial to 15.3 times density.

Using IDA to compare net present values, the worth of the bonusing on the site was determined to be 97.4 million dollars. Thus, despite higher construction costs and a lower net to gross floor space ratio for the taller building, a 91 percent increase in density in this healthy rental environment, resulted in a 170 percent increase in net present value and a 21 percent increase in IRR. It also implied a 68 percent increase in the proverbial land and developers profit. This case would suggest that in these circumstances of significant demand elasticity and severe containment, density bonusing may have had a higher value than was anticipated and that more substantial public infrastructure and amenity tradeoffs could have been forthcoming.

CONCLUSIONS

In general, sensitivity analyses of the effect of policy on the economics of development indicate a significant difference in impact between those which affect revenue flows and those which affect initial costs. Planning and other municipal policies which directly impinge upon rental levels and future income growth, such as containment of a cohesive office community or rent controls, have a relatively high impact on development feasibility. On the other hand, policies such as parking space requirements, or landscaping and design regulations which directly affect land value, construction costs or construction time have a somewhat lower impact on the yield of development projects. (Of course, they these kinds of requirements also have a positive impact on revenue flow as well.) Thus, if policy is directed at both promoting development and still controlling the built form of the city, then strategies with a direct negative impact on revenue flows should be avoided in favour of policies focused on project creation. However, appropriate planning should deal with these issues on a case specific basis and computerized development feasibility models now greatly facilitate the task.

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COMPUTERS AND STATUTORY PLANNING

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Abstract

This paper is in two parts.

The first part makes the point that there are general control system principles and that it is by failing to take account of these principles that we are developing poor planning controls. Planners are urged to take more responsibility for the quality of the controls being produced and not to just blame the lawyers and the legal system.

The paper advocates tapping into the knowledge and experience of computer systems analysts in order to develop better planning controls. It goes on to identify some of the concepts that emerge when control systems theory is applied to planning documentation.

These concepts include the modelling of planning control documentation using predicate calculus and graphics, the seven objectives and three key attributes of documentation, the resolution of conflicts between objectives, the modification of documentation and the obsolescence of documentation.

The second part describes how the statutory planning process may be automated by the use of one particular suite of proprietary software.

The system detailed is a three-level system. The top level takes the planner through the transaction on step by step generating the necessary documentation, diary entries and reminders. The second level deals with the generation of documents and the third level is constituted by a word processor.program.

An advanced prototype system is examined. This system is designed to facilitate the handling by municipalities of applications for planning permits in Victoria, Australia.

The description includes details of the system screens, how documents are generated, how they can be edited, the development medium for the system and the benefits of the system.

PLANNING APPEALS IN THE PLANNING INFORMATION BASE

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ABSTRACT

Appeals are a significant part of land use planning in the United Kingdom, unlike the majority of other countries with land use planning systems where plan allocations or zonings are dominant. There does seem some evidence however that the flexibility, not to say pragmatism, afforded by the appeal system , is being adopted, at least in attitude, in many other countries. Appeals are significant because they give Central Government the flexibility to make decisions different from plans. This is important because the planning system , in terms of the production of Local Plans is slow , and significant parts of the country are not yet covered by any statutory plan. Appeals are also significant because the 10,000 appeals sustained in the last five years have affected the appearance of the United Kingdom. These appeals have had a perceptible affect on the location of development and the acceptable quality of the environment. Appeals are also significant because Local Authorities are increasingly taking appeals into account in their preparation of policy.

Data analysis of 4,000 appeals has revealed statistically significant results for the relationship between several variables. For example the variation in appeal success is related to the type of appeal; to present and proposed land uses; and to the affect of policy. It has also been discovered that particular Authorities resist appeals much better than others and this is particularly true for housing appeals.

Appeals raise issues of justice and the process is insufficiently transparent for the public to know whether the decision is untrammelled by Central Government political interference.

Appeals should be a part of every data base for studying and controlling land use change. Appeals are a small proportion of all planning decisions but they are a highly significant proportion with a considerable affect on future pressure, future policies, and future development.

APPEALS AS PART OF THE BRITISH PLANNING SYSTEM.

Every year some 20,000 decisions are made by Central Government because Local Government has failed to satisfy developers and the public with its reasons for refusing development. Appeals are between 2% & 3% of all applications although they are a much higher proportion of the number of applications refused.

The appeal system allows flexibility and discretion by both Local and Central Government. The appeal system allows the accommodation of change relatively quickly and easily compared to Local and Structure Plans. On the other hand you lose certainty, predictibility, & some would say that you lose planning because the individual appeal is decided in isolation. I do not agree with the latter since the three parties in an appeal ensure that applications, the plan and other appeals are placed in front of the decision maker. Therefore " planning by appeal "is in my opinion the same as "planning by application ". It does not mean that the plan is disregarded or that a comprehensive view is not taken.

The applicant is the only person who can appeal to the Minister. He must do this within 6 months and he must lodge evidence in support of his appeal. There is no prohibition in any way upon appealing. Therefore there are appeals against conditions on a consent, or a refusal, an enforcement notice, a wasteland notice etc. etc. After the appeal to the Minister, whether successful or not, the appellant can continue to higher Authorities on points of procedure, fact, or representation, and can carry the appeal as far as the House of Lords. This latter process is increasing, as all appeals are increasing.

The questioning of Local Authority and Ministers decisions can therefore take place internally at three levels. External review of decisions can also be undertaken by the Ombudsmen, the Audit Inspectorate, by Parliament and by the National Development Control Forum. The latter bodies are concerned with performance, quality, etc. of both applications, plans and appeals.

In summary the appeal can question policy and plan in a significant way at several levels. The plan cannot prevent or restrict appeals.

COMPARISON OF PLAN QUESTIONING BY APPEAL IN THE U.K. WITH OTHER COUNTRIES

I gather the impression from my reading that the " plan is king " in other countries. Disputes about plans are settled in court and these disputes are about matters of law . In the U.K. most disputes are about matters of policy & about the application of that policy. In most other countries the concept is that change will result in the review of plans while in the U.K. the concept built into all legislation is that plans can be changed by appeals. The idea of variation and intervention is strongly represented in the legislation.

"The development plan (although a key feature in the control of development)... has relatively little direct legal affect on development".

The questioning of plans in other countries have the following general characteristics.

1. There is a legal right to question the development decision.

2. The questioning is about the legality of the decision rather than the policy.

3. Determination is very slow for example in France, 3 years.

4. A broader range of grieved persons may question a decision and may hold up the implementation of the development. Example in France the suspension of execution of a decision.

Underlying planning appeals in other countries is a strong protection of the property rights of people affected by development decisions. Another strong underlying concept is the creation of certainty for every land owner, tenant and neighbour through a detailed and legally binding land use plan. In all the countries I studied there were hints that the flexibility which is inherent in the British system was gradually being introduced in other countries for example village envelopes in Netherlands rather than detailed land uses and specifications for every village. Similarly in both Denmark and Germany the ability to review the binding land use plan was being simplified and speeded up.

THE DENOVO DATA BASE

The denovo data base has been produced from decision letters.

The land use in appeals is a useful indicator of the strengthand care needed in policyformulation. In Scotland in the period 81/87 more than 40% of the appeals were connected with housing. No other group comes close to this number or proportion. The reason maybe that people have more emotional feeling about a house and also consider housing to be a common sense situation that is worthwhile appealing. There is no other use that comes close to housing as a major thrust - offices are 5/6% of all appeals, retailing 5/9%, accommodation between 5/12% and vehicles 5/15% in any one year. It would be wholly inappropriate to use mean figures for any of the other uses since the variation from year to year is quite considerable.

Another indicator from within appeals to policy making is the factors and specific developments involved. A large proportion of appeals involve no change of use i.e. shop fronts for shops; sub division of existing offices; extensions at ground and upper levels to housing etc. Such appeals stand a substantially above average chance of success and it would seem that policies in this sector need to be more carefully applied and drafted. It maybe that planning, since many planners are design alliterate in my opinion, should stay away from these detailed issues and concentrate on the major land use changes.

The success of different policies with different land usesanddifferentchangesof use oughtto be a further reason for studying and increasing the effectiveness of policy. Our study of appeals in the period 81/87 in detail shows that the success of policies in appeal is sufficiently different to warrant examination. In general policies seem to be getting more effective. However policies concerned with listed buildings and conservation areas fair poorly compared to the success of green belt policy.

There are many other possible inputs from the analysis of appeals into planners decisions. For example it is clear that in general enquiries do not have a substantially different rate of success, as you would expect when one imagines the great range of land uses taken to Public Inquiry. On the other hand it is clear that some land uses fair rather poorly with consistent and considerably below average rates of sustainment at inquiry.

EXAMPLES OF OUTPUT FROM DATA BASE ANALYSIS

The approach to analysis of the appeals data base has been to look at trends through time and then to progress to attempting to look at relationships between characteristics of the appeal and characteristics of the decision. The first approach has already been covered in a series of articles in planning newspaper and therefore I am concentrating on the second area.

For example if we compare the area of green belt in a District Authority with the number of appeals about green belt issues on the basis that the more green belt then the more conflict between development interests and green belt. This rests on the idea that applications are dispersed equally in space and although this idea may not be correct since there is usually pressure on the edge of areas for development and that green belt is often the major policy constrained on these edges then the hypothesis seems reasonable. Using the hypothesis that there is a the relationship between the number of appeals and the number of appeals expected on the basis of the proportion of green belt forms a significant statistical relationship. However this analysis shows that the District has a significant variable in the number of green belt appeals.

My second example is considering whether particular existing land uses have more appeals than might be expected and whether particular existing land uses were more successful at appeal. The results of this analysis were uncertain for land uses in general. However statistically significant relationship was shown between existing land uses of cleared sites; gap sites; vacant land and the sustainment level.

Looking at one type of appeal - the enforcement appeal - the type of change does affect the rate of sustainment. The type of changes specified as whether this is from a same use situation or a change of use situation or a new construction situation. There were statistically significant differences in the rate of sustainment of these different types of use and therefore we can conclude that the rate of sustainment is affected by the type of change proposed.

Similarly to above statistically significant results were found between the rate of sustainment of particular cities and districts for all appeals. Therefore it is clear that some Local Authorities perform better than others. This conclusion is for all appeals, when it is broken down into land uses there is neither the number of observations nor the same statistical level except for housing which remains significant.

My final example is that looking at whether policies affect sustainment. In general the presence of policy in the appeal has a significant affect on the sustainment rate for all land uses but again breaking the observations down by land use leads to only housing being shown as statistically significant.

Analysis of the data base has ceased for the moment as we move to spatial analysis by looking at Regional, District and geo-coded appeal data. I have the feeling that housing, not because of the large volumes of observations but because of its characteristics, maybe the most profitable area for further analysis. It seems to me that there is more knowledge and less variation in housing proposals than there is in the wide range of other developments.

MAPS OF APPEALS

Mapping the appeal data at District and Regional level is the first step towards full geo-coding of data. The reasons for considering geo- coding of all the data, or of particular land uses e.g. housing, is amply demonstrated from the attached maps. The problem of very large regions like the Highland and Islands being compared with very small districts such as Eastwood on the edge of Glasgow.

Some general comments -

1. The total number of appeals is remarkably well spread with a large number of appeals in quite rural areas.

2. As expected the major centres of population attract the largest number of appeals.

3. Unexpectedly there seems an abrupt step down of the number of appeals in the areas immediately around the cities. This maybe a result of planning policies that defend the edge of cities perhaps more strongly than areas further away from the cities.

4. The concentration of pressure for development in a broad band across the Scottish heartland - the Central Belt of Scotland - is expected.

5. The wedge of appeal pressure north/south through the centre of Scotland is probably the result of the of improved road access along a major oil highway , an

area of considerable existing recreation infrastructure and of the varied landscape e.g. Perthshire and the Spey Valley.

The map of successful appeals is not considerably differentfromtotalappeals.Ifrankingis appropriate then the rural heartland areas do drop to a lower level, again suggesting that rural areas are better or more easily defended by planning policies.

CONCLUSIONS - APPEALS AS PART OF A DATA SYSTEM

WithdetailedknowledgeofScotland, and a more general knowledge of England and Wales, I feel able to suggest that an appeal data system should not be based in each Local Authority. Many local authorities in Scotland have too few appeals to make an individual system worthwhile e.g. in 1987 Kinross district had 1 appeal & 12 (30%+) authorities had less than 10 appeals.There are a variety of national organisations connected with Local Government that could carry this out e.g. COSLA , Planning Exchange , or a contract could be placed with a university . A strong argument for central monitoring of the effectiveness of the planning system is given by Davis, Edwards, Fielder (Ref.12) and they are particularly concerned with achieving a balance between central and local relationships in such monitoring.

"The main purpose for this national monitoring has been to improve the administrative efficiency of the planning system, measured in crude terms by relating inputs (staff, time , money) to outputs (plans produced, planning applications processed, appeals heard)".

On the other hand the real effectiveness of the system is about questions of whether there is the right amount of development in the right place at the right time and whether such development achieves consent quicly, slowly easily, without conditions etc.

Since I am sure that appeal data can be useful to the private sector, in preventing appeals as well as assisting appeals, I believe the Local Authorities could recoup the cost of such systems by charging for access. I can imagine that there might be some ethical split in Local Authorities about consultants and researchers having access to their data. However a freedom of information act , probably less free than in the U.S.A. , must surely come to the U.K.. At the present time large charges are levied if one wishes to see a past planning permission and similarly for access, if possible, to the planning applications data bases held by Local Authorities.I will concentrate on L.P.A.s possible uses but I see the private consultant giving advice to his/her clients in the same way that the technical officers give advice to councillors.

Many of my attitudes and ideas have already been described in earlier sections of this paper but I will firstly reaffirm some of the reasons why we ought to collect and monitor appeals and secondly some of the ways it will assist. The principal reason for appeal monitoring and research is that it provides a feedback on policy. On 10th April, 1987 the Non. William Waldergrave M.P. said -

"I hope that, for the sake of the planning system, that figure, (the no. of appeals granted) does not rise as a result of a failure to communicate our policies and decisions to those who carry the responsibility of dealing with 400,000 applications a year".

The Minister is emphasising that appeals are part of the communication of central Government policy to Local Government. He is clearly saying that he does not wish to see the proportion of appeals granted rise and that therefore the Local Authorities should carefully consider refusals.

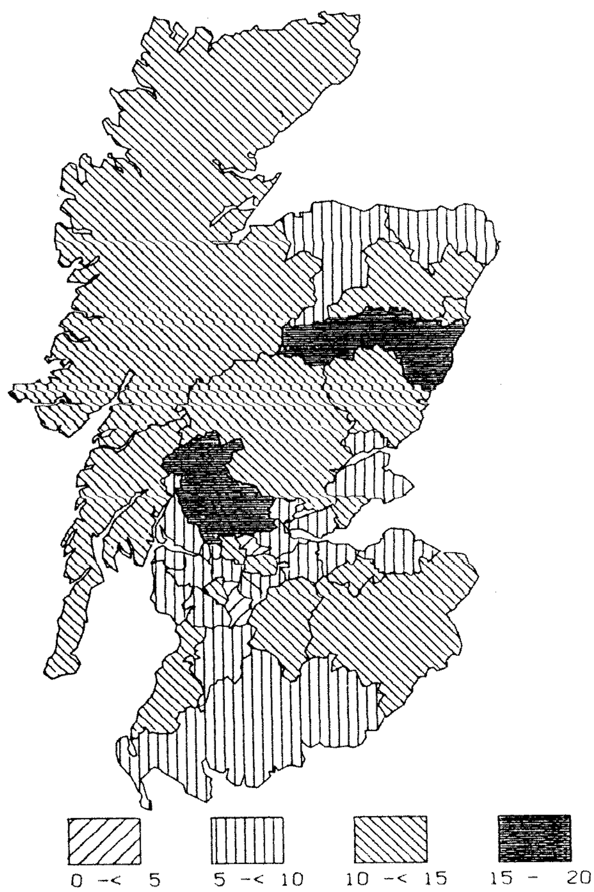
The characteristics used by the Reporter in his decision can be used to characterise the areas for future and existing policies and can be built into any survey work. Clearly they will also be built into the next set of appeal decisions, if necessary in the light of the reviewed policy. This circular process is a form of monitoring or policy response. It may offer great advantages over the actual monitoring of development with regard to policy because it will occur so much quicker, despite the delays in most appeals. Compare a series of appeals on a particular land use with preparation of a local plan or a new development control policy note .With good information on a central data base all D.C. staff could see the way the wind was blowing within 12 - 18 months . A local plan being prepared & then rejected could take 36 months.

Another problem that confronts planners is that they cannot judge the property development system, the pressure for development, the future plans of development, because so much of the property development process occurs without contact with the Planning Department. The Planning Department publishes its plans and policies and therefore developers can consider these in isolation from the Planning Department. After this consideration or as part of this consideration developers may contact and negotiate before submitting an application. This negotiation stage is often the first apparent indication of development of a particular kind or in a particular location. It is important to record negotiations as part of the development process. On the other hand Local Authorities have concentrated on collecting information on applications. Should it collect all information on all applications? Should it only collect information on refusals and particularly on refusals that go to appeal and fail. How should it treat refusals that do not go to appeal. Both these refusals are indicative of policy strength i.e. the developer has decided that it is not worthwhile (in association with his professional advisers) or in the other case the Local Authority's policies and judgements have been supported. Noting that in many cases the decision sets aside or ignores policy . For many Local Authorities the task of keeping track of all applications is too great and therefore to concentrate on refusals & appeals,(some appeals will result from conditional consents), would reduce the task to a managable level.

Appealsare 2% of the applications andthisyear approximately 40% of the appeals will be sustained. Therefore about 1% of the consents will result from appeals.Appeals must then follow from the fields used in data bases for planning applications. Therefore data base definitions in terms of uses and location and policy must be determined at the application stage and the appeal will naturally follow from them. The data base needs certain fields and characteristics to do with the appeal in particular that may not be present at the application stage. In particular the nature of the appellant, the type of representation ,the Reporter, etc. Further investigation may reveal additional factors and different strengths to factors than were apparent at the application stage. Therefore additional fields needs to be reserved for these elements in an appeal data base.

Planning Appeals Scotland 1980–1986

NUMBER OF PLANNING APPEALS PER 10,000 POPULATION



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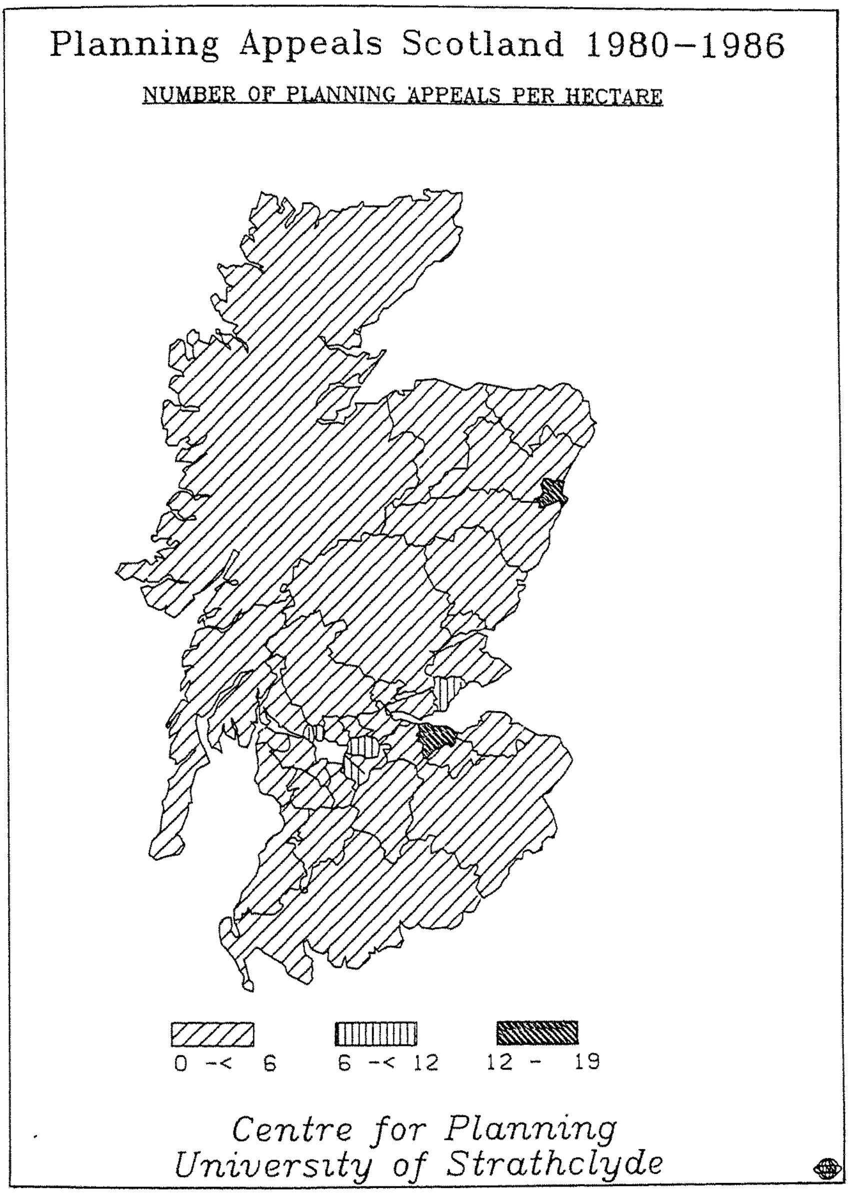
Planning Appeals Scotland 1980-1986
NUMBER OF PLANNING APPEALS PER HECTARE
0 -< 6
6 -< 12
12 - 19
Centre for Planning
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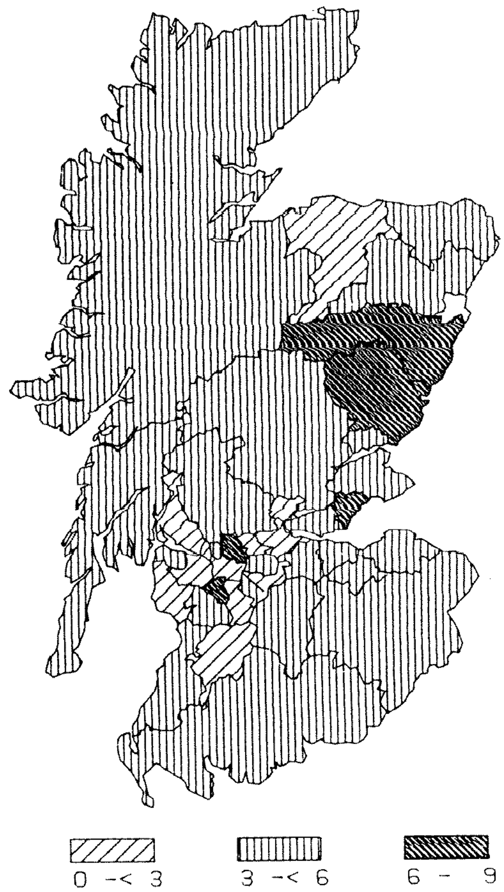
Planning Appeals Scotland 1980–1986

NUMBER OF PLANNING APPEALS PER MEMBER OF STAFF



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A METHODOLOGY FOR EFFICIENTLY STRUCTURING A SET OF ACTIVITIES

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ABSTRACT

In urban project or program planning, planners and managers often utilize a Gantt or PERT chart in performing analyses such as the Critical Path Method (CPM) and the Program Evaluation and Review Technique (PERT). Very little effort, however, has been devoted to the formulation of activity networks, which is the initial step before the aforementioned analyses. This paper addresses this problem by developing a systematic methodology to aid in the identification and rapid structuring of a system of activities. In essence, the user is asked to supply only the names of the activities and the sequential relationships between a limited number of them. A program is then used to deduce the remaining relationships and to present the results.

INTRODUCTION

Activity scheduling is one of the most important tools for determining how resources should be integrated in urban project or program planning (So, Stollman, Beal, and Arnold, 1979). The schedule is usually displayed in the form of a Gantt or PERT chart. Gantt (or bar) charts are most commonly used for exhibiting program progress or defining specific work tasks required to accomplish an objective. They detail the duration and scheduled dates for start and finish. They give little information, however, on the interdependencies of the activities. On the other hand, a PERT chart conveys these interdependencies through the construction of networks (Kerzner, 1984). Still, the relative times for start and finish are less clear than those presented via a Gantt chart.

A Gantt or PERT chart models the progress of a project or program. Prior to the formulation of either, one has to plan the system of connections of activities intuitively based on their proper technological sequence. All-too-often the large number of activities involved and the large number of interactions among these activities create a high degree of complexity for such an undertaking.

An objective in activity planning is that of transforming unclear, poorly articulated perceptions of elements into visible, well-defined structures useful for future studies. It thus seems desirable that some methodology be developed which would guide in identifying the structure within a system, and doing so in a quick and efficient manner. The methodology also should help avoid mistakes and oversights.

The formulation of the structure of a system means that a clear picture of the relationships among activities has to be developed. In this study the scope of the relationships considered is restricted to the relative sequencing of the activities, rather than a more detailed timing. In other words, the concern is for whether activity A starts before B, rather than A starts, say, 6 months before B.

Initially, the user's tasks is to identify sequential[1] relationship between each pair of "consecutively numbered" activities in a system. The sequential relationships for the remaining pairs of activities are attempted to be deduced based on logical reasoning. If the deduction is impossible, logical reasoning will be employed to eliminate some possibilities about the sequential relationship between the activity pair. Upon the complete determination of these relationships, a simplified[2] Gantt chart will be produced. A computer program has been written to implement the methodology developed and its application will be illustrated in an example dealing with a home interview survey project.

THEORY AND METHODOLOGY

Theory

An understanding of two key mathematical concepts is important before delving into the theoretical background of interpretive structural modeling (ISM) (Sage, 1977) as applied to planning of activities. A "relation" is an ordered pairing of the elements from one set with the elements of another. A binary relation is a particular one in which the first and the second sets are of the same set. An example of a binary relation involving the set of integers would be a comparison of the magnitudes of the integers, depending on which one was less than another. There can be three properties associated with a binary relation, namely: reflexivity, symmetry and transitivity (West, Griesbach, and Taylor, 1982). Not every binary relation possesses all these properties, and in ISM only transitivity is relevant. A relation, R, is transitive if when aRb is true and bRc is

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[1] Following in order of time, without reflecting the interrelationships between activities.

[2] One that outlines the sequential relationships among activities without detailing the duration and scheduled dates for start and finish for any activity.

true, then aRc is also true. Again we can consider the example of integers. Let a, b and c be any three elements in the set of integers and the binary relation be less than. If a is less than b and b is less than c, then the statement "a is less than c" is an obviously true conclusion.

ISM is initiated by specifying an activity set and a transitive relational statement. The user is requested to respond to a query with regard to the existence or non-existence of the relation between selected pairs of activities. A computer is employed to store the responses supplied by the user (which are explicit entries to the relation matrix[3]), to provide implicit transitive inferences based upon previous responses, and to generate queries for pairs of activities for which no transitive inference can be drawn with regard to the relation statement.

In structuring the sequential relationships of activities in a project, the user may have more than one relation statement to select (illustrated later). Moreover, not all the relations may be "uniquely" transitive. This complexity, however, has not precluded the application of ISM. The reasoning behind a "modified" ISM is based on transitivity. Transitivity includes unique transitivity and multiple transitivity. Unique transitivity means a definite inference can be drawn on the sequential relationship of two activities. Multiple transitivity means that a sole inference about the sequential relationship of a pair of activities cannot be drawn, but a reduced subset can be. In this case, the computer can be used to generate possible logical combinations of relationships, based on the sequential relationships for previous pairs of activities. An example of unique transitivity is:

Activity {2} starts and ends before activity {1} starts

Activity {3} starts and ends before activity {2} starts

Therefore, "activity {3} starts and ends before activity {1} starts" is a unique inference.

As an example of multiple transitivity:

Activity {2} starts and ends before activity {1} starts.

Activity {3} starts before activity {2} starts and ends after activity {2} ends.

There are five possibilities for the sequential relationship of activity {3} with respect to (w.r.t.) activity {1} and therefore no sole inference is possible. These five possible cases are shown in Fig. 1.

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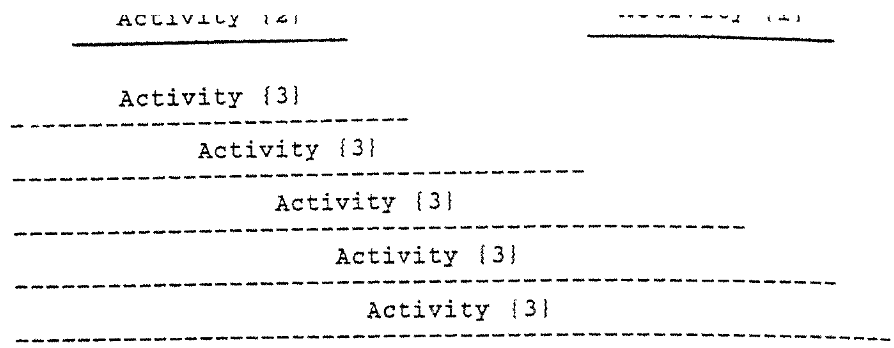
[3] A table in which the relationship for each and every pair of activities is recorded. The row and column indices are the activity identifications while an entry in the matrix represents the case possibility of an activity having the column index with respect to (w.r.t.) that having the row index. For instance: [1,2] in the relation matrix indicates the case possibility of activity {2} w.r.t. activity {1}.



Legend:- ---------- Possible Case for Activity {3}

Figure 1. An example of Multiple Transitivity Schematic Layout of the Sequential Relationships of Activities.

Methodology

The modified ISM methodology proposed here consists of the following seven steps: (1) identify the activities in the set (2) identify the set of relation statements (3) identify the initial input (4) establish a transitive inference mechanism based upon previous responses (5) generate a logical combination of relationships based on previous responses to guide the user in formulating subsequent sequential relationships for the other pairs of activities (6) store the relationship for each pair of activities in a relation matrix (7) produce the relationships in the form of a simplified Gantt chart. The entire process of the methodology is diagrammed in Fig. 2.

All steps are generic to the task of activity planning. In subsequent discussions, the application of the methodology in structuring the sequential relationships among activities will be exemplified in a home interview survey project.

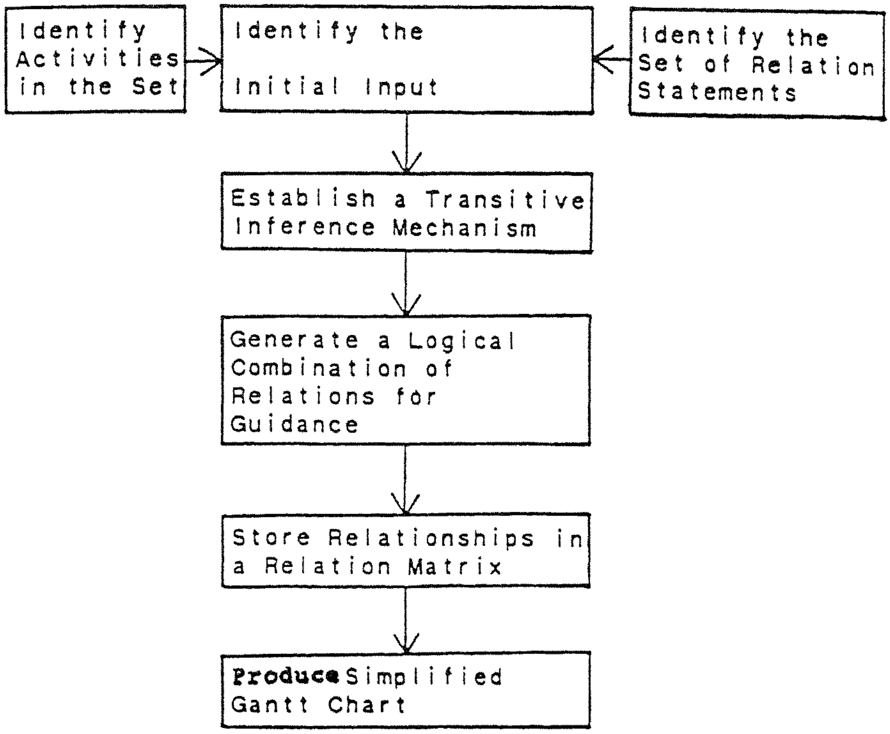


Figure 2. Flow Chart of the Modified ISM Methodology

APPLICATION OF THE METHODOLOGY

dentify the Activities in the Set

Eight activities have been considered as pertinent to a ome interview survey project. They include: {1} plan survey 2} design questionnaire {3} hire personnel {4} train ersonnel {5} select households {6} print questionnaire {7} onduct survey {8} analyze results.

dentify the Set of Relational Statements

Let us start by exploring the sequential relationship etween activities {1} and {2}. Their relative start and inish times first are specified. There are five ossibilities for which activity {2} can start relative to ctivity {1} (see top row of Table 1). Activity {2} can tart before activity {1} starts (designated by b{1}s); at he same time that (or "when") activity {1} starts designated by w{1}s); and so on. Now, in conjunction with ach of these situations, there are various possibilities for when activity {2} can end relative to activity {1}. As shown in Table 1, five cases can result when {2} starts before {1} starts; three cases when {2} starts either when {1} starts or during {1}, and exactly one when {2} starts either when {1} ends or after {1} ends. Consequentially, there are thirteen possible sequential relationships for activity {2} w.r.t. activity {1}. These are summarized in Table 1.

	{2} Starts				
	b{1}s	w{1}s	d{1}	w{1}e	a{1}e
{2} Ends	(1) b{1}s				
	(2) w{1}s				
	(3) d{1}	(4) d{1}	(5) d{1}		
	(6) w{1}e	(7) w{1}e	(8) w{1}e		
	(9) a{1}e	(10) a{1}e	(11) a{1}e	(12) a{1}e	(13) a{1}e

Table 1. Possible Sequential Relationships Between Two Activities {1} and {2}.

Each of these 13 cases is coded and is an element in the set of relation statements. Referring to the example, the activity "design questionnaire" (activity 2) can start only with "plan survey" (activity 1) ends; which corresponds to a case code of 12. In the relation matrix in Table 2, the entry of the number 12 in cell [1,2] reflects the case for activity {2} w.r.t. activity {1}.

<u>Identify the Initial Input</u>

The next step in the process is to request of the user the sequential relationships for consecutively numbered activities. In the example, the necessary sequential relationships to be input by the user thus are: {2} w.r.t. {1}; {3} w.r.t. {2}; {4} w.r.t. {3}; {5} w.r.t. {4}; {6} w.r.t. {5}; {7} w.r.t. {6}; {8} w.r.t.{7}. Many of the entries for the remaining cells in the relation matrix in Table 2 can be deduced; if not, the user is requested to input their relationships directly.

Activity	1	2	3	4	5	6	7	8
1		12	12	13	13	13	13	13
2			6	12	12	12	13	13
3				13	13	13	13	13
4					6	6	12	13
5						8	13	13
6							13	13
7								12

Table 2. Relation Matrix for the Example of a Home Interview Survey Project.

Establish a Transitive Inference Mechanism

Utilizing transitive inference, we can sometimes deduce the sequential relationship between the subsequent pair of activities from the defined relationships of the two previous pairs of activities. This process is initialized with the pairs (1,2) and (2,3). An attempt is made to infer the relationship of the pair (1,3), based on the fact that relationships for the first two pairs are initial input in the process. Whether the relationship of (1,3) is deducible or not, it has to be defined before the user can proceed to the next entry [1,4]. The same principle is applied here, where the known relationships of (1,3) and (3,4) are utilized to try to deduce the relationship for the pair (1,4). As an example of the process, let us look at "train personnel" (activity 4) w.r.t. "hire personnel" (activity 3). This is case 13 since {4} starts and ends after {3} ends. Now "select households" (activity 5) w.r.t. "train personnel" (activity 4) is case 6 since {5} starts with {4} starts and ends during {4}. Based on the transitive property of these cases, "select households" (activity 5) w.r.t. "hire personnel" (activity 3) is inferred to be case 13; that is activity 5 starts and ends after activity 3 ends. The relationship is entered in the [3,5] position in the relation matrix in Table 2.

Table 3 has been set up to facilitate the structuring of relationships among activities with any combination of the 13 case possibilities for two known pairs of activities. Each row represents a case possibility for {2} w.r.t. {1}, while a

{3} w.r.t. {2} / {2} w.r.t. {1}	1	2	3	4	5	6	7	8	9	10	11	12	13
1	1	1	1	1	0	1	1	0	1	1	0	0	0
2	1	1	1	2	0	1	2	0	1	2	0	0	0
3	1	1	0	3	0	0	3	0	0	0	0	0	0
4	1	1	0	4	5	0	4	5	0	0	0	12	13
5	1	1	0	5	5	0	5	5	0	0	0	13	13
6	1	2	3	3	0	6	6	0	9	9	0	0	0
7	1	2	3	4	5	6	7	8	9	10	11	12	13
8	1	2	0	5	5	0	8	8	0	0	0	13	13
9	0	0	0	0	0	9	9	0	9	9	0	0	0
10	0	0	0	0	0	9	10	11	9	10	11	12	13
11	0	0	0	0	0	0	11	11	0	0	0	13	13
12	0	0	0	0	0	12	12	12	13	13	13	13	13
13	0	0	0	0	0	13	13	13	13	13	13	13	13

Note: Numbers in the table represent the case codes for the 13 possible relationships. A zero indicates that a deduction is impossible and user input of the sequential relationship between activites {1} and {3} is required

Table 3. Inferred Case Codes for Relationships between Two Activities.

column is for {3} w.r.t. {2}. An entry in the table represents the resultant relationship inferred for the pair (1,3). A zero entry signifies deduction is impossible, so the user has to input the sequential relationship directly.

In summary, the initial input to the process is the sequential relationship for each pair of consecutively numbered activities. The relationships of these activities w.r.t. the others might be deducible via Table 3.

Apply "Multiple Transitivity" to Generate a Logical Combination of Relationships

A count of the number of zero entries in Table 3 indicates 72 cases, out of a total of 169, in which inference fails. To further relieve some of the burden on the user in formulating the sequential relationships among activities in these 72 incidences, we derive certain logical combination of relationships among activities as a guide, via the process of "multiple transitivity". For instance, "train personnel" (activity 4) w.r.t. "hire personnel" (activity 3) is case 13 whereas "hire personnel" (activity 3) w.r.t. "design questionnaire" (activity 2) is case 6. Out of the 13 total case relationships for (2,4), only a limited number are possible; namely the five: 9, 10, 11, 12 and 13, because of the fact that "train personnel" (activity 4) can start after or at the same time as "design questionnaire" (activity 2) ends, or even during it. However, the earliest time for activity 4 to finish is during activity 2 (i.e., {4} can finish d{2}, w{2}e and a{2}e). Providing the user with a logically limited subset of relation statements for the pair of activities being considered can help significantly in the efficient focusing of the original unclear image and the erection of a well-defined one. Presented with the five alternatives for {4} w.r.t. {2}, the user might decide that {4} will start when {2} ends. This would correspond to case 12.

Store the Relationship for Each Pair of Activities in a Relation Matrix

The overall methodology is employed beginning with the pair (1,3) and proceeds across the other elements on the first row. It then continues with the elements on the second row and so on, until a complete and clear description of the sequential relationships among all activities has been established. As each relationship is established, it is then stored into the relation matrix (see Table 2).

Produce Relationships in the Form of a Simplified Gantt Chart

In the final stage of the methodology the verbal description of the sequential relationships among activities is transformed into a pictorial representation. The output of the relation matrix is in the form of a simplified Gantt chart. There is no input for the specific start date nor for the duration of any activity concerned, as the purpose of this Gantt chart is simply to echo the rough mental image of the user. Nevertheless, the chart depicts the sequential relationships among all the activities and is a product of the transformation from an unclear, poorly articulated mental model into a visible, well-defined model useful for further analyses such as CPM and PERT.

CONCLUSIONS

In the preceding example there was a need for initial input of seven sequential relationships for all pairs of consecutively numbered activities, as well as for three other pairs of activities to produce a complete knowledge of the sequential relationships among the activities. The total thus was ten. Without applying this methodology, the user would have had to formulate 28 (8*7/2) relationships among the eight activities. We thus were able to be extremely efficient, reducing the number of questions requested of the user by 64% ((28-10)/28*100). We also avoided many possible illogical and inconsistent relation specifications.
Although the above comparison is just for one case, there is

other evidence to highlight the efficiency of this methodology in formulating sequential relationships among activities. By counting the number of zeros in Table 3, we find that there are 72 cases, out of a total of 169, where inference fails. This means that in 97 cases out of 169, or 57% , inference will succeed. The burden of structuring sequential relationships among activities is thus anticipated to be relieved considerably, with the additional gains in consistency.

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USING MICROCOMPUTER-BASED IMAGING TO EVALUATE URBAN DESIGN PROPOSALS

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ABSTRACT

Both desktop and laptop microcomputers are convenient data collection instruments in planning research projects requiring either personal or telephone interviewing or land-use surveys. Either questionnaire software or data base programs configured for data collection can be used to write questions to the CRT and store both verbal and numerical data on disks. Data collection programs written in BASIC are an attractive alternative. One advantage is that such programs are relatively easy to write for a project and to reuse later in other projects.

This paper presents several simple programming procedures for writing BASIC programs that will serve a variety data collection needs in planning research. Once written for one project, the program framework can be readily adapted to the data collection needs of other projects. Also presented are the presenter's observations, derived from personal experience, on the procedures and problems associated with microcomputer-based data collection.

LAND INFORMATION SYSTEM FOR THE PROGRAMMING AND MONITORING OF NEW TOWN DEVELOPMENT

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ABSTRACT

The coordination of basic infrastructure, housing, and community facilities is important in new town development in order to ensure that all essential facilities are available to new residents on arrival. A microcomputer-based LIS has been used to examine the applicability and usefulness of LIS in the estimation of land availability and population which are essential for the programming and monitoring of new town development. The capability of microcomputer in managing the LIS is also examined.

INTRODUCTION

Geographic information system (GIS) and land information system (LIS) was researched and developed in the 1960's. Early development of GIS was slow and applications were limited, partly because of the lack of software and partly because computer hardware was expensive. Since the early 1980's, there have been major breakthroughs in cost, speed, and data storage capacity of computer hardware and great advancement in GIS/LIS technology and software. GIS/LIS is becoming more affordable and practical. It is increasingly used by urban and regional governments and utility companies in North America. GIS/LIS is one of the major growing areas in the use of computer technology in urban planning and management. It is used in land information retrieval, development control, mapping (Newton and Crawford, 1988; Zwart and Williamson 1988), site selection (Dangermond, 1983; Smith and Robinson, 1983), and land suitability analysis (Lyle and Stutz, 1987; McDonald and Brown, 1984).

GIS/LIS often involves a large amount of data which is too large for microcomputer or mini computer to handle. As a result, GIS/LIS is mainly handled by mainframe computer system. With the advancement in microcomputer technology, especially in speed, cost, and data storage, there is an increasing role of microcomputer in GIS/LIS (Marble and Amundson, 1988). Microcomputer is often used to extract a portion of the GIS/LIS data from the central mainframe computer and process locally at a remote site, such as a district office (Yapp, Wilen, Gelinas and Morrison, 1986). This can save time in data communication between the central and district offices and free the mainframe computer at the central office for other uses. It can be a substitute for mini or mainframe computers for small communities and districts where the data base is manageable by microcomputer (Yeh, 1988).

Land is a limited resource. The monitoring of land supply is important in the management of the limited land resource. Development decisions can be more effectively formulated if local government and private sector have up-to-date information on the locations, amounts, and prices of available land. It will enable local government to coordinate more effectively public infrastructure investments with present and future land supply. It can allow planners to monitor the impacts of public policies and regulations on the amount and location of developable land for housing and industries, and vacant and derelict land. Without continuous monitoring of land supply, inaccurate or out-of-date estimates of the availability of developable land can lead to increased land prices if supply is not allowed to expand to meet demand (Bollens and Godschalk, 1987). There has been increasing interest to make use of the analytical and retrieval capabilities of computerized LIS to monitor land supply for urban planning and management (Home, 1984; Godschalk, Bollens, Hekman, and Miles, 1986). Most of the systems used are oriented to mainframe computers, but the more recently-started systems are increasingly incorporating microcomputers and mapping facilities.

NEW TOWN DEVELOPMENT AND DEVELOPMENT PROGRAMME

New town development in Hong Kong first started in 1959 with the development of Tsuen Wan New Town. The planning and development of two other new towns at Castle Peak (renamed as Tuen Mun in 1973) and Sha Tin began in 1965. However, the progress of these developments was slowed down by the slump in the property market after the bank crisis in 1965 and riots in 1967. The major boost to the new town programme came from the Government's Ten-Year Housing Programme in 1972 which aimed to provide 1.8 million people with permanent, self-contained accommodation in a decent environment. It was soon realised in the planning of the Ten-Year Housing Programme that land for such a massive public housing programme was difficult and expensive to obtain in the existing main urban areas. It was necessary and essential to actively develop new towns in the New Territories to provide land for public housing construction.

The New Territories Development Department (NTDD) (amalgamated with the Urban Area Development Organization to form the Territory Development Department (TDD) in April 1986) was set up in 1973 to co-ordinate the planning and development of new towns, including the provision of land for public and private residential developments, community facilities and necessary infrastructure. Each new town has its development office with its own project manager whose duty is to monitor and coordinate the progress of the new town development. A corporate planning approach was adopted by which a multi-disciplinary team comprising engineers, town planners, and architects, is employed to take care of the planning, programming, and construction works. At present, there are eight new towns at different stages of development. They are namely, Tsuen Wan, Sha Tin, Tuen Mun, Tai Po, Fanling/Sheung Shui, Yuen Long, Tseung Kwan O (Junk Bay), and Tin Shui Wai.

The British new town planning concept of "self-containment" and "balanced development" are adopted in the planning and development of new towns in Hong Kong with the aim of reducing the need of commuting between the new towns and the main urban areas. In achieving these objectives, adequate provision of working opportunities, shopping, recreation, and community facilities is necessary (Lands Department, 1984). They are also planned to provide an optimal split between public/private, ownership/rental, and high/low density developments. Land in new town is largely obtained from land reclamation which is cheaper and administratively easier to obtain than resuming privately owned agricultural land. The costly development of Fanling/Sheung Shui New Town where land is largely resumed from private owners attests to this.

The process of new town development commences with planning and engineering studies from which development plans and programmes are prepared. The implementation of the plans starts with the acquisition and clearance of land. It is followed by land reclamation, site formation, and the provision of essential engineering services, such as roads, footpaths, cycle tracks, drainage, sewerage, water, gas, electricity and telephone cables. Land then becomes available for the building of public and private housing, factories, commercial buildings and community facilities. The Government is actively involved in the development of new towns through numerous buildings, engineering (civil and highways) and waterworks items in the Public Works Programme. The development of public housing estates are funded and constructed by the Housing Authority. The programming of all works are coordinated by the new town development office to ensure that, whenever possible and having regard to various constraints, the goal of balanced development both at the end of each stage of development and on the completion of the total programme is achieved.

A development package approach is used in the development of new towns. Each new town is divided into different stages of development. Each stage is subdivided into development 'packages' based on the Outline Development Plan in which all essential services, roads, and community and recreational facilities for the workers and residents in the package are included. This is to ensure that all essential facilities are available to new residents on arrival.

The coordination of new town development is mainly carried out by a new town development programme which is prepared and updated annually. The first development programmes for the new towns and rural townships were prepared in 1974. They were published annually for each new town since 1975. A development programme covers a 10-year period, rolling the programme period forward by one year in each annual revision. Each updating takes into account the progress already made and the anticipated availability of government resources, both staff and money.

The development programme is prepared based on some known factors, such as funds anticipated for all TDD programmes, and the Housing Authority's 10-year Housing Programme and Long Term

Housing Strategy. Based on these factors, the timing of land availability, services provision, and housing construction for the next 10 years commencing the year when a programme is prepared can be estimated. They are further used to forecast the likely population growth in the programme period. This in turn helps to decide on the completion dates of infrastructures. Working backward from these dates, the programme of administration, design and construction works which must be undertaken in order to finish the projects on time to meet the needs of the growing population, together with the estimates of financial expenditures can be derived. Once finalized and approved, a development programme becomes the guiding document for all concerned in new town development. The urban planner uses it as a basis for planning and development decisions, and offices responsible for various facilities and services compile or adjust their own works, training, and other programmes accordingly. The development programme is used to coordinate all concerned departments to ensure that everything will be made available on time. It also serves as a guide to central policy decision-making, including the allocation of financial resources, and the preparation of territorial development strategies and sub-regional structure plans (Pun, 1984).

Forecast of the timing of land availability is one of the most important process in the preparation of the development programme. It determines where and when public and private development can start. Serviced land available for development is mainly obtained from land formation and service engineering projects, land resumption and clearance, and expiry of short term tenancy or temporary use. Information on the timing of land reclamation, clearance, and servicing and engineering projects are gathered from various government departments concerned to estimate the timing of land availability of different planned land uses in a 10-year period (Table 1).

New town development in Hong Kong is mainly public housing-led (Yeh and Fong, 1984; Wang and Yeh, 1987), with over 50% of the planned population in public housing for large new towns and over 40% for small new towns. As there is great demand for housing, particularly public housing, housing is often fully occupied soon after it is built. Future population increase in the new town can be estimated reasonably accurately from the estimation of future housing stock based on land availability. A 'Flat Supply Method' which relates housing stock to population forecast is used in the population projection of small area in Hong Kong (Chak, 1986). The general methodology is :

$$P_t = (H_{t-1} - D_t + N_t) \times PPOF_t$$

where P_t = forecast population in yr. t
H_{t-1} = estimated total no. of flats in yr. t-1
D_t = no. of flats estimated to be demolished in yr. t
N_t = no. of new flats estimated to be completed in yr. t
$PPOF_t$ = persons per occupied flat ratio in yr. t

Table 1 Availability of Serviced Land by Planned Land Use in Hectarés for the Next 10 Years

PLANNED LAND USE	Total Before Yr_1	Yr_1	Yr_2	Yr_3	Yr_4	Yr_5	Yr_6	Yr_7	Yr_8	Yr_9	Yr_{10}	After Yr_{10}	Total
Industrial													
INDUSTRIAL SUBTOTAL													
Commercial													
Commercial/Residential													
Residential 1													
Residential 2													
Residential 3													
Residential 4													
Village Housing													
RESIDENTIAL/COM'L SUBTOTAL													
Housing Authority Rental E.													
HOS/PSPS													
Housing Society Estates													
PUBLIC HOUSING SUBTOTAL													
Community Facilities													
Govt Instit'ns & Deptl Qtrs													
Other GIC Facilities													
GIC FACILITIES SUBTOTAL													
District Open Space													
Roads & KCR/MTR/LRT													
Other Specified Uses													
Undetermined Uses													
OTHER USES SUBTOTAL													
TOTAL													

Based on the timing of land availability of different planned land uses, population in different house types for the next ten year period is estimated (Table 2). Community facilities required to support the population increase are then forecast in accordance with the Hong Kong Planning Standards and Guidelines.

The forecast of land availability is a time-consuming and labour-intensive process which is at present done semi-automatically, generally as an annual exercise. After the relevant information is collected, the timing of land availability of different parcels of land is marked on an Outline Development Plan or Layout Plan. The area of each parcel is calculated manually and recorded into a table by planning area or street block. The area together with other land information are stored in a microcomputer data base using dBASE III. The process is tediously repeated annually in updating the development programme. Much time-consuming re-tabulation will be necessary if the spatial units for the estimation of land availability other than planning areas, such as sub-districts of district board, are required. A fully automated land information system with mapping capabilities can help to speed up the annual updating of the timing of land availability and the re-tabulation for different spatial units. It can also provide map information on land availability and population at any point of time to monitor new town development and assist decision making.

LAND INFORMATION SYSTEM FOR NEW TOWN DEVELOPMENT

A study has been carried out to examine the applicability and usefulness of a microcomputer-based LIS for the estimation of land availability and population for the new town development programme. A 386 microcomputer with math coprocessor, 70 MB hard disk, and tape backup system are used for the study. An A-0 size digitizer and pen plotter are used for inputting and outputting maps and plans. The GIS software used is pc ARC/INFO, one of the microcomputer GIS software which contains most of the GIS functions available for mini and mainframe computers (Marble and Amundson, 1988; Levine and Landis, 1989).

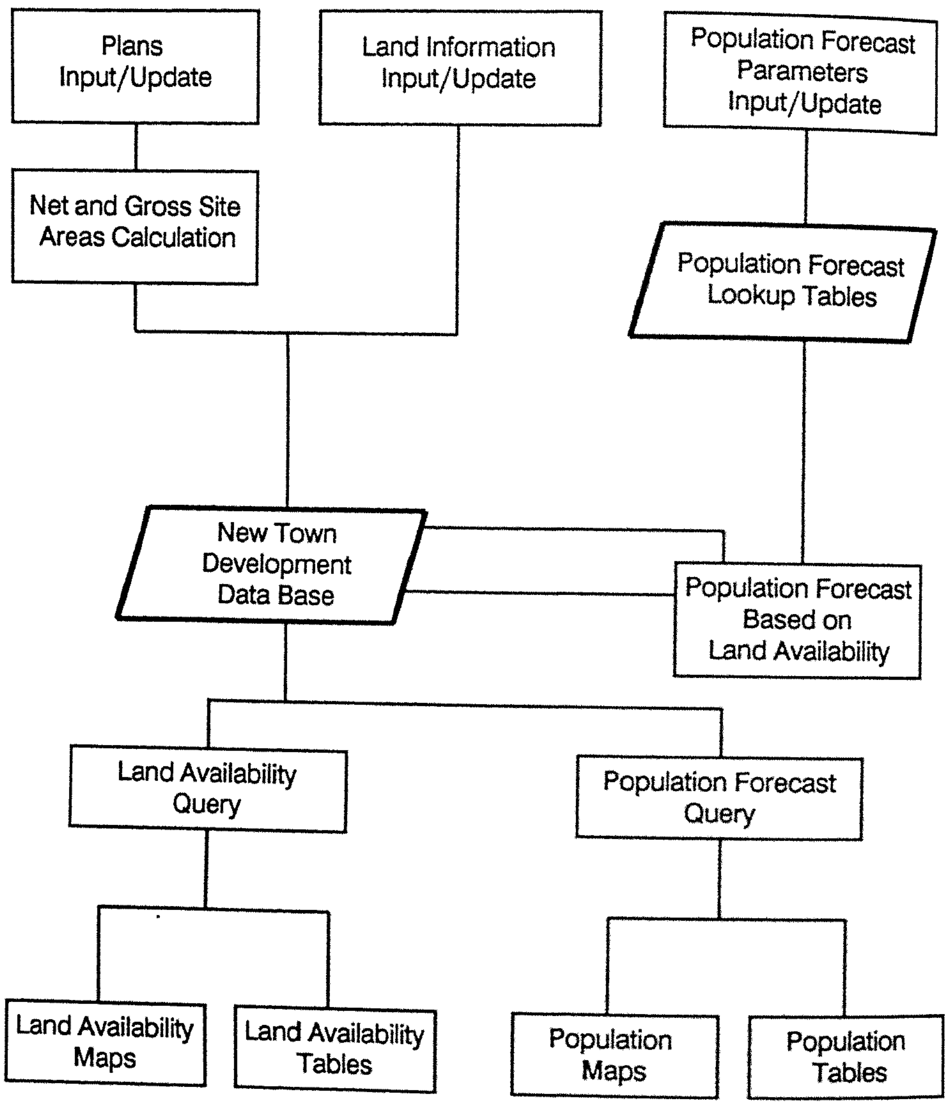
Ma On Shan extension of the Sha Tin New Town is chosen as the study area. It is chosen because the land area is more likely to be managed by the microcomputer. The total development area of Ma On Shan extension is 240 ha which is more manageable by the microcomputer than the 1,602 ha Sha Tin New Town (including Ma On Shan extension). Furthermore, it is a rapidly developing area in Sha Tin New Town with many areas still under land formation and servicing. This will provide more variation in land availability and thus enable a better assessment of the usefulness of LIS in the programming and monitoring of new town development.

The LIS is divided into two main components (Fig. 1). The input components consist of modules for inputting and updating the new town development data base and population forecast

Table 2 Estimated Population by Planned Land Use for the Next 10 Years

HOUSING TYPE	Yr_1	Yr_2	Yr_3	Yr_4	Yr_5	Yr_6	Yr_7	Yr_8	Yr_9	Yr_{10}
Commercial Residential										
Residential 1										
Residential 2										
Residential 3										
Residential 4										
Village Housing										
Institutional Quarters & Others										
Temporary										
Private Housing SUBTOTAL										
Housing Authority Estate										
HOS/PSPS										
Housing Society										
Temporary Housing Area										
Public Housing SUBTOTAL										
T O T A L										

Fig. 1 Land Information System for Monitoring and Forecasting of Land Availability and Population



lookup tables. The output components consist of modules for land availability and population forecast queries. Maps and tables can be output from the system.

Plans Input/Update

There are 7 layout plans for the planning areas of Ma On Shan at a scale of 1:1,000 and 1 outline development plan at a scale of 1:5,000. They are digitized as separate coverages and later joined together to form one large coverage. The site number is used as the parcel identifier (PID) for relating the land information.

Net and Gross Site Areas Calculation

Net site areas are automatically calculated by the software. A small program is used to calculate the gross site areas required from the system. Gross site area is net site area plus a portion of the adjoining land, such as cut slopes, local roads, and local open space. It is calculated by grouping sites into 'zone parcels' and apportioning part of the gross area of the 'zone parcel' according to the net area of the site. The gross site areas calculation routine is activated whenever a plan is updated.

Land Information Input/Update

There are around 200 sites in Ma On Shan. The following land information is input and updated :

- Planning Area No.
- Site No.
- Layout Plan No./Outline Development Plan No.
- Statutory Land Use Zone
- Current Land Use
- Land Production Mode and Land Status
- Public Works Programme Item No. and Priority Category
- Land Formation Date
- Land Serviced Date
- Sale Date
- Expiry Date of Short Term Tenancy/Temporary Use
- Land Availability Date
- No. of Living Quarters (if known)
- Date of Updating

Population Forecast Parameter Input/Update

The following parameters in the population forecast parameter lookup tables are input and updated :

- Persons Per Occupied Flat Ratio (PPOF) by Residential Zone by Year
- Large Site Reduction Factor (LSRF) by Residential Zone
- Plot Ratio (PR) by Residential Zone
- Average Flat Size (AFS) by Residential Zone
- Occupancy Rate (OR) by Year of Completion
- Domestic Use Rate (DUR) by Residential Zone

Population Forecast Based on Land Availability

Flat supply method is used for estimating population of different residential zones. Generally, residential land is considered to be occupied by residents 3 years after it is available for development. Users can override the automatic calculation of year of occupancy and the estimated number of flats (living quarters) by inputting their own data. The basic formulas used are :

a) Existing Residential Land Use and Future Residential Land Use with Known No. of Flats :

$$P_{it} = F_{it} \times PPOF_{it}$$

b) Future Residential Land Use with Unknown No. of Flats :

i) Public Housing

$$P_{it} = GSA_{it} \times PHPD_t$$

ii) Private Housing

$$P_{it} = NSA_{it} \times LSRF_i \times PR_i/AFS_i \times DUR_i \times OR_j \times PPOF_{it}$$

where
P_{it} = Population of zone i in yr. t
F_{it} = No. of Flats (Living Quarters) of zone i in yr. t
$PPOF_{it}$ = Person Per Occupied Flat Ratio for zone i in yr. t
GSA_{it} = Gross Site Area for zone i in yr. t
NSA_{it} = Net Site Area for zone i in yr. t
$LRSF_i$ = Large Site Reduction Factor for zone i
$PHPD_t$ = Public Housing Population Density in yr. t
PR_i = Plot Ratio for zone i
AFS_i = Average Flat Size for zone i
DUR_i = Domestic Use Rate for zone i
OR_j = Occupancy Rate for jth year of completion

Residential zones are zoned as RS, R1, R2, R3 and R4 where RS (Residential Special) is for public housing, R1 has the highest density and R4 the lowest.

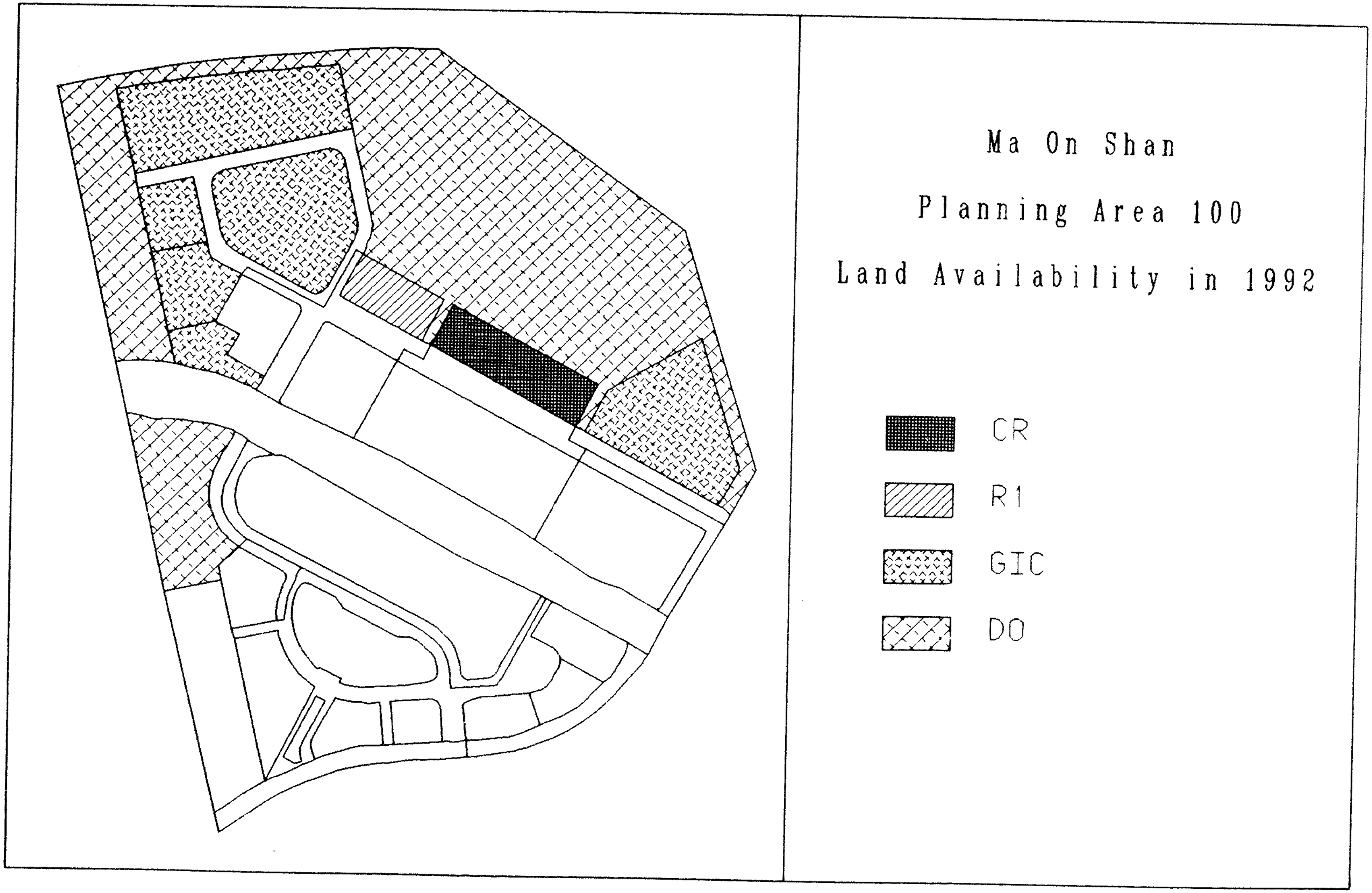
Land Availability and Population Forecast Queries

Maps and tables of land availability and population forecast by land use by year can be obtained either on the monitor or from the plotter and printer (Fig. 2). User can overlay a boundary different from that of the planning area to extract land availability and population forecast information within that boundary.

CONCLUSION

The study shows that the microcomputer-based LIS is an invaluable tool in handling the estimation of land availability and population in the programming and monitoring of new town

Fig 2. Sample Output of Land Availability Map



development. The system allows easy updating and query of the new town development data base with the capability of mapping output. Change in site boundaries can be easily updated without the need of manual recalculation of net and gross site areas. The LIS will save much staff time even if it is used once annually for producing the new town development programme. The advantage of the system will be more appreciated and cost-effective if the frequency of its use increases. The new town development data base of Ma On Shan takes up approximately 1 MB of disk storage space and shows that microcomputer system is quite capable of managing the data base for the whole of Sha Tin New Town.

Problems are often encountered in automating land information stored in traditional method (Werle, 1984). Some of the existing manual methods have to be altered to accommodate computerization. For example, in the manual method, parcels of land belonging to the same development but separated by a road are assigned the same site number. It is workable in the manual system because the areas are calculated, added, and then input into the data base as one record. However, they have to be entered as separate parcels with unique identifiers for the LIS.

The Buildings and Lands Department of the Hong Kong Government has recently purchased a land information system for mapping and planning of Hong Kong. The system is served by a network of workstations. The new town development LIS developed in the study can be more useful when the Hong Kong LIS is in full operation in 3 to 4 years' time. Land information can be downloaded for distributed processing by microcomputers or workstations at a new town office for the programming and monitoring of development. It will also allow government departments and private developers to search for the availability of a particular type of land in the new towns of Hong Kong. The system, if made accessible to the public, can help private sectors to make investment decisions, particularly when public-private partnership is much emphasized in the urban development of Hong Kong.

Further development of the system can include probability determination of land availability date. The present land availability date is deterministic. One possibility is to assign probability to land availability date, and another possibility is to use optimistic, most probable, and pessimistic land availability dates similar to the method of assigning activity time in PERT (Wiest and Levy, 1977).

The flat supply method in population forecast based on land availability may work well in Hong Kong because of the great demand for housing and over half of the flats are public housing. However, its applicability may have to be tested for other areas which have different demand for housing and where housing is mostly private.

Although the new town development LIS can be updated at any time, the frequency of updating has to depend on the management of the system and the frequency and cooperation of other related departments in supplying updated information to the system. Unlike the existing semi-automatic system, the effect of any changes in zoning and dates of land formation and availability can be easily and quickly examined by the LIS. However, LIS is only a tool to facilitate the retrieval and analysis of land information. Frequency of use, interpretation of the information and analysis, and what actions to take still rest on the decision-makers.

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GPM: GEOGRAPHICAL PROJECT MONITORING

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ABSTRACT: The monitoring of development projects is currently conducted as an exercise in the physical progress and financial accounting of the project. Project monitoring can be improved by the adoption of geographical concepts in analytical tasks. Accordingly, we introduce a methodology called Geographical Project Monitoring (GPM) which includes a software system for integrating project monitoring with computer mapping and Geographical Information Systems (GIS). The methodology is illustrated with an example from the Monaragala district of Sri Lanka.

INTRODUCTION

This paper describes the initial efforts in the construction of a methodology called Geographical Project Monitoring (GPM). A project is the basic physical building block of a development program and, therefore, it is also the basic unit of accounting in project administration. Because of the need to monitor the implementation of projects, international development agencies like the World Bank, Food and Agricultural Organization of the United Nations, and the US Agency for International Development have issued detailed guidelines for the proper monitoring and evaluation of project data [Casley and Lury, 1982; Clayton and Petry, 1983; and Casley and Kumar, 1987, 1988]. This literature shows that monitoring is concerned primarily with the physical progress and financial accounting of the project. As such, it is primarily concerned with questions of "how many?" and "how much?". GPM introduces the question of "where?" on the premise that the spatial context of the project affects both the implementation and the quality of the monitoring process.

In the recent World Bank publication of 1987 by Casley and Kumar, titled, Project Monitoring and Evaluation in Agriculture, considered by many to be an authoritative book on the subject, there is only one reference to the use of geography in monitoring; even that is only a passing reference to the use of maps as visual displays in the chapter on "Communicating Information" (p.95). The book is typical of the general literature on this subject in not recognizing the important analytical role that geographical concepts can play in project monitoring.

We shall begin the paper with a brief description of the state-of-the-art in project monitoring. Next, we shall describe several geographical concepts the use of which can improve the quality of project monitoring by drawing on concepts in spatial analysis, cartographic representation, geographic scale, region building, hierarchies, and Geographical Information Systems (GIS). The latter refers to computer-based storage, processing, retrieval, and display systems for spatial data derived from existing maps, remotely sensed images, surveys and so on. Next, we shall review some software systems that can be adapted for designing a GPM. Indeed, GPM cannot be conceived as a practically useful idea without the present-day microcomputer software in data base management and graphics. Since monitoring is above all a tool for the routine management of projects, GPM becomes practical only because of low-cost technologies for the fast manipulation of spatial data. Finally, we shall present examples in selected aspects of GPM using a data base provided by the Integrated Rural Development Programme (IRDP) office in the Monaragala district of Sri Lanka.[1] Although project evaluation and monitoring are closely related topics, our paper will focus only on the latter.

PROJECT MONITORING

During the eighties several international development agencies recognized the importance of standardizing monitoring procedures and its terminology. Much work was done and of these the best known are the two volumes by Casley and Kumar, Project Monitoring and Evaluation in Agriculture and The Collection, Analysis and Use of Monitoring and Evaluation Data published in 1987 and 1988, respectively. They were produced to supercede the earlier publications. The two volumes are a synthesis of the work of the past 15 years and represent the-state-of-the-art in thinking on monitoring and evaluation. Our review of monitoring will draw on the work of Casley and Kumar.

Monitoring can be defined as a process of measuring, recording, collecting, processing and communicating information to assist project management decision-making. Most authorities view monitoring as an integral part of project management. The purpose of project monitoring is to provide relevant information to indicate to management whether project objectives are being met and whether the project operation is "on course". That is, whether tasks are being achieved on schedule; whether inputs and output are achieving 'benchmark' levels; and whether objectives need adjustment in the light of performance and experience [Clayton and Petry, 1983: p. 3]. In this sense monitoring can be viewed as part of a feedback process of communication and control. In a feedback system, data on system performance is monitored by sensors and relayed to comparator organs which are designed to detect differences between actual and desired output of the system The discrepancies so detected will activate effector organs which will modify the system performance to bring it into line with desired goals (Fig. 1). In project administration, the monitoring component can be compared to the sensors and the comparators, and the management decision-making to the effector organs.

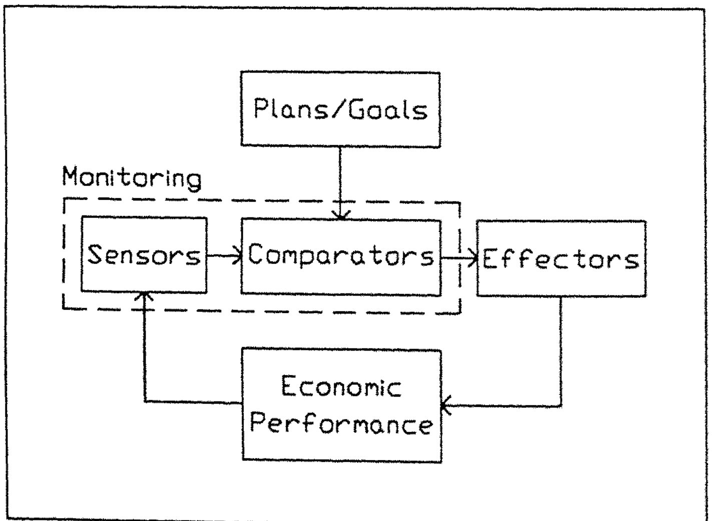

Figure 1 Project monitoring as feedback

Although the twin tasks of monitoring and evaluation are related in many respects, they do constitute two distinct functions with different objectives and methods. Monitoring is an internal project activity which is on-going and is concerned with day-to-day routine operation of the project, while evaluation is performed on a long-term basis. Evaluation is the assessment of a project's performance and impact on the target population and area, a task which requires a longer time span; and so the demand for evaluation lies more with central agencies as opposed to project managers [Casley and Kumar, 1988: pp. 2-15].

In the past project monitoring was developed for tracking the progress of physical delivery systems. These were typically infrastructure projects related to the building and maintenance of irrigation canals, roads, and public facilities such as schools and hospitals. During the eighties issues of equity, regional decentralization, and people's participation emerged as important themes in development [Streeten, 1981; and Gran, 1983]. Correspondingly, there arose in rural development the idea of "people-centered" projects. The management of physical delivery systems common to infrastructure projects is well understood. In people-centered projects the goals are less tangible and the means of attaining these goals are less precise. Often the achievement of these goals requires changes in attitudes and behavior of people. Indeed one of the tasks of managing people-centered projects in many instances is to give the intended beneficiaries an increased awareness of constraints on their lives so as to stimulate the demand for the services that the project has to offer. As we move to people-centered projects, the tasks of internal monitoring becomes more important, and more challenging. The physical and financial progress has to be supplemented by data relating to linkages among infrastructure, personnel, and the target population [Casley and Kumar, 1987: pp. 4-5].

GEOGRAPHICAL CONCEPTS FOR PROJECT MONITORING

The scope of monitoring covers projects at the national, sectoral, regional, and local levels. In this paper we shall confine our comments to projects at the regional and local levels, especially to those of the people-centered type described by Casley and Kumar [1987: pp. 4-5]. Of the several research traditions in geography we shall further confine our comments to the spatial tradition in geography [Haggett, Cliff, and Frey, 1977: 1-24].

The case for geographical project monitoring will be developed in two parts. First, we assert that the quality of project monitoring can be improved simply by the use of maps and spatial concepts in analytical tasks. Second, we argue that for the most effective use of maps it is necessary to incorporate monitoring within the framework of a Geographical Information System (GIS). A GIS is a computer-assisted system for the capture, storage, retrieval, analysis, and display of spatial data. Since the object of monitoring is to supply information to managers on a routine basis the analytical use of maps will be effective only if there is a technological capacity to create accurate maps very quickly.

Of the many concepts in spatial analysis we have selected a few that would illustrate our argument for GPM. These are: (1) the concept of the region, (2) analysis of spatial distribution and spatial correlation, and (3) spatial sampling frames.

A central idea in spatial analysis is the concept of the region. Grouping locations into homogeneous areal units or regions is not unlike the more general exercise of classification of phenomena into statistical classes [Grigg, 1965]. Three main types of regions are recognized in the geographic methodology: uniform, nodal, and planning regions [Haggett, Cliff, and Frey, 1977: p.450-453]. Uniform regions may be defined as contiguous areas within which a given phenomena has little place-to-place variation; for example, regions defined by their dominant landuse such as plantation crops or paddy cultivation. Uniform regions are also referred to as homogeneous or formal regions. The concept of uniform regions is central to such tasks as identifying the locational patterns of income classes, occupational types, and poverty groups, and the monitoring of the provision of services to, and their utilization by, the target populations. Nodal regions may be defined as areas (contiguous or non-contiguous) which are organized through interacting bonds or links. A network of extension agents servicing a dispersed farm population from a central office is an example of a nodal region. Nodal regions are commonly referred to as functional regions. Planning regions may be defined as areas delimited on an ad hoc basis for purposes of administration or of the organization of projects or programs. The concepts of uniform and nodal regions will overlap in a planning region, as for example, in the case of an extension network designed to serve a farming population occupying a region with different kinds of landuse. For most monitoring purposes a simple examination of statistical data and maps is adequate for identifying the appropriate regional sub-divisions. However, if needed, the regional classification can be done through the use of sophisticated methods of numerical regional taxonomy [Cliff, Hagget, and Frey, 1977: pp.450-490]. A regional hierarchy is generated when smaller areal units are grouped into larger areal units. The regional hierarchy may be the end product of a process of map generalization, or it may be given as in an administrative framework (Fig. 2 and Fig. 3). As will be shown later in our discussion of the application of GPM in the Monaragala district we can aggregate the monitoring indicators to any level of the regional hierarchy and display the results in tabular or map form.

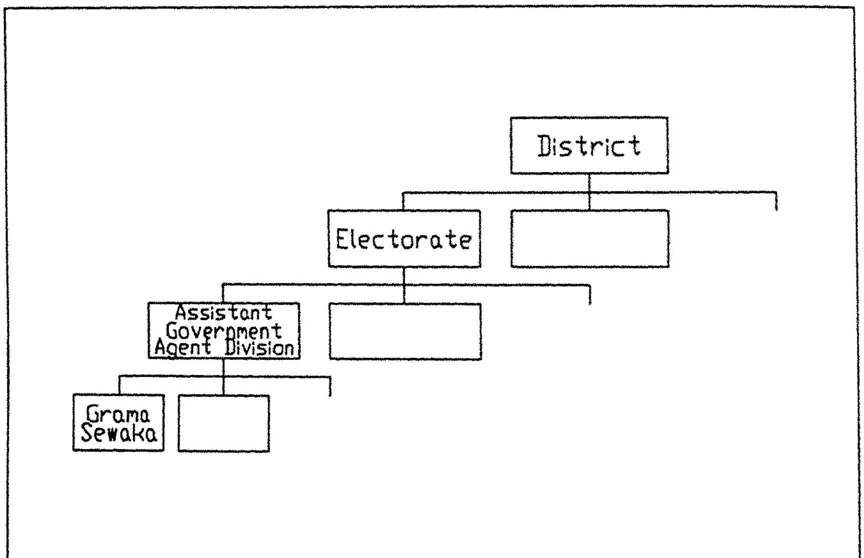

Figure 2 District administrative hierarchy in Sri Lanka

Another contribution of spatial analysis to monitoring is in the area of exploratory analysis. As Casley and Kumar [1988, p.114] have argued, "For monitoring purposes, simple exploratory analysis may be all that is needed. Evaluation may require more complex techniques, but exploratory analysis is still an essential first step... to reveal the simple structures and patterns in the data." The techniques discussed in Casley and Kumar are primarily statistical and graphic; their omission of the potential of maps to show patterns in data is unfortunate. The area of spatial

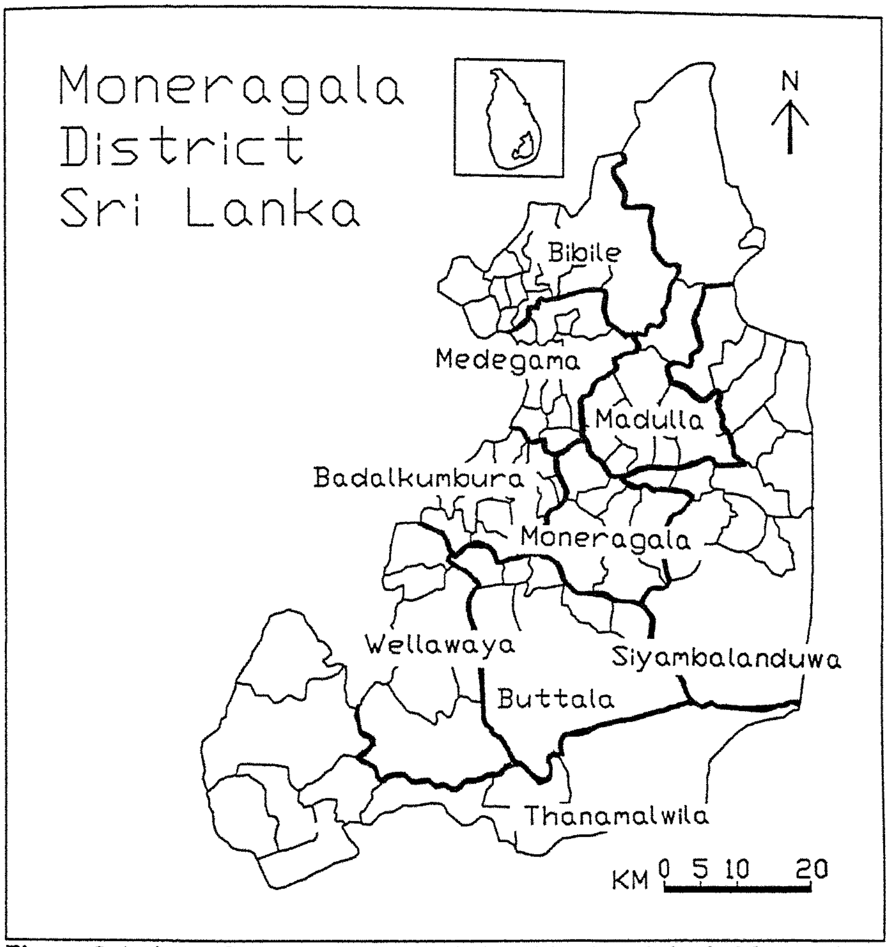

Figure 3 Assistant Government Agent (AGA) division boundaries in Monaragala

pattern analysis is now quite well developed. However, the simple act of mapping the data is often adequate to reveal useful spatial patterns. For example, consider the distribution of poverty in the Monaragala district of Sri Lanka as indicated by the surrogate of the percentage of population eligible to receive food subsidies (Fig. 4).[2] Such a map would provide useful baseline data in planning for a program of poverty eradication.

Maps comparisons help us to establish correlations between different kinds of geographic distributions. The simplest kinds of comparison can be made by placing two maps side by side. For example, a comparison of the amount of project outlays made by the office of Integrated Rural Development Program (IRDP) at the end of 1988 and the presence of poverty (as measured by the surrogate of the percent of food stamp holders) for the Monaragala district shows that the highest allocation of funds were in fact not made in the poorest regions (Fig. 5; see also Fig. 4). This at first appeared surprising given the poverty orientation of the programs of the IRDP office; an

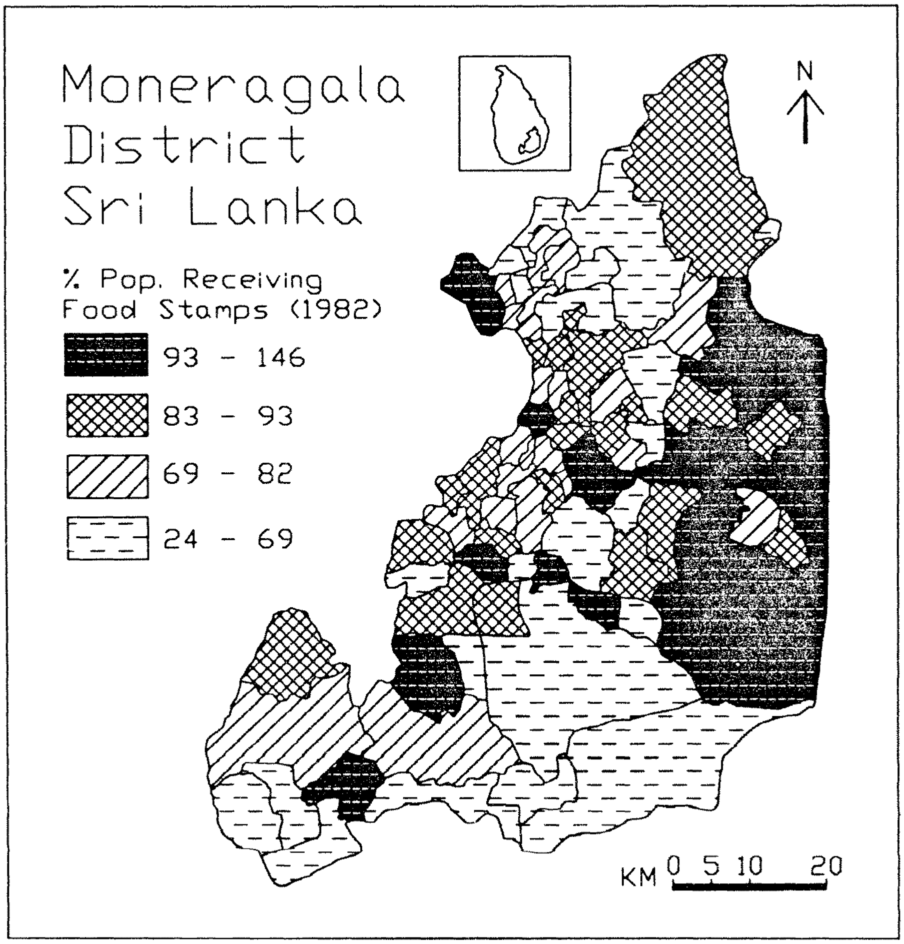

Figure 4 Distribution of food stamp holders in 1982

explanation of this weak correlation is discussed later in our analysis of the Monaragala example.

A useful application of map analysis for monitoring is in the use of areal sampling frames. Sampling is an established methodology in project monitoring, particularly in the use of sample surveys as exploratory and diagnostic tools [Casley and Kumar 1988:pp. 76-95]. In sampling theory, the standard deviation of the sampling distribution of sample means is called the standard error of the estimate which is used as a measure of the reliability of sample estimates. Usually the standard error of the estimate of a sample drawn from a variable population is higher than that drawn from a more uniform population. We can overcome this problem by increasing the size of the sample when working with highly variable populations. But in general the variability of a population is not known until a sample is taken and examined. But, when the sampling frame is related to an areal distribution, we can use the map to help us make decisions about sample size [Dixon and Leach, 1978]. For example, the number of observations required to estimate the mean height of a gently undulating plain (or a low variable population) is far less than that required to estimate the mean

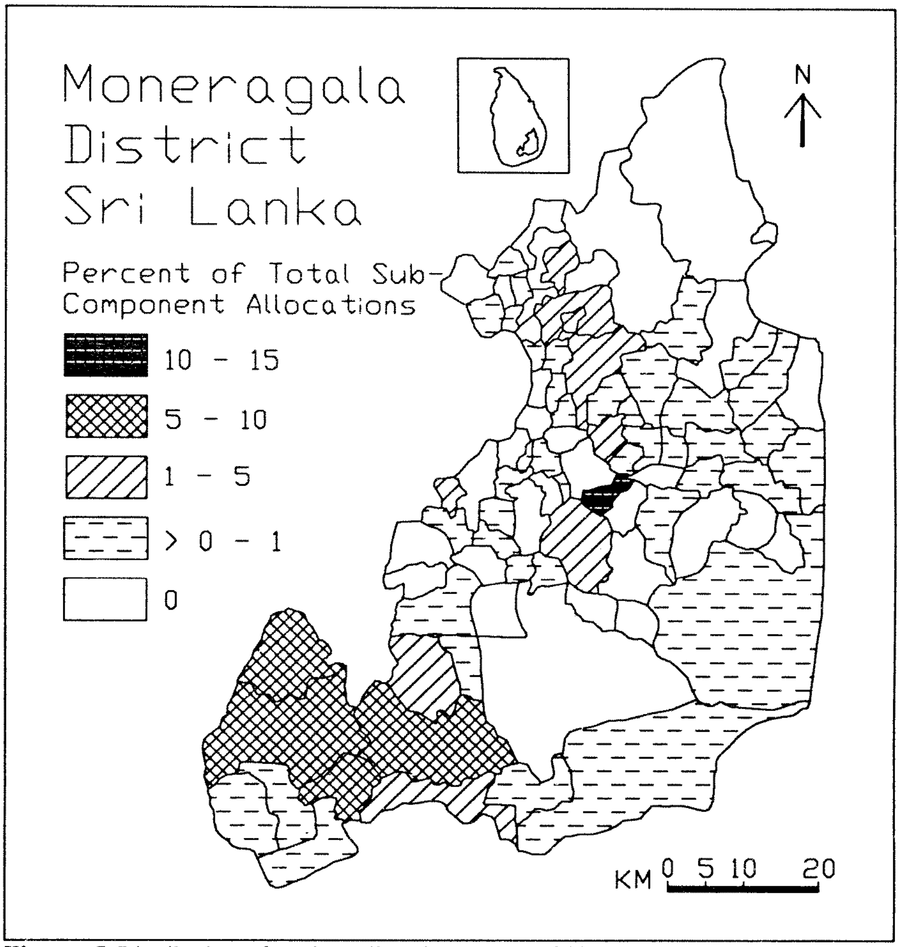

Figure 5 Distribution of project allocations up to 1988

height of a mountainous area with high local relief. Stratification is an established method for obtaining better sample estimates from a variable population, and maps can be used for stratifying the population. For example, in a rural area of the Kurunegala district of Sri Lanka it was hypothesized that household incomes varied by access to the principal marketing routes. To test this statement, the population of households was divided into two groups using a criterion of distance from the main road. All the households were first plotted on the map and then divided into two groups by overlaying a set of "buffer zones" on either side of the main marketing roads (Fig. 6). The sampling fractions were determined according to the proportion of houses in each of the strata. Maps may also be employed to reduce costs when sampling over a large area or from a very dispersed population. We can reduce the travel time involved in conducting field interviews by using a cluster design where the sampling is done intensively at a few chosen locations. Maps of the underlying population and access routes are often employed in determining the cluster design [Berry and Baker, 1968; Dixon and Leach, 1978].

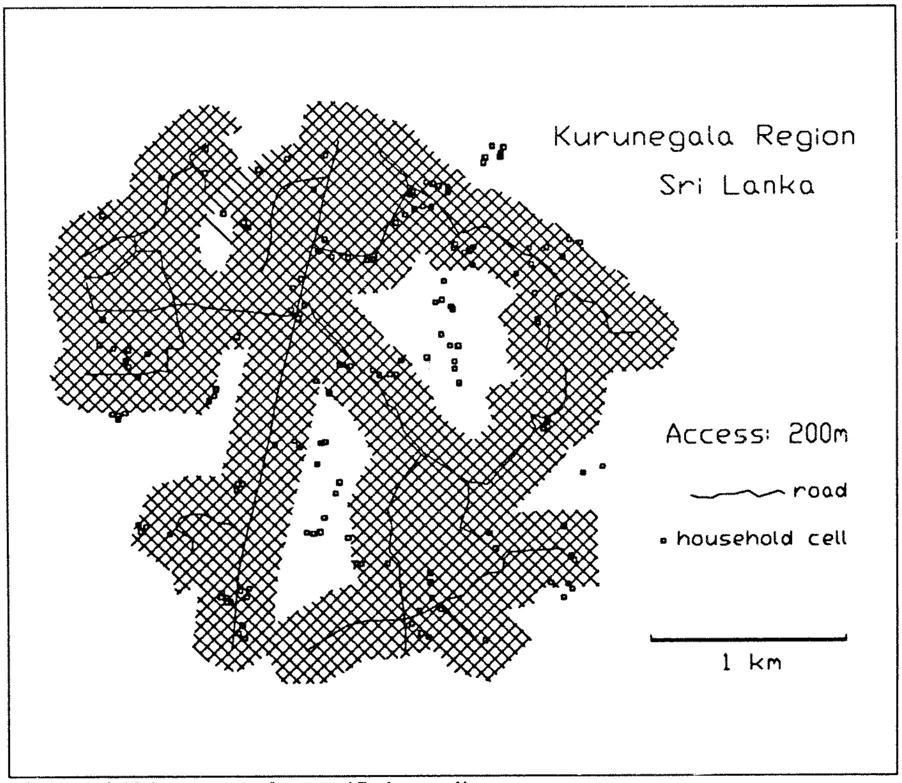

Figure 6 Using a map for stratified sampling

The geographical exercises described above can be done without access to a computer. However, in the case of project monitoring it is of utmost importance that results of map analyses be available on a routine day-to-day basis so that the management function can proceed smoothly. A time-consuming map analysis process may perhaps be justified in evaluation but it is not feasible in monitoring. Indeed a lengthy map analysis would act as a drag on the monitoring function. Thus the effective use of spatial analysis in monitoring requires a GIS for coding, storing, processing, retrieving, and updating spatial data rapidly, and for answering queries made from the geographic database.

COMPUTER SOFTWARE FOR GPM

We have argued that for GPM to be effective the project administration should have access to an automated system for rapid map analysis. There are two broad approaches to the choice of a software system for GPM:

(1) use of a single, integrated GIS system for data entry, file management, statistical and spatial analyses, and graphics;

(2) use of a loosely integrated system built around existing database management, statistical, and graphics packages.

One of the most sophisticated GIS packages available for microcomputers is PC ARC/INFO, but its cost (about US $10,000) plus the costs of training make it currently inaccessible to a large number of potential users in the planning offices of the Third World. IDRISI developed at Clark University by Ron Eastman is a very viable low-cost alternative to ARC/INFO. However, for our work on GPM we opted for a modular system called CARP: Computer Assisted Regional Planning, which is built around popular software already available and in use in the developing countries of Asia [Yapa, 1988].

The CARP system is not a new package.[3] It is a conceptual scheme which integrates existing package programs through a set of linker programs written in BASIC. The project was first developed and implemented on behalf of the IRDP offices of the Hambantota and Monaragala districts of Sri Lanka in 1987. It was commissioned by the Sri Lankan Ministry of Plan Implementation and funded by NORAD, the Norwegian Agency for International Development.

CARP is a loosely linked modular system built around popular commercially available package programs. There are several advantages to this approach: First, existing GIS packages like ARC/INFO are beyond the means of small regional planning offices because of high costs of purchase and of training. Second, the commercial packages used in CARP and the knowledge to use them are now widely available throughout the major Third World cities. Third, the packages are well documented and frequently updated. CARP was specifically designed to take advantage of the "software infrastructure" and the support structures that already exist for data base management and graphics in the Third World, particularly in the cities of Asia.

CARP consists of a set of linker routines which integrates a computer aided drafting packages (AutoCAD) with a data base manager (dBASE) for the purpose of developing a simple, low-cost GIS type system. Indeed, in many planning offices of Sri Lanka many officers are already familiar with the use of dBASE in project monitoring.

AutoCAD is the brand name of a computer-aided drafting (CAD) package marketed by Autodesk, Inc in Sausalito, California. It is the best known package available in the rapidly growing area of CAD software. Like all. CAD packages AutoCAD turns the computer screen into an electronic drawing board. AutoCAD allows us to draw, erase, modify, copy, move, or rotate any part or whole of the drawing electronically.[4]

CARP uses dBASE III to store thematic data. As a data base manager dBASE is not only powerful, but it is also one of the most popularly used packages in this area. dBASE III is a relational data base. dBASE III has the facility to export and import data files, a feature which enables us to interact with AutoCAD using the CARP linker programs.

The third component of CARP contains the linker programs written in BASIC. Of the CARP functions only three are of interest to the concept of GPM. They are:

(a) digitizing spatial entities,
(b) drawing choropleth maps, and
(c) analyzing map overlays.

CARP contains a set of menu-driven commands that has adapted the digitizing capability of AutoCAD for joining line segments to draw boundaries of regions. The digitized data is captured and exported by AutoCAD into a CARP routine that generates regional boundaries. The technical procedure is discussed at length elsewhere [Yapa, 1988].

Making choropleth maps in CARP requires two basic data files: a locational data file containing the X,Y coordinates of the boundary segments and a file containing the thematic data to be mapped. The two files are related to each other through a point unique to each boundary called the 'pline tail'. The boundary data is contained in a file where each boundary is described by an AutoCAD command called the PLINE as shown below:

```
PLINE 1.45,3.05 1.31,3.51 1.45,3.05 0.85,2.77
0.83,2.76 0.65,3.00 0.39,3.58 1.05,4.21 1.42,4.92
2.23,4.92 2.24,4.89 2.19,4.56 2.13,4.25 2.12,4.23
1.73,3.97 2.13,3.72 1.45,3.08 C
PLINE 2.68,3.35 3.04,3.59 2.68,3.35 2.98,3.03
3.34,2.95 3.34,2.99 4.28,3.66 4.33,4.45 3.73,5.02
2.21,4.87 2.24,4.89 2.19,4.56 2.13,4.25 2.13,4.22
2.75,3.79 2.66,3.37 C
```

Each PLINE defines a unique region. Such boundary files are produced in CARP through a series of linker programs that interact with AutoCAD.

The thematic data to be mapped is first stored as a dBASE file. The data to be mapped is grouped into appropriate statistical classes through dBASE procedures. Each row of this file contains data that is linked to the boundary file through the 'pline tail' coordinates. Once the hatch patterns for the map classes are selected, AutoCAD will proceed to shade each region (bounded by the PLINEs) with the pattern appropriate to its class by linking the Thematic Data File and the Boundary File using the 'pline tail' coordinates (Fig. 4 and 5). An example of a Thematic Data File is given below:

Region Id	Pline tail coordinates	Region type
1	1.31,3.51	Corn
2	3.04,3,59	Peanuts
3	1.10,2.42	Fallow
4	2.20,3.38	Cotton

A CAD feature that is very attractive to map makers is its ability to draw on several stacked layers. The drawing layers can be turned on and off at will so that any number of layers can be visible on the computer screen at one time allowing us to visually examine geographic correlations. A drawback of CAD for geographers is that when two or more region polygons overlap, for instance, rainfall and vegetation, there is no direct way to obtain the coordinates of the new polygon forming the area of overlap, a task which is more in the realm of GIS. In CARP, special procedures are employed using both AutoCAD and dBASE to do this exercise. Very briefly, the map overlays in AutoCAD are first rasterized and the resultant grid cell data are moved into dBASE for comparison and analysis. All spatial type queries for the map overlays are done from the corresponding grid cell data in dBASE. It was this technique that was used in our earlier example for classifying households into different strata for determining sample sizes (Fig. 6).

DESIGNING GPM IN CARP

The standard data file constructed for project monitoring will have records which describe the characteristics of project components or activities. Before we use such a file in GPM the information on project activities must be pegged to specific locations or areas. This section describes the procedures for setting up the monitoring file to interface with the mapping routines in CARP.

The data in project monitoring applications is often hierarchical in nature. A program consists of several projects. Each project is divided into a set of components, each of which is divided into sub-components, and below that into activities. Most records of financial and physical progress are kept by activities. Project activities may also be organized by sub-sectors and sectors of the economy and by the departments and ministries responsible for them. Even time is hierarchical, when progress is reported by weeks, months, quarters, and years. The main interest in GPM is the organizing of data by areal units, particularly by administrative regions, which may also be hierarchically structured (Fig. 2).

This tendency towards hierarchy suggests that a project monitoring system should be organized as a hierarchical database. When data have a parent/child or one-to-many relation, hierarchical methods allow quick and easy access to the data through the parent or root records. These systems perform well if the data structure is simple and the type of query made can be known beforehand. When the records are organized by project components and sub-components, searching the file on another criterion such as sector is very time consuming. A hierarchical structure is not suitable for setting up a data file for GPM, because in GPM, project hierarchies are not usually considered individually, but always in relation to a regional hierarchy. We have opted to store the project monitoring data in a relational database (dBASE), but at the same time we have taken care to maintain the hierarchical information. This is done by a procedure which allows hierarchies to be represented in a relational context, through the use of hierarchically structured codes. Thus, every record of the database contains, among other attributes of the item, one or more columns containing hierarchically structured codes. The GPM system design in CARP relies upon this concept for the maintenance and comparison of hierarchies.

A GPM system has several databases but for our present purpose we shall describe four, of which three are input files:

Basic Monitoring Files - project accounting and administrative data
Administrative Boundaries - outlines of administrative units within the project area, represented as X,Y coordinate pairs
Thematic Data for Administrative Regions - socioeconomic and demographic variables observed by administrative units (e.g. census data)

The Basic Monitoring File has as its records project activities or sub-components. The data in this file is not mappable because it has no correspondence to the file with the locational data of administrative boundaries. Our intent is to transform the Basic Monitoring File to one where the records correspond to the administrative units of the region. This new file which is CARP-compatible file will be called the **Regional Monitoring File**. However, before we can proceed to a discussion of how Regional Monitoring files are constructed, we need to get a clearer picture of the nature of the input files.

The Basic Monitoring File: This is a standard dBASE file with project activities as the records. It contains basic accounting and administrative information, covering all aspects of project operations: dates, allocations, expenditures, inter-agency connections, input deliveries, output levels, etc. For the purposes of GPM, each record should contain geographic information about the location of the project and the areas served by the project activities. For ease of discussion we shall consider only one item of geographic information, namely, the area in which the activity is located. If an administrative hierarchy exists the location specifier for each record should be a hierarchically structured code as shown in Table 1.

Table 1 The Basic Monitoring File

Project Activities	Allocation	Expenditures	. . .	Location
1	100,000	50,000		2206
2	80,000	40,000		3305
3	2,000,000	100,000		3306
.	.	.	.	
.	.	.	.	
.	.	.	.	
N	1,000,000	100,000		3306

In the example given in Table 1 the location specifier for each record indicates a regional hierarchy of three levels from the district administration of Sri Lanka. Each district is divided into electorates. Each electorate is divided into Assistant Government Agent (AGA) units. Each AGA is divided into Grama Sewaka Divisions (the latter refers to a cluster of villages). This is the lowest level for which statistical data is published. The first digit and the second digits in the location code stand for the electorate and the AGA division, respectively. The last two digits represent the number for the Grama Sewaka Division. Any single location specifier code may appear as many times in the file as there are project activities at that location. Using basic dBASE commands we can aggregate project activity information by areal units at any of the three levels. This process of activity aggregation by areal units gives us the Regional Monitoring Files at the different levels of the administrative hierarchy. For example we can produce three such files for the data in Table 1 Other hierarchical information such as project activity level (components and sub-components) and economic sectors and sub-sectors are assigned codes similar to that of the location specifier. Using elementary dBASE commands project activity information can be aggregated over two or more hierarchical indicators. For example, we can produce a file of activity expenses aggregated by regions and by sectors.

Administrative Boundary File: These files contain sets of X,Y coordinate pairs which describe the outlines of administrative regions. An administrative boundary file will be available for each level of the regional hierarchy. Such files are produced in CARP through the appropriate chaining of boundary segments.

Thematic Data for Administrative Regions: While the ability to relate project data to administrative locations may be useful in and of itself, the real power of GPM lies in the ability to relate project data to other non-project variables at the same locations. Socioeconomic and demographic data are often collected with administrative districts as the enumeration units.

Regional Monitoring Files: This is a CARP-compatible Thematic Data File constructed from a Basic Monitoring File. It can be augmented with thematic data for administrative regions. Once this file has been created, its data can be associated with the region boundaries in the Administrative Boundary File and mapped, using the CARP system. The final form of the Regional Monitoring File resembles any other Thematic Data File in CARP except that the columns of information relate to monitoring indicators. The structure of this file is shown in the example of Table 2.

Table 2 The Regional Monitoring File

Region (Grama Sewaka Divisions)	X,Y coordinates	Variables M1	M2	M3 . . .	Mn
2206	2.2,3.1	.	.	. . . .	.
3305	8.4,8.2	.	.	. . . .	.
3306	1.4,1.3	.	.	. . . .	.
.	.	.	.	. . . .	.
.	.	.	.	. . . .	.
.	.	.	.	. . . .	.
3306	5.6,4.2	.	.	. . . .	.

The column of X,Y coordinates refer to 'pline tails', the unique points on the regional boundaries which help us to link this data to that of the region boundary files. Since a Regional Monitoring File is linked to a corresponding boundary file of administrative regions, we can generate several Regional Monitoring Files, one for each level of the administrative hierarchy.

There are several considerations in a Basic Monitoring File of dBASE that will complicate the construction of Regional Monitoring Files that we will not discuss here. These issues include the assignment of allocations when a project is located in several areas, and it benefits more than one area. In such instances we need to have a set of weights or a weighting function.

GPM - AN EXAMPLE

This section develops an elementary application of the GPM concept to the project activities of the IRDP office of the Monaragala district of Sri Lanka. By most criteria, Monaragala is one of the poorest regions of the country. Administratively, the district is divided into three parliamentary electorates, nine Assistant Government Agent divisions (sub-district units), and 88 Grama Sewaka divisions (village clusters).

The District Integrated Rural Development Programme (IRDP) directed by the Ministry of Plan Implementation started in mid- 1983. The program is implemented by the district IRDP office which introduced a people-centered participatory approach to development. Much of the district development administration is still done through the line agencies of the ministries of the central government. The IRDP office exists at a level parallel to the district offices of the line agencies. The IRDP office does not exercise any regional authority over the district offices of the line agencies. In Sri Lanka IRD program in each district is sponsored by an international donor agency. The IRD programs in Monaragala and in the adjacent district of Hambantota are sponsored by NORAD, the Norwegian Agency for International Development.

The Basic Monitoring File which is in dBASE format contains financial and other descriptive information for 34 projects operating in the Monaragala District. The 34 projects are broken down into 208 components, which are further broken down into 934 sub-components. The file records are established at the level of the sub-components.

For each of the 934 sub-components the Basic Monitoring File contains (among other things) the following information:

- a description of the sub-component
- the total funding allocated to it

- the total non-reimbursable expenditures to date
- the total reimbursable expenditures to date
- the region(s) in which the sub-component is based (location)
- the region(s) which the project is intended to benefit (area cover)
- the economic sector and sub-sectors into which the activities of the sub-component fall

The following data were assigned hierarchical codes: components and sub-components; the location of the sub-component and the area covered; and the economic sectors.

The Thematic Data File containing socio-economic data of the Grama Sewaka Divisions is also in dBASE format. Among other things, the file contained the following:

- total 1981 population
- ratio of males to females
- area in square kilometers
- population density (per square kilometer)
- percent of population who were on food subsidies in 1982
- percent of families receiving assistance in buying fuel in 1982.

The socio-economic data cannot be related directly to the Monitoring File because a record in the latter is a sub-component and in the former is an areal unit (Grama Sewaka Division).

The base map for the analysis was digitized from maps provided with the census data, using the CARP system. The region boundary line segments were digitized and joined to form closed polygons representing the Grama Sewaka Divisions. These same line segments were chained differently to form regions at different levels of the administrative hierarchy.

We shall begin by constructing several Regional Monitoring files to correspond to the administrative hierarchy in Monaragala which will help us to ascertain the geographic scale at which project activities are being conducted. In Monaragala resources are allocated at all four levels of the regional hierarchy. Up to the end of 1988, the total allocations came to nearly 150 million rupees (or about six million US dollars). Each of the 934 project sub-components (the level at which all allocations and expenditures are accounted for) is classified according to the ten economic sectors shown below (as well as into a sub- and sub-sub-sector).

Sector number	Name
01	Agriculture and natural resources
02	Industry
03	Public Utilities
04	Transport and communications
05	Tourism, trade, and finance
06	Education, youth, sports and culture
07	Health, labor and social welfare
08	Housing, community and estate development
09	General public services
10	IRDP planning office overheads

The information in Table 3 shows the percentage of the total allocations received by each region at all four levels of the Monaragala hierarchy across eight of the ten sectors (sectors 02 and

Table 3 IRDP Allocations by Area and by Sector

	SECTOR								
	1	8	9	4	6	3	10	7	TOT
District									
0000	.013	.002	.073	.000	.006	.002	.076	.011	.183
TOT	.013	.002	.073	.000	.006	.002	.076	.011	.182
Electorates									
1000	.007	.000	.003	.000	.000	.000	.000	.000	.010
2000	.001	.000	.004	.000	.000	.000	.000	.000	.005
3000	.000	.000	.001	.000	.000	.000	.000	.000	.001
TOT	.009	.000	.007	.000	.000	.000	.000	.000	.016
AGAs									
3200	.001	.000	.011	.000	.008	.000	.000	.004	.024
3300	.002	.000	.002	.000	.008	.000	.000	.003	.014
1300	.005	.000	.002	.000	.000	.000	.000	.007	.014
1100	.000	.000	.009	.000	.000	.000	.000	.000	.010
1200	.003	.000	.001	.000	.000	.000	.000	.002	.005
2200	.003	.000	.000	.000	.000	.000	.000	.000	.004
3100	.002	.000	.001	.000	.000	.000	.000	.000	.002
2300	.000	.000	.000	.000	.000	.000	.000	.000	.000
2100	.000	.000	.000	.000	.000	.000	.000	.000	.000
TOT	.015	.000	.026	.000	.016	.000	.000	.015	.072
Grama Sewakas									
2206	.001	.073	.001	.002	.000	.073	.000	.000	.149
3301	.022	.001	.011	.028	.012	.005	.001	.004	.087
3202	.028	.006	.002	.028	.003	.005	.001	.004	.077
3405	.034	.005	.002	.015	.007	.005	.001	.004	.073
3409	.022	.002	.004	.006	.008	.006	.001	.003	.050
2107	.000	.043	.001	.000	.000	.000	.000	.000	.044
3408	.013	.001	.003	.004	.001	.014	.001	.003	.040
1307	.002	.000	.001	.020	.005	.001	.000	.001	.031
2205	.001	.019	.001	.000	.001	.000	.000	.000	.021
1309	.004	.000	.001	.006	.005	.001	.000	.001	.019
3305	.000	.000	.005	.009	.000	.000	.000	.001	.015
1305	.004	.000	.001	.004	.003	.001	.000	.001	.014
1109	.000	.000	.000	.013	.000	.000	.000	.000	.013
1204	.002	.001	.001	.003	.002	.001	.000	.001	.011
				(All Others < .01)					
TOT	.135	.152	.041	.143	.099	.114	.007	.032	.723
TOT	.172	.154	.147	.143	.121	.117	.083	.057	

05 received very little of the IRDP allocations). Note that most of the money (72%) is allocated at the Grama Sewaka level, indicating that the majority of spending takes place at the most localized level of the hierarchy. This suggests a healthy level of decentralization in project spending.

After the Grama Sewaka level, the second largest portion is allocated at the opposite end of the hierarchy, at the district level (18%). Investigation of sub-component data shows that all the district-level spending is related to administration and co-ordination of district-wide activities and to the planning unit overhead. Only a small percentage (1.6%) is allocated at the electorate level of the hierarchy, and the level of the nine AGAs received about seven percent. What we see therefore is a reasonable distribution of project allocations along the regional hierarchy. Administrative activities occur at the district and AGA level, while agriculture, transportation and people-centered sectors like housing and education receive allocations at the local level (see).

A striking feature of the distribution of allocations at the Grama Sewaka level is the extreme spatial concentration (). Just eleven of the 88 Grama Sewaka Divisions received over 60% of the total allocations, and almost 90% of the Grama Sewaka allocations. The Grama Sewaka Division of Muppane alone (in the Monaragala AGA division) received about 15% of all money allocated. This expense is related to several poverty-oriented infrastructural projects that were carried out near the town of Monaragala, the administrative capital of the district. Apart from the investments in Muppane, the other allocations are essentially concentrated in three areas where the IRDP project office had launched three area development programs (ADP): (1) in the Thanamalvila AGA division of the south-west; (2) in the Medagama-Madulla AGA divisions to the north of the town of Monaragala, and (3) in the Badalkumbura division in the western border of the district (Fig. 3). Each of the area development schemes consists of a series of development activities, mostly related to the agricultural sector. It is noteworthy that little or no IRDP resources went into projects that were classified as industrial. This in itself is not significant because the money from the IRDP office constitutes only a small part of the resources available for the district.

A map comparison of the allocation of IRDP investments and of the distribution of poverty as measured by the percent of population on food stamps shows only a weak correlation (Figs. 4 and 5). The poorest areas of the district lies in the AGA division of Siyambalakumbura to the east and in the northern parts of Madulla to the north-east of the district. The value of the correlation coefficient for these two distributions is 0.08. We must be careful not to draw any conclusion from this correlation and map comparison alone. First, the reasons for the choice of the sites for the three area development programs are very complex and cannot be discussed without more background information. Second, the area development programs are very new (about three years old at the end of 1988), and other area development for the financial year 1989 have been launched already. Third, the IRDP investments must be seen in the context of the overall expenditure in the district which include the money spent by the line agencies of the sectoral ministries and the funds available at the electorate level from the decentralized budget of the central government. Finally, we must be careful not to confuse a monitoring exercise with evaluation. The figures provided in and the maps (Figs. 4 and 5) are part of a monitoring exercise and not intended to test hypotheses about the regional distribution of poverty and IRDP allocation. The test of such a hypothesis belongs in the realm of evaluation and should take into account the overall pattern of expenditures in the district over several years.

CONCLUSION

We have demonstrated the utility of using mapping techniques in the improvement of project monitoring by drawing examples from the analysis of spatial distributions, spatial correlations, map overlays, regional hierarchies, and areal sampling. Since monitoring involves the provision of information for routine management it is important that the geographical analysis be done rapidly. This is possible with today's technology of computer mapping and GIS. Our own interest was to develop a system which is accessible to planning offices in the rural areas of the developing countries. We have attempted to do this through a software concept that links popular packages that are commonly available to planners in the Third World.

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End Notes

1. We were unable to follow-up some of the statistical findings in the field because of the very unsettled political conditions in the rural areas of the Monaragala district throughout the years 1988-89.

2. According to the figures provided to us by the IRDP office of Monaragala, in some Grama Sevaka Divisions the percentage of the population on food stamps exceeds 100 %. The only explanation we can offer for this discrepancy is that the population figures are those published in 1981, and the data for food stamp holders are from late 1982. Many Grama Sevaka Divisions have experienced a steep increase in population growth due to rapid immigration of people from other districts for which we do not have the data.

3. The brief description of the CARP software given here draws heavily from previously published work [Yapa, 88, 89]. CARP is available through WiscWare, Unviersity of Wisconsin, Madison, WI and through the Department of Geography, Pennsylvania State University.

4. See Cowen [1988] for a comparison of CAD and GIS. See also the THE GIS FORUM, Vol. 1, No. 7, July, 1989 for a discussion of CAD approaches to GIS.

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A GKS-BASED MICROCOMPUTER GRAPHICS PACKAGE FOR URBAN AND REGIONAL ANALYSIS AND PLANNING

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ABSTRACT

As the microcomputer revolution is deeply transforming the world of business and commerce, the world of the urban and regional planner is still sadly lagging behind. Too small a market for profitable software development, the writing of planning software remains largely left to non-professional programmers such as graduate students, researchers or the planners themselves, and more often than not on a minimum budget.

It was with this target group in mind that the program package described in this paper was designed. It provides an integrated programming environment for IBM XT/AT compatible microcomputers based on the WATFOR-77 compiler of the University of Waterloo, Canada, and its implementation of the Graphical Kernel System (GKS) graphics standard. The package consists of a library of more than seventy FORTRAN77 subroutines which form, in the GKS terminology, an 'application layer' between the graphical primitives of GKS and a multitude of planning-related tasks of spatial analysis and presentation ranging from simple line draws and polygon fills to complex three-dimensional transformations of spatial data.

The imbedding of graphics functions into the traditional programming language of geographers and planners distinguishes the package from stand-alone graphics packages and makes it particularly suited for immediate visualization of the results of computations such as simulations. Its minimal hardware requirements facilitate its application in planning education and in decentralized work environments.

In the paper an overview of the functions supplied by the subroutine package is illustrated by demonstration programs. In addition, examples of more advanced applications such as transport network analysis, demography, migration analysis and digital terrain modelling is shown.

DESIGNING ADVANCED SPREADSHEET TEMPLATES FOR NOVICE MICROCOMPUTER USERS

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ABSTRACT

Microcomputer spreadsheet programs such as *Lotus 1-2-3*, having revolutionized the ease of developing computerized quantitative planning models, now offer enhanced capabilities for developing sophisticated specialized templates with custom menus and algorithms.

This paper presents design principals for effectively organizing worksheet templates and demonstrates how they can be utilized. Program features found within spreadsheet programs are identified and used to produce spreadsheet templates which can be effectively utilized by novice microcomputer users unfamiliar with most spreadsheet program commands.

COMPUTER APPLICATIONS IN PLANNING: HISTORICAL BACKGROUND

Up until a decade ago the utilization of computers for the storage, analysis, and dissemination of planning information was done on large mainframe or mini computers accessed and run by computer specialists mostly using custom prepared batch programs. Such programs often took weeks or months to develop. It frequently took hours or longer to obtain results from any run of the finished program. Computer applications for planning were mainly restricted to universities and large governmental organizations, such as state, regional, or major urban county planning departments, with access to huge computers and the budgets to hire staff and/or consultants to program and run them.

During the past decade the use of computers for planning applications has changed due to the increasing availability of successively more powerful microcomputers (Brail, 1987; French & Wiggins, 1989; Klosterman, 1988; Ottensmann, 1985). Sometimes called "personal computers," or "PC's," microcomputers are revolutionizing the use of information in planning. Spreadsheet programs were one of the applications which initially got microcomputers into planning offices. By 1988 nearly sixty per cent of the public planning agencies surveyed in California were using spreadsheet software, edging out database management software as the most used type after word processing. (French & Wiggins, 1989)

Persons with no previous computer experience can in a few hours learn the operating fundamentals of spreadsheet programs and the microcomputers they run on. For example, as of January, 1983 I had never run a spreadsheet program, yet within eight hours of first booting up *VisiCalc* I had a five year cohort component population projection model running (Bossard, 1984). It would have taken me many months to learn a programming language and develop and run the same model on a mainframe or minicomputer. Even then, each run of the model would have taken hours as batch runs were submitted to a physically remote computer.

Now, after about an hour of study my novice user graduate urban planning students can learn to run a worksheet template on a PC (Bossard, 1987b). After thirty hours of study most graduate students are proficient enough to develop moderately complex worksheets utilizing a variety of functions including the windows and titles features, but not macros (LeBlond & Cobb, 1985). With a PC, users can interactively run a program by themselves (hence the "personal"), usually receiving results in moments. The quick turnarounds associated with interactive processing of worksheets expedite program development, editing and review. The "what if" feature of spreadsheets, (i.e. changing an assumption and rerunning the model within moments) facilitates sensitivity analysis and has promoted their growth. Because it is so much easier to build models in spreadsheets than with conventional programming languages nonprogrammers have flocked to microcomputer spreadsheet programs.

Another factor promoting the growth of PC's has been the continuing technological evolution of computer hardware and software which for several decades has significantly increased the computing power that can be bought with a dollar each year. It is likely that the period of rapid improvement of computer productivity will continue for at least another decade (Needle, 1988 quoting Bill Gates) as existing technology is more efficiently used. Further advances in technology of electronic storage and transmittal may continue to push the computer technology revolution ahead at a rapid pace for several decades before the maturation phase is reached (Klein, 1977). We can look forward to continued increases in computer hardware capabilities.

The recurring increases in hardware capability and following innovations in spreadsheet software capabilities have resulted in impressive improvements in what can be done with spreadsheets. State-of-the-art spreadsheets today have immense physical capacities, 3-D linking capabilities, numerous functions and programming commands, as well as options for graphical displays, database analysis, and interchange with other programs (Personal Computing, 1988).

Bigger, more feature rich and powerful spreadsheet programs have allowed the development of larger and more complex worksheet models which typically have been thrown together in a "quick and dirty" mode by their self-taught user-originators. These user-developers oftentimes may pass their worksheets along to others. These hand-me-down worksheets, while *usually* understandable to their originators, often are confusing and misleading to others who try to use them, leading to data errors (Ditlea, 1987) and inappropriate conclusions. A solution to this problem is to carefully design and plan the initial worksheet so that it can be effectively used by others. (Duffy, 1987; Nguyen & Little, 1987; Sawicki, 1985)

MICROCOMPUTER SPREADSHEET TEMPLATES

Situations Where Templates Can Be Used

Templates are worksheets designed to be used over time with different data, perhaps by different users. Template users can include: (1) their developers, (2) clerks not familiar with the operating structure of the worksheet model, (3) professional students seeking to learn the model, and (4) other professionals seeking to modify or use the model for their own purposes without having to enter all the spreadsheet formulas, labels, and commands. Templates can be used by clerks to routinely enter data into and run models to update previous analysis. Templates can also be used to help disseminate and teach the organization, structure and operating principles of a model to students and professionals. Another situation where templates can be useful is to present a general model to others in such a way that they can readily customize it for their own uses.

This paper emphasizes developing templates for use by novice professional students who may sometimes only want to run the template models as "black-boxes" to obtain results, yet in other circumstances may seek to understand the inter-relationships among the model's structural components. Sometimes the needs of our target group coincide with those of other professionals wishing to understand the model and customize it for their own needs, while other times our target group's needs coincide with those of the clerk-technicians. These different template user roles may lead to differences in optimal template design.

Hierarchy of Design Concepts

The design of spreadsheet model templates should start with a plan (Schatt, 1989). Goals for the template should be based on a complete definition of the problem to be solved and the results expected to solve it (Alberte-Hallam, Hallam & Hallam, 1985). Three levels of design concepts will be considered, starting with general principles of well-designed systems and general design criteria for spreadsheet template systems, before going to specific design guidelines for various sections of the templates.

General Principles and Spreadsheet Template Design Criteria

The general principals of a well-designed system are that it should be: (1) easy to understand; (2) easy to learn; (3) easy to use; and (4) productive (Nguyen & Little, 1987, p. 12).

Many of the persons using spreadsheets for urban planning are not trained computer programmers or systems experts and are not likely to be knowledgeable regarding design criteria for computer programs. Therefore Table 1, "Design Criteria for Spreadsheet Template Systems," based on the work of Tim Nguyen and Joseph Little (Nguyen & Little, 1987), is presented below.

If when creating a worksheet the template developer bears in mind the recommended general principles of well-designed systems, along with the design criteria presented in Table 1, the result should be a more effective tool than many of the quick and dirty worksheets passed on by careless self-taught developers.

Table 1
DESIGN CRITERIA FOR SPREADSHEET TEMPLATE SYSTEMS

1. Prepare the User
2. Guide the User
3. Present Informative Screen Displays
4. Employ Consistent Operations
5. Use English For Worksheet Commands
6. Anticipate the User's Needs
7. Provide Positive Feedback and Immediate Results
8. Minimize Actions Required of the User
9. Deliver Speedy Execution

Source: Based on (Nguyen & Little, 1987, pp. 15-21)

(1) Prepare the User: Preparing the user before they begin using the template can be accomplished by providing documentation which indicates what the system is supposed to do, what input is required, what effort is expected of the user, and what results can be expected. (Nguyen & Little, 1987, p. 15) Documentation reviewed in Table 3 below helps satisfy this criteria.

(2) Guide the User: "Guidance in operating the system must be available and apparent. A new user must be shown what they should be doing, and what they must know in order to proceed.... The way one proceeds from start to finish should be clear to the first-time user." (*Ibid.* p. 18.)

(3) Present Informative Screen Displays: Screen layouts should be understandable. Screen displays should contain clues regarding the next action. (*Ibid.*, p. 19).

(4) Employ Consistent Operations: System operation should consistently reinforce the preparation. An easy-to-understand system must be predictable. (*Ibid.*, p. 16)

(5) Use English For Worksheet Commands: The various commands or menu choices in the template should be English-like in form. Novice users should not have to know the command language syntax of the spreadsheet program. (*Ibid.* p. 17)

(6) Anticipate the User's Needs: "The system should anticipate the user's needs, and ... advise them accordingly." (*Ibid.*, p. 18).

(7) Provide Positive Feedback and Immediate Results: "The user's tasks should proceed in steps. Each step should result in intermediate results that are visible to the user....If positive reinforcement of his behavior is immediate, the user's comfort level will increase as proper system operation is being confirmed throughout the process." (*Ibid.*).

(8) Minimize Actions Required of the User: "Commonly used functions should be easier to access than rarely used ones." (*Ibid.*, p. 19).

(9) Deliver Speedy Execution: The program must seem to be fast if the user is to perceive it to be productive. (*Ibid.*, p. 20).

Summary: "The needs of the user are paramount. Speed and economy are desirable, but consistent operation, positive feedback, and logical flow of control are crucial to ensuring that the application is actually used." (*Ibid.* , p. 21.)

PHYSICAL PARTS OF WELL-DESIGNED SPREADSHEET TEMPLATES AND THEIR USAGE

This section consists of guidelines assembled from personal experience and a variety of cited sources. One of the most important specific design criteria for spreadsheet templates is to organize the worksheet by function - separating it into functional areas (Miller, 1989, p. 50; Duffy, 1987, p. 274). Table 2 presents the functions of the various sections into which spreadsheet templates should be divided. Specific design guidelines are given below for each worksheet section.

Table 2
FUNCTIONAL SECTIONS OF WELL-DESIGNED TEMPLATES

1. Documentation
2. Data Entry
3. Data Processing
4. Information Output
5. Macros & Menu Control

Internal Documentation Section Guidelines

The more complete and better organized the documentation is within the worksheet template, the more likely it will be that the template can be successfully used by others without having to bother the developer (Bianchine, 1989). Internal documentation within worksheets is generally favored over external documentation which may become separated from the template. Table 3 presents guidelines for worksheet internal documentation.

Table 3
INTERNAL DOCUMENTATION SECTION GUIDELINES

1. Documentation should be provided both in a separate section and throughout the worksheet
2. Undertake documentation as an ongoing task, NOT as one of the last things done when developing a worksheet!
   (Duffy, 1987, p. 26)

Documentation should:

3. Identify the purpose of the template
4. Provide identification of
   A. Name of file & latest revision date
      (Grauer & Sugrue, 1989, p. 270)
   B. Name of author & person responsible for file maintenance
   C. Phone number & location of place for assistance

*** Note: 3 & 4 could be in a help screen which automatically appears after the template is loaded. (Duffy, 1987, p. 275)

5. Indicate the cell locations of functional areas
   A. Provide a directory list of range names and cell locations of worksheet components:
      1. Locate major sectors listed in Table 2
      2. Input data range locations
   B. Provide a schematic map of worksheet functional areas
      (Brail, 1987, p. 125, 132)
   C. Frame data columns with distinguishing symbols
      (Bossard, 1987b)
      1. Input data: !!!!!!
      2. Output data -------
      3. Model parameters ++++++++
      4. Consistency checks ??????
      5. Directions or descriptions ~~~~~~~
6. Place operating instructions within the template
   (Schatt, 1989, p. 187)
7. Place explanatory text within the template
8. Document formulas
   A. Display explanations of all formulas, usually directly adjoining then in plain English
   B. Provide access to text format listings of all formulas

Data Entry Section Guidelines

Table 4
DATA ENTRY SECTION GUIDELINES

1. Provide for data entry in a distinct area (Schatt, 1989)
2. Make your data input resemble existing forms (*Ibid.*; Duffy, 1987, p. 274)
3. Enter data in either columns or rows, but not both (*Ibid.*)
4. Use the cell protection feature to control access to areas where data should not be entered. (*Ibid.* and Miller, 1989, p. 53)
5. Use manual recalculation when entering data in large worksheets.
6. Incorporate internal checks of data input (Miller, 1989 & Weisskopf, 1988, p. 99 & 250)
   - A. Incorporate limit checking of data entries
     1. Test cell entries for upper & lower limits
     2. Format column width to not allow more digits than expected
   - B. Locate inconsistent input data by displaying a graph of the input data range
   - C. Use macros for efficient data entry
     1. Use string function to insure that input has the expected number of places
     2. Use @IF function to check for correct data input form
     3. Macro prompts can display a table of standard codes to prompt uniformity of database entries.

Data Processing Section Guidelines

Unrecognized errors in worksheets may lead to potentially dire results for users (Sawicki, 1985; Ditlea, 1987; and Berry, 1989). While the guidelines outlined in Table 5 present a few suggestions for organizing the data processing section of a worksheet template so that it is less likely to contain errors, there can be no substitute for careful construction and documentation (Ditlea, 1987).

Table 5
DATA PROCESSING SECTION GUIDELINES

1. Set aside a separate section for data processing
2. Use step cells as intermediate steps in formula development (Weisskopf, 1988, p. 85)
3. Use range names for important cells
4. Always carefully test your worksheet before using or distributing it (Miller, 1989; Sawicki, 1985)
   - A. First hand-check all formulas with simple predictable data
   - B. Then test the calculation procedures with actual data
   - C. Finally test the calculation procedures with extreme data

Table 5 cont.

5. Incorporate internal checks (Sawicki, 1985; Grauer & Sugrue, 1989; Miller, 1989)
    A. Triangulation techniques, redundancy, & cross-checks
    B. Use @IF statements to print warning messages if internal checks are not satisfied.
6. See that the user saves the template under a name different than the original name (Duffy, 1987, p. 277)

Information Output Section Design Guidelines

Organizing processing section results into output tables and graphs facilitates the goal of many worksheets of turning raw input data into information that is useful for making decisions. Table 6 presents guidelines for achieving that end.

Table 6
INFORMATION OUTPUT SECTION DESIGN GUIDELINES

1. Set aside a separate area for outputs (Duffy, 1987)
2. Do not stack output reports above one another
3. Provide a variety of output reports
    A. Clearly label rows and columns
    B. Freeze the date and time of data calculation within the output report
    C. Use macros to program graphic output
    D. Make report options selectable from menus
    E. Use add-in programs like *Allways* and *Impress*, or graphics based spreadsheets like *Excel* for refined output formats
4. Use range names for output ranges
5. Use macros for print routines (Weisskopf, 1988, p.306)

Macro and Menu Control Section Design Guidelines

While simple templates may be developed without menus, menus can be of such great help in frequently used templates that one *Lotus 1-2-3* expert has declared: "Always use menus." (Weisskopf, 1988, p. 15) Menus can be created within worksheets by use of computer programming codes placed in spreadsheet features called macros. Use of advanced macro features in spreadsheet programs is a type of computer programming, with the macro language syntax being a programming code. Macros allow the development of customized features within worksheets. However spreadsheet macro languages may take considerable time to learn. It may take a day studying specialized sources to develop a variety of menus, although a few hours effort should enable a spreadsheet user to be able to create simple view menus which allow a user to go to various sections of the worksheet for viewing. (Ewing, 1986; Nguyen & Little, 1987; Bianchine, 1989; and Weisskopf, 1988)

The range of spreadsheet functionality has grown during the past decade from initially being chiefly an easy to use alternative to programming for entry level users, to now giving users the option to develop customized programs with refined features through programming.

The design guidelines presented in Table 7 are not uniformly applicable for all types of worksheet users. Worksheet templates designed for use by novice clerks or professionals simply seeking "black-box" output should strictly follow guidelines 1, 2, and 3, always using macro driven menus which never release control of the worksheet to users. These users never need see the macro code, or even need be aware of its existence. However templates designed to also teach the user about their structure and operation should contain options to allow the user to view the section where well documented macro programming code is located and perhaps include suggestions or options for modifying that code to accomplish objectives which might differ from those envisioned by the original template designer. With the wide variety of circumstances under which worksheet templates could be used for urban and regional analysis, planning and management, there should be a broad scope of possibilities for utilization of customizable worksheet templates by spreadsheet sophisticated users. Therefore the novice professional worksheet template user should be encouraged to explore the modifications possible of existing templates while developing the capability to formulate worksheet templates themselves.

The advantages and disadvantages of macro-driven templates listed in Table 7 boil down to favoring macro-driven templates for worksheets that will be frequently used, on moderately powerful machines, using spreadsheets with capabilities comparable to *Lotus 1-2-3*, and with a template developer available who is willing to invest many hours in learning spreadsheet macro commands and operating techniques. The more persons to use the template, the more complicated the model being developed, the more likely that a macro-driven template will be worth developing.

Table 7
MACRO & MENU CONTROL SECTION DESIGN GUIDELINES

1. Isolate macros in a section where novice users are not likely to mess them up
2. Always use menus (Weisskopf, 1988, p. 15)
   - A. Offer choices with menus
   - B. Add documentation to your worksheet with menus
   - C. Include a view menu to allow users to go to various areas of the worksheet for viewing
3. Never release control of a worksheet to a novice clerical user! (Bianchine, 1989)
4. Advantages Achievable With Macro-Driven Templates (Bianchine, 1988)
   - A. Training can be facilitated
   - B. Productivity of personnel can be increased

Table 7 cont.

C. Integrity of data and macro code can be maintained

D. Less support may be required of template developer

5. Problems To Be Aware of With Macro-Driven Templates

A. Performance may be slowed

B. More planning and programming is required

C. More maintenance is required

EXAMPLES OF WORKSHEET TEMPLATE DESIGNS

The widespread use of spreadsheets in urban planning offices (French & Wiggins, 1989) is not fully reflected in the range and variety of worksheet templates available to the professional and academic communities in the USA. For example the admittedly nonexhaustive reading list for my graduate course in "Computers in Planning" (Bossard, 1989) has references to only seven spreadsheet template authors (Bossard, 1983, 1984, 1987a, 1987b; Brail, 1987; Landis, 1985; Levine, 1985; Sawicki, 1985; and Sipe & Hopkins, 1987).

Currently my quantitative methods modelling course at SJSU uses four Lotus 1-2-3 spreadsheet templates. They include: (1) six extrapolation techniques used by Klosterman in his forthcoming CAPP text; (2) a cohort-component population projection model which I have developed; (3) a retail trade distribution gravity model derived from an example by Krueckeberg & Silvers (Krueckeberg & Silvers, 1974); and (4) a location quotient model derived from one by Sipe & Hopkins (Sipe & Hopkins, 1987) but which is amenable to the adjustments discussed by Klosterman in his forthcoming CAPP text.

All my templates use menus, extensive documentation, and are divided into separate functional sections for inputs, processing, outputs, documentation, and macro code. Some of my templates include menu selectable macros to print or display output graphs or tables.

For the full potential of microcomputer urban and regional models to be realized, some urban analysts should be trained in the art and science of creating well-designed spreadsheet templates which will provide a supportive, effective environment for undertaking problem analysis and decision making.

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USING A MICROCOMPUTER TO EXPLORE RELATIONSHIPS IN INFORMATION UTILISING GRAPHICAL AND SPREADSHEET TECHNIQUES

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1. ABSTRACT

There has always been a temptation to develop elaborate computer packages to help in solving problems when in fact it may be possible to adapt a package which has been provided for another purpose. This paper explores some of these alternative approaches particularly through the use of spreadsheets. The advantages of using a spreadsheet approach as opposed to a dedicated program are discussed. The disadvantages of using a spreadsheet approach are then investigated and methods for overcoming them are suggested. The paper continues with some examples of more unusual graphical applications of spreadsheets within the planning environment. The paper finishes by exploring the needs for dedicated packages and suggests how such packages might be developed to make them more accessible.

2. INTRODUCTION

Personal computers have now become an everyday office tool and this has resulted in a wide range of general purpose software packages which are simple and straightforward to use being developed for application on them. This paper argues that the analysis of information using computers should be attempted in a way which is simple, straightforward and understandable and that wherever possible standard applications packages should be used. If this approach is accepted it should mean that a much wider range of professional and research staff will be able to benefit more directly from the application of information technology within urban planning and management. The paper will concentrate particularly on how spreadsheets can be used to analyse information used in urban planning.

3. WHAT A SPREADSHEET IS AND HOW IT CAN BE USEFUL

Although it is likely that in the context of this paper most conference delegates will understand what a spreadsheet is, and what it can do, it is worth reiterating a number of the principles involved in spreadsheeting in order to give an appreciation of the authors views on the use of spreadsheets. A useful introduction to spreadsheets is given by Meier (1988a & 1988b).

Spreadsheet programs were originally designed to allow people to use computers for financial planning. At their simplest they hold information in a two dimensional array part of which can be displayed on the visual display screen of a computer. The screen, in effect, becomes a window, typically covering 8 columns by 20 rows, onto the information spread across a very large sheet of "paper", typically over 200 columns wide and more than 8000 rows long. Each cell (at the intersection of a row and a column) of the spreadsheet can hold three types of information text, numbers (including dates) and formulas (calculations). The text, typically, gives an explanation for the numerical information on the spreadsheet and thus is of paramount importance since it is this text which gives a spreadsheet meaning. Many spreadsheets can handle text in an analogous way to word processor programs thus increasing their usability and understandability. The formulas usually reference, as their variables, other cells in the spreadsheet containing other formulas or numbers. Formulas not only cover the algebraic rules of arithmetic but are also provided to allow column or row totals, averages and many other common functions to be calculated. Such a tool has a much wider applicability than just straight financial planning. The spreadsheet has been recognised as one of the most powerful tools to have been developed for microcomputers. Mainframe versions of popular microcomputer packages are now, belatedly, being provided. It is now possible that much of the mathematical programming previously attempted using dedicated programs might be more efficiently done using a spreadsheet tailored to the application. The best known of the spreadsheet programs available is Lotus 1-2-3(1) and this will be the package used in the examples discussed here.

There are many problems in urban planning and management which can be tackled through using a spreadsheet (Brail, 1987, Harrison & Parker,1986, Landis, 1985, Ottensmann,1984) and the applications need not be confined to just the simple areas. Examples are given later in this paper (see page 6). It is clear that there has been a different approach to the application of spreadsheets to urban planning issues between the U.K. and the U.S.A. In the U.K. there has been a much greater use made of dedicated programs than spreadsheets in both planning practice (Bardon, 1988) and planning education (Banister, 1985a) whereas in the U.S. there has been a greater trend towards the use of spreadsheets in practice (Klosterman & Landis, 1988) and education (Banister, 1985b). In the U.K., for example, local authority planning departments are three times more likely to have a database packages and four times more likely to have a word processor than a spreadsheet (Bardon, 1988) and nearly all the classic numerical applications are covered by specialist, often in-house developed, dedicated application programs. Part of the reason for this has been the relative speed with which microcomputers have been introduced and the tradition that many mainframe applications had to be developed rather than being obtained "off the shelf".

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(1) Lotus and 1-2-3 are registered trade marks of Lotus Development Corporation, 55 Cambridge Parkway, Cambridge, MA 02142, U.S.A.

4. THE ADVANTAGES OF USING A SPREADSHEET APPROACH RATHER THAN DEDICATED PROGRAMS

There are a number of advantages associated with using spreadsheets rather than relying on dedicated packages. These will be dealt with in this section together with some discussion of the implications. Some of the points raised here have been derived from Klosterman & Landis (1988) and Brown & Gould (1987).

i) A spreadsheet is user friendly. This means that many who are not fully computerate can take advantage of computers to help them in analysing data with a minimum of training. Spreadsheets in some ways widen the franchise of computer use and take some of the mystique away from computer specialists who, at one time, were the only people allowed to use the machines. The democratising role that these more accessible less specialist packages have should not be minimised and we should play special attention to it at a conference like this consisting mainly of specialists (Bjerknes, Ehn, & Kyng, 1987). It is surely important to widen the franchise of computer use.

ii) The spreadsheet approach must assume that the user knows how to use and manipulate a spreadsheet. Although spreadsheets are relatively intuitive it takes a considerable period of time to become familiar with all their facilities. We can argue that all planners should be introduced to and encouraged to use spreadsheets in much the same way as a knowledge of word processing is now becoming essential. Dedicated package, on the other hand, only requires a knowledge of the technique to make use of the package, if, and only if, it has been derived with an intuitive user interface. Many dedicated packages have a very complex user interface and thus may be more difficult to use than a spreadsheet. Thus learning to use a spreadsheet can open up more doorways. This point is again related to the democracy issue raised earlier (see section 4.i).

iii) Spreadsheets are easy to learn and relatively intuitive. The interface developed by Lotus for their products, for example, has gained widespread acceptance and appears to be simple and straightforward to use for the more computer naïve. It has not been derived through the processes that psychologists use for dealing with the human-machine interface (Kitajima, 1989) but rather through a process of trial and error. The placing of values into the cells of a spreadsheet using the cursor keys is an intuitive process that can easily be understood.

iv) Spreadsheets allow users to make mistakes without catastrophic consequences arising. Some dedicated programs, for example, can be crashed relatively easily and this can lead to the need to re-input much of the data. Others require the user to return to earlier stages in the process and repeat themselves.

v) Spreadsheets are immediately useful with only a limited knowledge of computer fundamentals. Again this brings into play the issue of distributing computer use away from specialists to the end-user. For example in the U.K. it is common for population forecasting to be the responsibility of county or strategic level planners. Generally planners at local level have to rely on forecasts made using the county's mainframe. With a spreadsheet, and clearly a knowledge of appropriate forecasting techniques, such forecasts can be conducted at a more local level. For example, the author was recently involved with providing population forecasts for Wyre Borough, Lancashire in order to refute the figures that had been derived by Lancashire County Council (L.C.C., 1987). Lancashire's figures had been developed using a dedicated, rather inflexible, mainframe program. The author used Lotus 1-2-3 and derived more flexible population forecasts which were eventually accepted as more reliable by the inquiry inspector (Banister, 1988).

vi) Spreadsheets are user extendable. The example cited above gives an indication of this. Spreadsheets can be adapted to calculate further results. For example headship rates could be added to a population forecast model to allow an exploration of household formation.

vii) Spreadsheets make "what if" type questions easier to pose and easier to answer. Their flexibility means that a much wider range of possibilities can be explored than would be possible with a dedicated program. Rapid changes can be made to any assumptions built into a model in order to explore the consequences these changes will have upon the results. The changes can usually be observed on screen since a spreadsheet program recalculates changed values (almost) instantaneously.

viii) To use a spreadsheet requires a copyright licence for the spreadsheet. Dedicated programs are often created "in-house" and can thus be distributed freely within an organisation. If spreadsheets are seen, like word processors, as a basic tool then they should be made available on all machines in an organisation thus overcoming this possible problem.

ix) Spreadsheets allow easy links to be made to other packages. For example a summary table can be created and then inserted into a word processed report with minimum needs to tidy it up.

x) The graphics options within a spreadsheet do not allow for particularly sophisticated presentations. Bar graphs, line graphs and pie charts are usually provided. In may situations these are adequate. Later in this paper (see page 6) this problem is dealt with in more detail. Spreadsheets, particularly if they are linked to presentation packages, can produce some interesting graphical presentations including simple maps.

xi) Spreadsheets can be linked together to allow for the transfer of related information between them. Many planning tasks require information to be linked together.

xii) There are links available between commonly used spreadsheets and other packages. For example Lotus 1-2-3 worksheets can be read and created by SPSS/PC+.

xiii) The information contained within a spreadsheet can be analysed in simple database fashion. Simple sorts and select mechanism are provided in all but the least sophisticated spreadsheets. For example such an option may give an opportunity to explore where the greatest pressures for schools might arise if data on children of school age were sorted into ascending order.

5. THE DISADVANTAGES OF USING A SPREADSHEET APPROACH BOTH APPARENT AND CITED

i) The most important failing of spreadsheets and the way that they are sometimes used is that it is quite easy to allow errors to creep in and cause, unknowingly, some falsification to the output. A minority of these errors are created by mistyping which is a problem which can arise with any computer program. Perhaps the most dangerous form of error in a spreadsheet are mis-specification of formulas (Brown & Gould, 1987). Brown & Gould suggest that one of the causes of this is that formulas are not apparent on a spreadsheet since only the resulting value of the formula is displayed. They also suggest that there is

> "anecdotal evidence that electronic spreadsheets are highly susceptible to user-generated errors".

Their paper explored 27 spreadsheets devised by experienced users and found an average of 0.7 errors per spreadsheet with over 70% of these errors being created by incorrect formulas. Since spreadsheets are easy to use they allow users to attempt solutions "on the fly" without adequate testing to see if the spreadsheet is functioning properly. A dedicated program is likely to have gone through a rigorous testing schedule to minimise the risk from errors. Clearly any spreadsheet need to be put through such a test programme.

It is possible to devise what are called spreadsheet templates which are spreadsheet programs that have been developed to solve a particular problem and which can then be used by users other than the originator. It is of paramount importance that these templates have been rigorously tested and evaluated. Spreadsheet macros, user defined functions, which automate sequences of spreadsheet commands and keystrokes need to be put through a similar thorough testing programme to try and remove errors. It should also be clear that any templates and macros that are devised and tested should be thoroughly documented.

ii) Klosterman & Landis (1988) suggest a further problem with spreadsheets.

> "The lack of application software designed for planning purposes has forced local planners to use electronic spreadsheets continually to "reinvent the software wheel" some of these approaches have been computationally incorrect".

The error problem has been dealt with in the previous section. The other implication of this comment is that dedicated packages are better and avoid the problem of "reinventing the software wheel". In the U.K. the evidence of Bardon (1988) suggests that a number of authorities have been doing just this with dedicated packages. This clearly should not be seen then as a criticism unique to spreadsheets.

Other authors have suggested that a lack of dedicated packages in planning have led to spreadsheets being developed and used. For example Gar-On Yeh (1988) suggests

> "the use of microcomputers in planning was much hindered by the lack of specialized software. This situation has improved recently." and "The use of commercial packages designed for general purposes has been a dominant trend in the use of microcomputers in planning."

The author contends that there is nothing wrong with the approach that attempts as far as it is possible to do so to use general purpose packages, and in particular spreadsheets. Such an approach (see section 4.i) makes information technology available to a wider cross section of people.

Batty (1987) suggests in a diagram dealing with "software types concatenated with user-role" that spreadsheets are for end-users rather than analysts. The arguments that have been advanced in this paper would suggests that tools like spreadsheets should be used by all computer users from the end-user to the analyst. Many of the tasks he suggest require programming in a high level langauge can in fact be performed by non computerate people with the aid of a spreadsheet. This clearly should have a number of implications for training.

6. EXPLORING RELATIONSHIPS IN INFORMATION USING SPREADSHEET GRAPHICAL TECHNIQUES

It has been stated earlier that spreadsheets can be applied to a large number of situations related to urban planning and management (see page 2). This section will deal with a number of of examples and in particular will concentrate on the scope for spreadsheets to present analyses in a graphical form.

One of the examples cited earlier (see page 4) concerned population forecasting. Since a spreadsheet can only present output in a limited range of graphical form the graphical output from Lotus 1-2-3 is likely to look like Figure 1. Although all the information is presented in Figure 1 it is not the kind of output which would traditionally be accepted for displaying population age and sex information, normally such information would be presented as a population pyramid.

A dedicated program for population forecasting could have a graphical output which did present the information in an appropriate form and would thus have an advantage over a simple spreadsheet in terms of producing results for a report. There are ways to overcome this problem by using other standard "off the shelf" business packages which are dedicated to presenting

Figure 1

high quality graphical outputs. Figure 2 shows just such an output. Figure 2 was developed using Lotus Freelance Plus[2] linked to the spreadsheet which created the output shown in Figure 1. This process of linking the spreadsheet to the presentation package and changing the form of output took about 5 minutes. Freelance Plus has the standard Lotus user interface and thus is relatively intuitive to learn.

A further advantage of this kind of approach is that this output can be pasted into a word processing package. This paper, in fact, demonstrates this process. The word processing package, in this particular case, is WordPerfect[3] and the graphics were transferred by using Computer Graphics Metafiles[4] .Few dedicated graphics packages have such links.

Any data which can be presented through the graphical techniques that a typical presentation packages has can be linked

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(3) WordPerfect is a registered trade mark of WordPerfect Corporation, 1555 North Technology Way, Orem, Utah 84057, U.S.A.

(4) Metafile is a registered trade mark of Donald H. McNeil

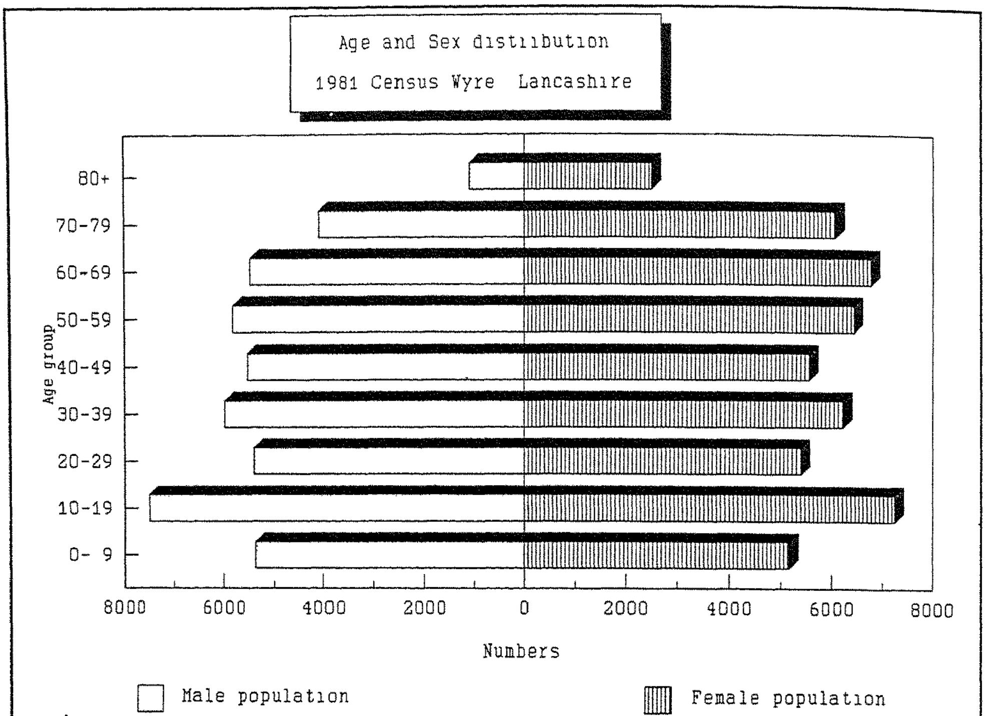

Figure 2

to that presentation package through a spreadsheet. Freelance Plus can be used to present in a straightforward fashion bar, line, pie, XY scatter, area or pictograms or a mixture of all these types. A further advantage is that not only can the output be integrated with text but it can also be presented for a variety of output device, for example 35mm slide film and it is even possible to present slide shows on a computer's graphics screen.

In urban planning and management much of the information we deal with can best be presented in the form of maps. In fact some techniques such as sieve mapping rely on a mapped output. A sieve map can be presented in a spreadsheet. If the zones are presented in a rectangular grid, like satellite images, with two columns for each coordinate pair and then a column for the boundary of the area of search. The rest of the matrix should contain values for each of the variables for each grid square in the area and a final formula to decide if a grid square fits the search criterion. These data can be presented using the symbols and not the lines of an XY graph. Figure 3 shows such an output, as enhanced through Freelance Plus.

The data shown in Figure 3 could be linked to the spreadsheet from a remote sensing system collecting satellite data. While the output is relatively crude it gives an indication of how geographical information can be linked to produce a spreadsheet output.

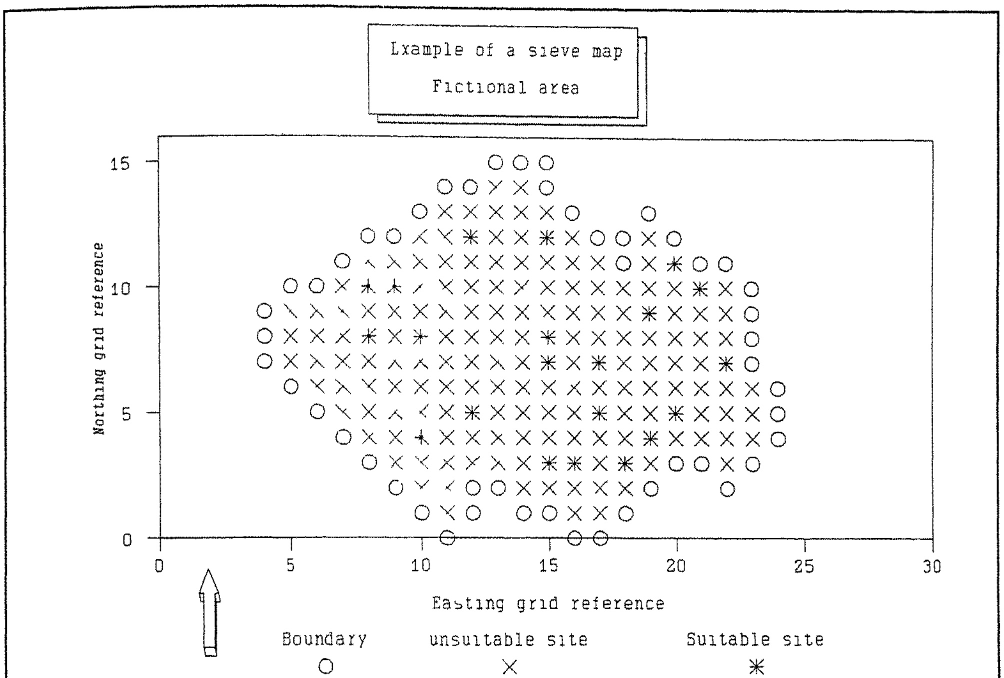

Figure 3

The final example of using a spreadsheet to present mapped data gives an indication of how point information might be presented. Again this is a simplified example which just shows the three nations comprising Great Britain. The spreadsheet contains the grid coordinates for all districts in Great Britain together with a set of rules about which categories the districts fall into. These set of rules could be relatively complex and might for example have used Census data. To be ultimately more useful many fewer than the 462 districts of Great Britain should have been plotted. They have been plotted here to illustrate the point. Lotus 1-2-3 will allow a maximum of six categories to be displayed. Figure 4 shows this graphical output enhanced through Freelance Plus.

7. THE NEED FOR DEDICATED PACKAGES

The foregoing may suggest that the author does not see a role for dedicated packages within planning. This is far from the truth. There are many areas where only a dedicated package can be used. In particular areas involving complex graphics, for example choropleth mapping, or more complex graphics based databases such as geographic information systems. What is being suggested is that much of the initial analysis and perhaps much of the analysis needed by practising planners can be accomplished by using spreadsheets linked to presentation packages and word processors.

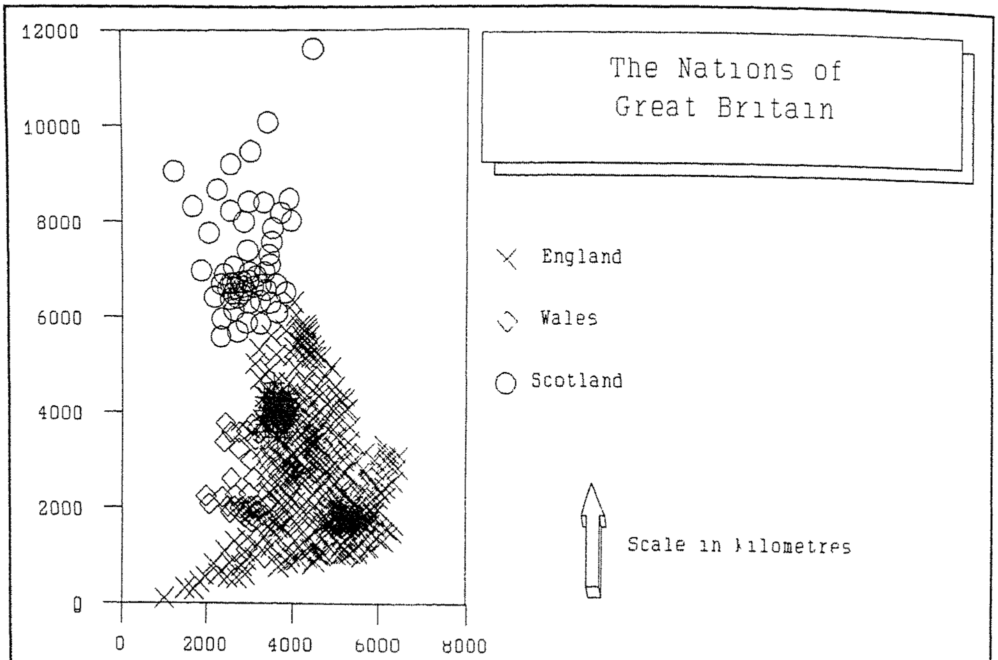

Figure 4

What is required of these dedicated packages is that they be designed as far as it is possible to do so in such a way that they are intuitive in their use in much the same way as a spreadsheet can be intuitive in use. This is because those of us who are computerate should see an important role in spreading the use of information technology much wider than the current circle of people. The only way to do this is to make packages more accessible. Clearly this means that the user interface must be thought out and designed very carefully with, for example, help and tutorial facilities built in.

The other important aspect of dedicated packages is that they must provide links to the general purpose applications like spreadsheets. For example with such links datasets could be prepared for input to a mapping package using a spreadsheet. Or Census data, after selection, could then be fed directly into a spreadsheet for a fuller analysis using "what-if" techniques. Some links do already exist between spreadsheets and dedicated packages but they tend to be difficult to use and therefore at present they are only used by the computerate.

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APPLICATIONS OF MICRÓ COMPUTER BASED SPATIAL ANALYSIS FOR URBAN AND REGIONAL PLANNING

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ABSTRACT

Until recently the usefulness of micro computers in analyzing the large data sets now used by urban and regional planners has been limited. Recent advances in software now make it possible for the characteristically large data bases required by urban and regional planners to be accessed and analyzed on micro computers. Two large data bases are used to illustrate two different approaches; one adopted in Canada's National capital region, and the other for the Maryland National Capital Park and Planning Commission, U.S.A.

In the first example interviews produced a data base of 60,000 urban trips which were analyzed to show travel movements in the region. A trend surface analysis technique (potential mapping) was used to augment the more usual origin - destination analysis.

In the second example over 250,000 property records were accessed to produce maps of socio-economic characteristics for a very large suburban region.

Both examples were completed using standard micro-computers. The spatial analysis software employed is able to handle these large data bases by using a data structure known as quadtrees.

The paper describes the analysis techniques, data structures and planning applications of the two examples, with a summary of the essential preconditions for use elsewhere.

MONITORING LAND USE IN THE METROPOLITAN REGION WITH REMOTE SENSING DATA

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ABSTRACT

Land-use information is important for rational planning. In this paper, the use of computers and digital remote sensing methods for obtaining land-use information are considered. Results of several land-conversion studies in the Toronto region are presented, as well as potential future strategies for improving the accuracies.

INTRODUCTION

Large metropolitan regions throughout the world are experiencing many problems associated with rural-to-urban land conversion. These problems include inefficient land-use allocation and environmental degradation. The variety, intensity and complexity of these problems are a function of the metropolitan regions' size and rate of growth. A fragmented jurisdictional system exacerbates the challenge of formulating and implementing either a general land policy or specific planning and management measures. Of critical concern is the dearth of current, comprehensive and integrated land-use information.

Land-use information is an essential prerequisite for physical planning in local municipalities. For that reason, local planning agencies attempt to maintain a current land-use data base designed to serve local needs. Land-use data bases often fall far short of municipal requirements. Frequent deficiencies include outdated information, inappropriate classification systems, incomplete geographic coverage and low data reliability due to disparate data sources and collection methods. In the metropolitan region it is necessary, not only to collect and collate land-use data sets obtained from constituent municipalities, but also to collect regional land-use data not otherwise obtained at the local level. Thus, data consistency, compatibility and accuracy become even more problematic.

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The advent of airborne and resource satellite digital imagery and computer-based image-processing capabilities provides an opportunity for augmenting or replacing conventional methods of land-use information collection for metropolitan regions. This paper reports on a four-year program of research undertaken by the authors to evaluate remotely sensed land-use and land-cover information for monitoring rural-to-urban land conversion in the Toronto metropolitan region. We begin by presenting an overview of information needs of metropolitan planning obtainable from multispectral imagery. Then, we examine the comparative advantages of remote sensing methods versus conventional methods for collecting this information. The main section of the paper assesses land-use data obtained from three multispectral scanners and evaluates the adequacy of this information for monitoring rural-to-urban land conversion in the Toronto metropolitan region. Results of the research emphasize the trade-offs made between levels of land-use information detail, methods of analysis and accuracy. Consideration of strategies and methods for improving the results indicate several paths for future research.

LAND-USE INFORMATION NEEDS

Remote sensing methods can address specific land-use information needs of metropolitan planners. These needs are identified under three categories: 1) the rural-to-urban land conversion process, 2) direct impacts of land conversion, and 3) intra-metropolitan systems adjustments. Land conversion within the metropolitan region is spatially and temporally discontinuous. Therefore, planners must monitor it closely in order to determine short-, medium- and long-term rates of growth and change. Because the initiative for conversion lies with the private sector, public planners in market economies must monitor in order to determine compliance with regulations and agreements.

Direct impacts of land conversion, measurable by remote sensing methods, include the loss of agricultural land and woodlots, degradation of wetlands, and gross changes in environmentally sensitive areas. Intra-metropolitan systems adjustments caused by growth include the location, spatial extent and rates of aggregate construction materials extraction and site rehabilitation, solid waste disposal, and storm water runoff. These regional data sets can be employed in forecasting and modelling efforts associated with the testing of plans and scenarios. In countries where systematic data collection is a low government priority, remote sensing of metropolitan regions can assist in estimating population, traffic generation, crop and wildlife production, and land degradation.

METHODS OF COLLECTING INFORMATION

From a conceptual perspective, the collection of land-use information involves observing the real world, devising a classification scheme to generalise it, performing the classification and then displaying the results of the classification on a map base. The world may be observed directly, or indirectly through some form of measurement, such as photography.

Conventional Methods

The most common way that land use was recorded in the past was by means of a ground survey. With a map base as the medium on which the information was to be recorded, the map-maker would traverse the study site to observe and record the different land uses on the map base. The advantages are, first, that the procedure is relatively simple and cheap in that students can be employed to map an area during the period of a summer. Second, the land cover or land use is observed directly so that few errors of interpretation are likely to occur. Major disadvantages are that the survey usually takes a long time, land uses can change between the start and the end of a survey, and terrain and privacy may make direct observation difficult.

A second conventional approach to land-use mapping involves using aerial photographs as a surrogate for the real world. In the convenience of an office, the map-maker is able to interpret the aerial view of the real world and to translate it into a land-use map. The main advantages are that the data for the study area are recorded in a relatively short time, a permanent record of the landscape is preserved so that later reviewing and checking of the information can be readily done, and the time taken to produce the map should be faster than ground survey. Problems arise, however, if it is not possible to interpret the land cover observed on the photograph and relate it to a specific land use. In such cases, and also to determine the accuracy of the map, field checking is necessary. If many photographs are needed, acquisition and information extraction costs can be high. Current photography is often not available (Moore and Wellar, 1969; Rhind and Hudson, 1980).

Airborne- and Satellite-Based Land-Cover Mapping

With the launch of Landsat-1 in 1972, a new era of imaging the Earth was initiated. Resource satellites orbiting the world are now able to provide synoptic, repetitive views of the Earth's surface on a frequent basis, assuming of course that clouds are not obstructing the view. Due to the large areas of ground covered by each picture element or pixel, the early satellite images showed less detail than many anticipated. A pixel of approximately 60 m x 80 m cannot show the detail that can be observed even on a small-scale aerial photograph. However, the aerial photograph does not provide a synoptic view of a 185 km x 185 km portion of the Earth's surface.

During the 1980s, the tendency has been to launch satellites carrying sensors which have increasingly higher spatial resolutions (Table 1). In other words, the area of ground covered by each pixel on a sensor has become smaller and we are able to observe more detail. This can be highlighted if we realize that the area of ground recorded by one Landsat multispectral scanner (MSS) pixel at 60 m x 80 m would be recorded by 48 pixels on a SPOT panchromatic (P) image with its 10 m x 10 m pixel size.

Table 1. Summary of Major Characteristics of Earth Resource Satellites.

Year of First Launch	Satellite System	Imaging Sensor	Aerial Coverage (km)	Spatial Resoln. (m)	No. of Spectral Bands
1972	Landsat-1 (USA)	multispectral scanner (MSS)	185 x 185	60 x 80	4
1982	Landsat-4 (USA)	multispectral scanner (MSS)	185 x 185	60 x 80	4
		Thematic Mapper (TM)	185 x 185	30 x 30	7
1986	SPOT-1 (France)	multispectral (XS)	60 x 60	20 x 20	3
	High Resoln. Visible (HRV)	panchromatic (P)	60 x 60	10 x 10	1
1988	MOS-1 (Japan)	multispec. electronic self-scanning radiom. (MESSR)	100 x 100	50 x 50	4

Satellite sensors have been supplemented by airborne sensors. From the normal operating range of altitudes, standard aircraft are able to obtain data with pixel sizes ranging from about 20 m x 20 m down to as small as 30 cm x 30 cm. Clearly there are trade-offs. The smaller the pixel size, the more data that have to be generated to cover a given area of ground.

The point to be emphasized, however, is that there is available today a continuum of data sources for recording and displaying data describing the real world. For mapping land use, it is possible to select the most appropriate spatial resolution of a sensor or scale of an aerial photograph to meet the requirements of the detail and scale of the map on which the land use is to be recorded. In other words, it is the purpose and requirements of the map that can now be the controlling factors for any map. There is no need to compromise information needs to fit the available technology.

Satellite and airborne imagery are recorded in digital mode. In other words, for each pixel a digital number (DN) represents the amount of energy that has been recorded for that pixel. There are two major choices that can be made. First, the image can be processed to give a pictorial representation of the Earth's surface. This "hard-copy" image can be treated like an aerial photograph and the land-use information can be interpreted directly from the image. The second approach involves computer processing. The DNs are entered into a computer and software permits an image to be displayed on a colour monitor. By means of digital classification algorithms, maps of land cover and sometimes land use can be generated. The process is a complex one and development work is still going on to improve the procedures used and the classification accuracies that can be achieved.

MONITORING LAND CONVERSION IN THE TORONTO REGION

Rural-to-urban land conversion is the process whereby a city expands into the countryside. As pointed out by Martin (1984), it can be described as a set of linked land-transaction and land-use decisions made by primary decision agents (farmers, speculators, developers, builders and home buyers) facilitated or regulated by secondary decision agents (engineers, planners, financiers, lawyers and real estate agents). Land use and land-use change, the most tangible evidence of conversion, can be detected by airborne and satellite imagery and is the type of information examined in this research program.

The Study Area

The study area, bordered by Lake Ontario to the south and the City of Toronto to the west, has served as the location for the six studies summarized in this paper. Because of its substantial stock of relatively flat, undeveloped land and its proximity to Toronto, the area has sustained continuous, intense urban development pressure. Conversion has occurred rapidly and, for the most part, in large homogeneous tracts. It has been very difficult for municipal planners to monitor the progress of conversion at land-development sites. These characteristics have made the area very useful as a test bed for a variety of remote sensing methodologies applied to change detection for urban-planning purposes (Martin, 1989).

Image Processing

To determine the capabilities of spaceborne and airborne digital data for mapping and monitoring changes at the rural-urban fringe, a series of studies has been undertaken during the past four years using data from a variety of sources. Different approaches have also been used in the analysis of the data.

Landsat MSS data from 1974, 1978 and 1981 were used to detect land-use change in the study area employing separate images comparison and multidate composite image methods (Martin, 1986; 1989). Images were modified, either by supervised classification or by principal components analysis. Average overall change-detection accuracy of 84% was obtained for a 15-category classification and 91% accuracy for a simple conversion and no-conversion classification employing separate image comparison modified by supervised classification. Spatial variations in accuracy levels were attributed to differences in land-use complexity across the study area and change-detection methods.

As spatial resolution of the imagery increases, higher land-cover and land-use classification accuracies do not necessarily follow (Toll, 1985b; Haack et al., 1987; Khorram et al., 1987). This is because with higher spatial resolution there is increased spectral heterogeneity of the pixels representing a specific land use. For example, at relatively low resolutions (60 m x 80 m), the pixels of a residential area integrate all the different land covers that occur such as lawns, trees, roofs and paved surfaces. At higher spatial resolutions, many of the land covers are uniquely recorded on individual pixels, which results in the spectral heterogeneity. In other words, a "lawn" pixel may be adjacent to a "paved surface" pixel followed by a "tree" pixel, all with very different spectral characteristics.

To investigate the effects of spatial resolution on land-cover and land-use identification, Johnson (1986) and Johnson and Howarth (1987) studied imagery acquired by the Multi-Detector Electro-Optical Imaging Scanner (MEIS II), an airborne imaging system developed under the auspices of CCRS (McColl et al., 1983; Till et al., 1983). Data acquired with a 2.5 m x 2.5 m pixel and spectral bands simulating those of the SPOT satellite were subsequently resampled to spatial resolutions of 10 m x 10 m, 20 m x 20 m and 50 m x 50 m. Using an unsupervised maximum-likelihood classifier to maintain objectivity, the four different spatial resolution images were classified into a series of land covers consisting of surfaces such as bare fields, paved surfaces, compacted surfaces (construction sites), vegetation, water and residential roof. The results showed that overall static classification accuracies are 89.2%, 83.3%, 93.8% and 85.7% for the 2.5 m, the 10 m, the 20 m and the 50 m data sets, respectively. In areas where the land cover of the pixels changes frequently (e.g., residential, industrial/commercial) accuracies of classification generally improve with the higher spatial resolution data. For more homogeneous areas, such as agricultural fields, increasing spatial resolution increases the accuracy of identification of boundary pixels.

As part of the Programme d'Évaluation Préliminaire SPOT (PEPS), the authors undertook an investigation (PEPS Project No. 229) "to assess the capability of SPOT imagery to contribute to the improved monitoring of rural-to-urban land conversion in metropolitan regions" (Howarth et al., 1988, p. 491). A major part of this work was concentrated on developing "a method for detecting, classifying and quantifying residential expansion at the edge of the built city" (Howarth et al., 1988, p. 491). Studies have involved mapping of land cover and land use for one date (June 4, 1987) and for the identification of changes between two dates (July 22, 1986 and June 4, 1987). In the first study, supervised and unsupervised classifications were used to map land cover and land use at varying levels of detail ranging from ten classes to only three classes. A seven-category supervised classification consisting of cleared land, construction under way, low-density residential, medium- and high-density residential, industrial/commercial, open space and woods resulted in an overall accuracy of 60.4%. By collapsing the two development classes and the two residential classes, the accuracy increased to 73.5%. Even with a subdivision of the classes into the three major uses of under development, urban and vegetation, overall accuracies of only 80.9% were achieved (Martin et al., 1988).

Both visual analysis and supervised classification have been used in change detection. The two procedures have been applied in a comparison of two individual images and have also been used on a multidate image consisting of one band of data from each of the two dates. Using similar land classes to those in the single-date study, overall accuracies ranging from 57.5% to 79.9% have been achieved. When the classes are combined into simple conversion and no-conversion categories, classification accuracies of up to 94.6% have been achieved, which would be quite sufficient for most practical purposes.

One of the reasons for the relatively low accuracies obtained in these studies is the fact that individual land covers can occur in a variety of land uses. For example, herbaceous cover can be encountered in residential areas, along roadsides in both urban and rural areas, and bordering agricultural fields. Similarly, paved surfaces are encountered in a variety of different land uses.

The results also show that the standard per-pixel classification algorithms that are applicable to low resolution Landsat MSS data are not applicable to the heterogeneous pixel arrangements encountered on SPOT imagery. Alternative ways are required to analyse the higher spatial resolution data.

STRATEGIES FOR IMPROVING RESULTS

As indicated earlier, we are now at a stage where technology is able to provide us with digital data at a wide range of spatial resolutions from the 60 m x 80 m spatial resolution of Landsat MSS data to the minimum pixel size of 30 cm x 30 cm available with the airborne MEIS II system. In most cases, there is not a wide range of spectral resolutions for these sensors, but each system is able to record in several bands in the visible and near-infrared portions of the spectrum.

With the full range of data available, it is now up to researchers with experience in applications development to determine the most appropriate techniques for extracting information from the digital imagery. In the work reported in this paper, the emphasis has been on interpreting digital imagery displayed on a colour monitor, and supervised and unsupervised classification of the data using a maximum-likelihood classifier. However, a range of alternative procedures can be used to analyse the data.

Digital Enhancements

Most images are enhanced using simple techniques such as linear contrast stretch. These procedures increase the dynamic range of the data that are displayed on a colour monitor or are used in generating hard-copy images. Other enhancements can be used, however. For example, a procedure that would be appropriate for urban areas is edge enhancement where any large changes in DN from one pixel to an adjacent pixel can be emphasized. Thus street patterns and buildings can be enhanced on high resolution imagery. In other cases, such as removing the variability in agricultural fields, smoothing of an image may be more appropriate with the application of a low-pass filter.

Enhancements can be generated by combining images. For example, a SPOT panchromatic (P) image with its higher spatial resolution can be combined with a SPOT multispectral image (XS) to produce a composite in which both the spatial detail and the spectral detail are emphasized (Price, 1987). Other examples that have been demonstrated are the combining of radar imagery with Landsat or SPOT imagery (Toll, 1985a).

Improved Algorithms

The maximum-likelihood classifier is appropriate for relatively low resolution digital data where the DNs for each class are more likely to display a normal distribution. With higher spatial resolution data, this is not always the case. Land cover and land use classes may, in some instances, be best characterized in terms of spatial rather than spectral properties. It would appear that algorithms involving spatial measures and context are more appropriate in such cases. For the Toronto study site, it has been shown that use of an edge-density image improved the accuracy of supervised classification of SPOT XS data from 76.6% to 86.1% (Gong and Howarth, 1989b). Other classification strategies based on different algorithms can also be applied (Gong and Howarth, 1989a).

Integration with GIS

Increasingly, land-use information is becoming available in GIS data bases. It is for this reason that we need to concentrate our efforts at identifying changes at the rural-urban fringe, as land use in other parts of the built environment is already documented. Information derived from remote sensing data can be used to update an existing GIS. At the same time, data in the GIS may aid in the remote sensing analysis. This is an area of research where a lot of work has yet to be done to identify the most appropriate interactions between image analysis systems and geographic information systems (i.e., IAS/GIS integration).

Area-Specific Techniques

This topic can be viewed in two ways. First, the data source and the analysis procedures should be related to the specific task in hand. For example, if information on areas of change is required for a large metropolitan area, then spectral analysis of Landsat MSS data is probably most appropriate. If, however, detailed information on land development in a small area is required, then analysis emphasizing spatial detail using high resolution SPOT or airborne data would be more appropriate.

A second situation where area-specific techniques should be applied is extracting information for urban and rural areas. Urban areas are characterized by frequent changes in DN and small spatial patterns caused by roads and buildings. Rural areas are dominated by relatively large homogeneous fields. Thus, the most appropriate image analysis procedures to be used in the two different environments are likely to be different.

SUMMARY AND CONCLUSIONS

A lack of current, comprehensive and integrated land use information has constrained planners' responses to problems of rural-to-urban land conversion in large, rapidly-expanding metropolitan regions. Conventional field surveys and aerial photographic methods have not satisfied land-use information needs. However, airborne and satellite digital imagery, supported by an expanding image-processing computer environment, provide planners with the opportunity to augment and, in some instances, replace conventional methods of land-use information collection.

In this paper, a series of studies undertaken by the authors to determine the capabilities of airborne and satellite imagery to detect land conversion in the Toronto metropolitan region has been reviewed. Variations in land-use and land-use change-detection accuracies were examined with respect to classification systems, spatial resolution of imagery and detection methods. Considered together the various studies produced land-use and land-use change-detection accuracies ranging from 58% to 93% with more detailed classification systems and higher spatial resolution imagery producing lower accuracy levels.

Technology has provided analysts with a full range of digitally-based land-use information sources for detecting rural-to-urban land conversion in the metropolitan region. Improvements in the quality of this information will be gained from strategies that combine the use of digital enhancements, improved algorithms, integration with GIS, and area-specific techniques. The search for ways to extract more detailed and reliable land-use information from imagery must be balanced against the minimal, practical needs of planners and policy-makers if there is to be a useful role for remote sensing in the metropolitan region.

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INTEGRATING REOMTE SENSING AND GEOGRAPHIC INFORMATION SYSTEM KNOWLEDGE IN AN EXPERT SYSTEM FOR CHANGE DETECTION

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ABSTRACT

Remote sensing (RS) and geographic information systems (GIS) can provide essential support of each other's operations. RS can provide information on current and changed land use cover for a GIS, and, more importantly, a GIS can provide an essential expert knowledge base to help automate the technically demanding aspects of RS change detection analysis. No commercially available system provides effective support for this important synergistic relationship.

A prototype integration of both RS and GIS processing in association with an expert system has been developed. Vector and raster data are stored in a unified data base which is accessed by an expert system to control key aspects of RS change detection. New RS interpretations are accumulated in the common data base providing potential for developing a system with a "learning" function. The results show there is good promise for removing some of the technical aspects of RS change analysis which has limited its application by practicing planners, and for providing a significantly improved regional analysis tool.

INTRODUCTION

Monitoring land use change, especially in the urban fringe, is essential to sound planning. Yet, it is not uncommon to find planners who are forced to work with land use maps which are several years out of date. This problem is especially troublesome in areas adjacent to rapidly growing major urban areas. Without current information on the location and trends of actual land use change, the planner's ability to monitor the impact of planning controls (e.g.. official plans, zoning ordinances, etc.) and influence the directions of change are compromised. It can be argued that studies simulating long term alternatives for urban development cannot be conducted effectively without a sound current understanding of land use, and its patterns of change.

While digital remote sensing (RS) and geographic information systems (GIS) individually provide some useful tools for planners, the former requires expert knowledge and is technically demanding, and the latter often suffers from the lack of current information. It is not unusual for planners using GIS systems to be accessing information which is half a decade or more out of date. For some time it has been felt that that methods used in these two areas could enhance each other's operations (Hutchinson, 1982, Richards et al, 1982, Wang and Newkirk, 1987 a and b). Attempts have also been made to apply expert system approaches to reduce technical demands and improve accuracy of remote sensing (Goodenough et al, 1987). Unfortunately, data structuring problems which arise from raster storage (RS) and vector storage (GIS), have complicated the search for cooperation between the two approaches and the potential for implementation of expert systems.

The work reported here has been directed toward developing the basis for an integrated RS and GIS tool for more effective detection and classification of land use change in the urban field. A prototype system has been developed (Wang, 1989) which involves cooperative RS and GIS processing facilitated by a common data base. This, in turn, allowed the implementation of a specialized expert system to help automate RS land use change detection processing. The resulting reduction of technical demands on RS operators should increase the potential for more widespread use by practicing planners. To facilitate research, this initial work was focused on automated processes detecting the following classes of change: vegetation to bare soil, vegetation to construction, vegetation to urban, construction to urban and bare soil to vegetation.

CHANGE DETECTION

Both GIS and RS systems are able to perform some elements of change detection. Through polygon overlay, simplification and reclassification, most GIS packages can identify, classify and tabulate categories of land use change. Computational demands are extensive and there is *a priori* need for fully classified reference land use maps for recent time periods. The general lack of current land use data, noted earlier, is a major factor limiting GIS change detection. Consequently, a number of planning researchers have made effective use of raster based remote sensing data for change detection. However standard RS methods should be applied in the full knowledge of their technical requirements and limitations particularly in the case of change detection in the rural/urban fringe (Martin, 1989).

Standard approaches to RS change detection include visual interpretation of sequential images, and applying algorithms for image differencing, image ratioing. vegetation index and post-classification comparison (Howarth and Boasson, 1983, Schowengerdt, 1983). Change analysis algorithms (even those referencing multiple image bands) create one classification value per land unit pixel based solely upon spectral analysis. Many algorithms require, as well, training inputs and analysis sensitivity parameters provided by image analysis operators. In general, the operators must have a good understanding of the area under study to select appropriate training areas, algorithms and thresholds.

In spite of careful control by operators, accurate land use change classifications cannot be obtained by standard spectral analysis alone. Usually spectral analysis is limited to detecting a change from vegetation to non vegetation coverage. For more specific classification, the analyst must make use of additional (ancillary) external information such as previous land cover maps, topography classifications (land form and soil type), land capability classifications, and official land use zoning. The success of classifications using ancillary data depends strongly upon the skill and training of the operator and often involves time consuming iterative analysis. This has seriously limited the practical application of digital RS by planners. This is important to develop a system which can integrate the several kinds of spatial data required.

UNIFYING THE DATA BASE

Since this system depends upon cooperation between RS pixel based, GIS vector based and rule based operators, it is clear that efficient access to and transfer of information is essential. While the established data formats for each approach are very efficient for their respective tasks, none of the formats is effective for all purposes. Moreover, raster format implementations in RS systems tend to be dominated by a one value per pixel approach. There have been various attempts at combining raster and vector data (Goodenough, 1988). In the mid 1980's this mainly depended upon selecting one dominant format and converting the other data to that format. It has been shown (Piwowar and LeDrew, 1988) that such conversion can introduce errors of up to 9%. More recently, the authors suggest storing raster and vector data in its original format in a mixed data base (Piwowar and LeDrew, 1989). An expert system would be used to select the preferred domain (raster or vector) for processing and control data conversion based on the application at hand. The authors claim that conversion error can be cut in half by this approach. However computationaly intensive data conversion may still be required and would introduce some error. To avoid impeding expert system operations, and to reduce the need for data format conversion in the prototype automated system, it was concluded that an approach which used a common storage technique which stored and worked with both kinds of data without conversions was necessary.

It is possible use conceptual modeling of a database to develop a schema of data which is independent of physical representation (Hull and King, 1987; Peckham and Maryanski, 1988). An abstract representation is developed which captures the static and dynamic properties corresponding to usual operations performed with a class of information. Through an iterative process of classification, aggregation and generalization a *schema* is developed for the static properties and *operations* based on the schema are defined to accommodate the dynamic properties. The schema defines data base entities, their associated relationships and attributes; it also serves as a formal definition of the fundamental data structure of a system and represents knowledge by assigning unique meaning to data.

A conceptual modelling exercise was applied separately and iteratively to the RS, GIS and expert system components to develop an overall conceptual view. Detailed discussion will be found in Wang and Newkirk, 1988. A *subschema* is a subset of a data schema and may have a related subset of operations. Through this modelling approach, it was found that some communications subschemata could be defined which would have common meaning to the two or more main system components. Accordingly, the essential common elements for data structuring could be related as shown in Figure 1, thus permitting a specification of a common data base.

The unified data model was then developed by concentrating upon a representation of the appropriate communication subschemata and the main schemata for RS and GIS. This was based upon set-theoretic relations which provide the benefits of a strong mathematical background and a simple but very effective declarative language in which data structures and operations can be expressed (see Wang, 1989). It also provided a basis for the implementation of fuzzy data and approximate reasoning to enhance system effectiveness. This approach developed a consistent relational model which could eventually be maintained in an off-the-shelf data base management system.

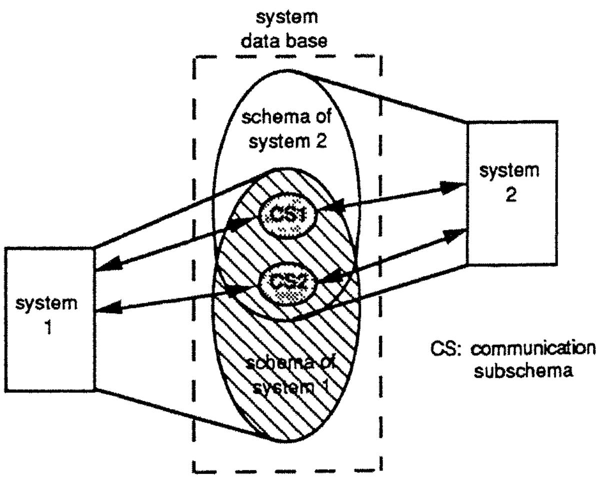

Figure 1: Data Modelling Subschemata

A relational-linear quadtree data representation was developed to implement the unified data model. The relational model was extended by defining a set of quadtree operators which can perform spatial manipulations. The quadtree approach is a hierarchical data structure based on the principal of recursive decomposition and is of increasing importance in computer graphics and image processing (Samet, 1988). The quadtree structure can conveniently represent both areas (i.e. raster) and points with attribute links (i.e. vector). Spatial representation is based on recording in a tree structure the decompositions of a square area into sets of sub squares which have dimensions one half of the immediately higher level at an appropriate level of resolution.

Basic quadtree representation can be extended through appropriate coding such that two dimensional images can be represented as a set (i.e. list of codes) which are essentially one-dimensional data. Useful spatial information can be derived directly from the codes (e.g. area, perimeter, neighbor information). The one-dimensional data occur as strings of integers and characters which can be conveniently stored and manipulated in a relational environment and therefore related to appropriate attribute information. A series of special spatial operators were defined on this representation and are fully described by Wang (1989).

The relational quadtree data structure was implemented using ZIM, an effective entity-relationship data base management system. It is the basis for all main data storage in the system. Raster and vector data is stored in the data base and can be accessed as required by vector or raster analysis and display processes. Since various attributes can be linked to individual pixels, it is possible to record membership values consistent with fuzzy set representation and approximate reasoning. This provides a data base with all of the characteristics required to implement an automated classification and change detection system.

AUTOMATING DIGITAL CHANGE DETECTION

Experiments with adding ancillary information to change detection processing have included preclassification, scene stratification, classification modification, post classification class sorting (Hutchinson, 1982) and probabilistic label relaxation (Richards et al, 1982). While this has contributed to some improved accuracy, the improvement has not been large because the ancillary information tended to be applied outside the actual change detection algorithm at just one stage.

The work reported here extends research on the application of expert systems to control image analysis (Goodenough et al, 1987) by considering ancillary information during analysis (Wang and Newkirk, 1987a) and incorporating approximate (or fuzzy) reasoning. This has been done to eliminate most interactive control by an operator. In this way, a computer could be given the majority of the task to identify and classify land use change.

Steps in Change Detection:

This overall approach to automated change detection can be characterized by 6 main steps:

1. Develop in a GIS (which is compatible with RS and expert system processing) a set of useful ancillary data for an area.
2. Imbed some basic reasoning rules in the expert system knowledge base for inferences about RS based on GIS ancillary data.
3. Add to the system two (or more) RS images for land use change analysis.
4. Allow the automated system to execute RS analysis steps under control of the expert system.
5. Perform selected accuracy checks to verify the change classification.

6. Allow newly classified land use and land use change maps to be added to the GIS for future reference - accumulating knowledge about the area.

The automated RS analysis (step 4 above) follows 4 steps:

1. *Image differencing* - to obtain "raw" change.
2. *Change mask derivation* - to select appropriate training areas for use by the classifier.
3. *Automatic classification* - supervised by the change mask.
4. *Change attribute extraction* - under control of the expert system.

A summary of each analysis step follows. Figure 2 provides a conceptual view of the processing sequence and information flow in the prototype system.

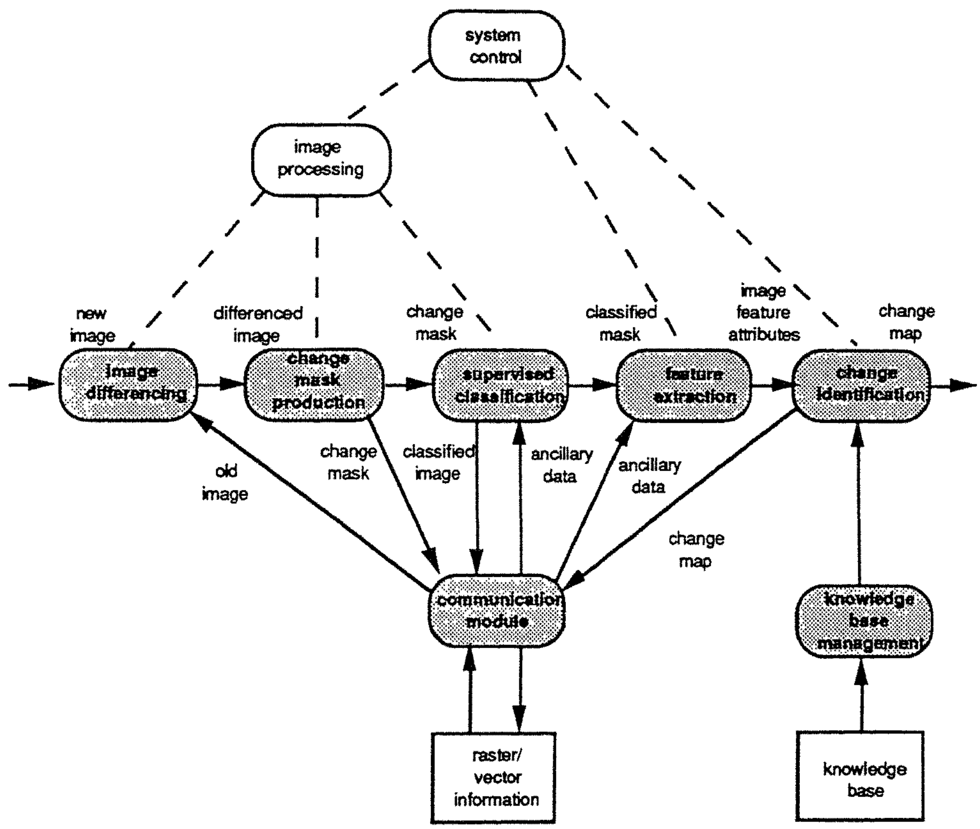

Figure 2: System Processing and Information Flow

Image Differencing:

All 4 bands of a properly registered and corrected raster image are input to the system. The system's information system retrieves an earlier "old" image and begins the straightforward task of pixel by pixel difference calculations. Image differencing is sensitive to areas of change (Toll et all, 1980) and provides a good basis for post classification comparison. It can be expressed

$$D_{ijk} = X_{1ijk} - X_{2ijk} + C$$

When: i,j locate the pixel, k is the band number, C is a constant, D is the difference, and X_1 and X_2 represent the old and new images respectively. Further analysis is required to classify the difference values D_{ij} to select areas of change and no change. One cannot simply assume that only values of $D_{ij} = 0$ represent no change. A special new image called a Change Mask is calculated for this purpose.

Change Mask Derivation

The change mask is a special image M used by subsequent algorithms to selecting algorithms training areas for supervised classification. This is achieved by applying *K-L expansion* followed by *K-means clustering*. K-L expansion enhances the resolution of areas of change and K-means clusters all pixels into change and no change categories. These processes can proceed without operator interaction and result in a binary map of change/no change.

K-L expansion is a factor analysis technique commonly applied in statistical pattern recognition. It is a transformation T which maps the difference image space D to a new space F

$$F_{ijk} = T\ (D_{ijk})$$

on the basis of the eigenvectors of the covariance matrix of D. This mapping T creates a new space with orthogonal axes between classes thus enhancing resolution. It has been found (Byrne et al, 1980) that the second component (i.e. second highest eigenvalue) emphasizes brightness between the two images. This highlights the areas of change under investigation. This approach in the prototype system is discussed in more detail in Wang and Newkirk, 1987a.

K-means clustering is performed on the K-L second component of F after it has been rescaled into the range 0-255. The initial means vector of {0, 127, 255} starts the clustering; no threshold setting is required. At termination, classes 1 and 3 represent change and are assigned a mask value $M_{ij} = 1$. Class 2 represents no change and is assigned a value of $M_{ij} = 0$.

Automatic Classification

Once the change mask has been derived, all of the non change areas ($M_{ij} = 0$) can be used as training areas for the classification. Based on existing (ancillary) ground truth information (from previous analysis or land use maps), the non changed areas' classifications are used to determine the statistical parameters for supervised classification.

Land cover classification is executed providing a newly interpreted land cover map which can be added to the system data base. The large number of training pixels used improves classification accuracy. Clearly, this algorithm depends upon the accuracy of reference data in the GIS. However the results (discussed later) show that the method itself can provide very accurate results.

Some extensions by Wang have been made to the prototype system to make use of fuzzy data in storage and analysis in this process. It has been shown for spatial classification purposes (Newkirk, 1979) that it is preferable to maintain membership grades for several attributes of a given pixel rather that the usual 1 pixel 1 value paradigm common to most raster based systems. Membership functions for land use classes can be suitably defined to support partitioning with respect to fuzzy mean and covariance. Pixels with similar membership grades can be aggregated into regions. More detailed discussion may be found in Wang, 1989. Some fuzzy set operations were involved in the computation of the land classification whose error tabulations are discussed later.

Change Attribute Extraction and Classification

Each pixel has a set of attribute data (both "hard" and fuzzy) which includes classified land cover at specific dates (including the newest information just classified), and ancillary information such as landform, soil capability, zoning classifications etc. For each pixel where $M_{ij} = 1$ (i.e. where change was detected), its appropriate attributes are assembled. Pixels with similar attribute sets are aggregated into regions.

Once common regions of change have been identified, the expert system can perform reasoning based on their attributes to make some inferences about the kind of change which has taken place. This requires initial provision of a suitable rule base which can be referenced by the expert system. Since the spatial data base maintains fuzzy as well as "hard" attribute data, and since inferences may be subject to some degrees of uncertainty, the prototype's inference system has been extended to process approximate reasoning. This is based on an extended form of modus ponens where certainty levels have been associated with the rules (see Wang, 1989).

The regions of change aggregated by common attributes are considered as elements of fuzzy sets. Based on attributes, membership grades can be calculated for each region representing the level to which a region involves a specific type of change. A region may have one or more membership grades depending upon local variability.

The process of approximate reasoning on the collection of membership grades provides a "hardened" classification for each region identifying the change which took place. The accuracy tests reported later evaluated this process. In particular, reasoning was hardened to a single class of change per pixel (i.e. the most likely class). This does not mean there was no uncertainty regarding some pixels but, rather that a choice was made. It would be possible to add a class "too uncertain to classify" or "blended classes" where the two most predominant classes (above some certainty level) could be identified. This may provide an area for further research.

ASSESSMENT OF RESULTS

The sequence of analysis steps as described, take a suitably registered and corrected raw RS image through to the output of a classified land use map and a land use change map without user intervention. Tests were conducted to assess algorithm and overall accuracy on several areas. In one case, an integrated RS/GIS information data base with ancillary data was developed for a 256 x 256 study area of mixed urban and rural use southwest of the City of Hamilton, Ontario, Canada. Four bands of MSS Landsat data and an associated interpreted land use map for 1974 were included in the data base. A new set of MSS data for 1978 was input to the system and processed through all steps. Both the "new" land cover classification and the change classifications were evaluated by comparing an approximately 1 % sample of pixels with corresponding air photographs. As may be expected, the accuracy when detecting land cover is slightly better than classifying the particular nature of land use change. However, in both cases the results were good with overall accuracy of 91% and 88% respectively.

The following tables provide a detailed assessment of the errors encountered. The results for each of the randomly selected set of pixels have been accumulated in a table where the rows represent the actual (correct) condition and the columns represent the classification obtained by the automated process. The diagonal elements represent correct results and the off diagonal elements represent errors of commission and omission. The rightmost column represents, for the random sample, the success in correctly classifying each specific category. The last row, designated "certainty" represents the confidence which can be associated with a specific output map classification category for the sample selected.

Table 1 provides the accuracy assessment for the 1978 Hamilton Land Use Automated classification. Table 2 provides a similar assessment for a slightly larger random sample of the 1974 to 1978 Land Use change classification for the same area.

Table 1 SAMPLE LAND USE CLASSIFICATION ERROR ANALYSIS

	CLASSIFIED AS								Actual Use
ACTUAL	Water	Industry	Residence	Forest	Cropland	Bare soil	Pasture	Total	Correctly Classified
Water	32	2	0	0	0	0	0	34	94%
Industry	3	62	3	0	0	2	1	71	87%
Residence	0	7	163	1	1	0	2	174	94%
Forest	0	0	1	70	6	0	0	77	91%
Cropland	0	0	1	6	159	0	4	170	94%
Bare soil	0	4	0	0	0	42	2	48	88%
Pasture	0	0	2	2	6	2	74	86	86%
Total	35	75	170	79	172	46	83		
Certainty	91%	83%	96%	89%	92%	91%	89%		

660 Total Classifications
602 Correct Classifications (diagonal)
91% Overall Accuracy

In table 2, the land change codes are as follows:

Code	Meaning
C>U	Construction to Urban
V>C	Vegetation to Construction
V>U	Vegetation to Urban
V>B	Vegetation to Bare soil
B>V	Bare soil to Vegetation
NC	No change

Table 2 SAMPLE CHANGE CLASSIFICATION ERROR ANALYSIS

	CLASSIFIED AS							Actual Change
ACTUAL	C>U	V>C	V>U	V>B	B>V	NC	Total	Correctly Classified
C>U	66	0	0	0	7	0	73	90%
V>C	0	22	0	5	0	1	28	79%
V>U	0	2	18	0	0	2	22	82%
V>B	0	5	1	58	0	2	66	88%
B>V	4	0	0	0	152	4	160	95%
NC	0	1	3	2	48	298	352	85%
Total	70	30	22	65	207	307		
Certainty	94%	73%	82%	89%	73%	97%		

701 Total Classifications
614 Correct Classifications (Diagonal)
88% Overall Accuracy

The reader is cautioned that only a few tests have been completed with the prototype system. Accordingly these results should be considered tentative until more tests are completed. It should also be noted that the amount and quality of the ancillary data in the system under study directly influences the accuracy of interpretations.

SUMMARY

The main results achieved include:

(1) the successful prototype implementation of the integrated system on a Digital Equipment VAX 11/785 utilizing Dipix Aries III and VAXStation 500 display devices. All software was written in C and data base management used ZIM.

(2) land use and change classification systems (for a restricted set of land uses) which can process all steps from the input of a new image to production of classified outputs without user intervention.

(3) the practical integration of RS (raster) and GIS (vector) information in a common system data base.

(4) implementation of both hard and fuzzy data representation and appropriate reasoning in the integrated system.

(5) automated interpretation at a satisfactory level of accuracy.

(6) the accumulation of imagery and interpretations in the system's information base providing a means for the system to begin to "learn" about an area.

This research has established that there is good promise for developing commercial systems which could sufficiently automate joint RS and GIS operations for them to be of practical use to planners.

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HOW TO USE DECOMPOSING METHOD OF MIXED PIXEL TO RENEW THE CITY'S GREEN AREA DATA BANK USING LANDSAT CCT DATA ?

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ABSTRACT

This paper discussed the possibility of using space-borne remote sensing data monitoring city's development and ecology. In the past many people believed that the city information system(CIS) needs a lot of details, therefore the airborne remote sensing data to be used as a main data source of CIS and the application of relatively low resolution space-borne remote sensing data to be neglected. This paper pointed out that as long as the decomposing method of mixed pixel to be used the space-borne data still can play an important role in CIS. Up to now we can answer three questions if we use decomposing method to remote sensing image·

. How many independent elements are contained in one image ?

. What is the average characteristics of spectral reflectance of every independent element?

. What is area ratio of every independent element in every pixel ?

In fact, mixed pixel problem is an unavoidable difficulty in quantitative analysis of remote sensing data which is also directly connected to the question how to conjoin remote sensing data to GIS.

INTRODUCTION

It is an important problem to renew data bank of CIS for planning and management especially in a big developping country such as China owning so large population, since rapid development of industrial cities at an astonishing speed and city's ecological environment deteriorated rapidly the timely monitoring of city are badly needed. It is vital for CIS to renew data bank in order to become a powerful means of decision making. Obviously, remote sensing data can become one of main data source to get information of city. Up to now airphoto and airborne multiband scanner data were recognized as a main tool to collect data for CIS in China. It's working steps must contain airphoto taken, mosaic assembly, drawing thematic map through visual interpretation and input them into computer through proper means such as digitizer. Airphoto can offer many details, but it costs much labour and more money. In fact, it is impossible and unnecessary to input every detail of airphotos into computer, for example, during 80's one project of accounting green area of Beijing was performed on a base with grid size of 100 meters by 100 meters. So we think if we can decompose mixed pixel of Landsat data then this kind remote sensing data has a potential ability to offer some basic information for city's management and environmental monitoring, for example to answer such questions,how fast does the city expand ? what speed does the suburbs farm land reduce ? what is the changing tendency of city's green area ? and so on. So the key point is if we can find a reliable decomposing method for mixed pixel.

THE DECOMPOSING METHOD OF MIXED PIXEL

Basic Idea

The aim of decomposing method of mixed pixel is able to answer three questions:

. When the characteristics of spectral refelctance is the base to judge different objects,the first question we have to answer is how many independent elements the image does contain.

. What kind characteristics of spectral reflectance does every element have ? In another words, what kind objects does the image contain ?

. What is the area ratio for every independent element in every mixed pixel ?

Suppose one image has M pixels,T bands data and N independent elements,then a data matrix $|D|$ can be formed.

$$|D| = M \left\{ \overbrace{\begin{matrix} d_{1,1} & d_{1,2} & \cdots\cdots & d_{1,T} \\ d_{2,1} & d_{2,2} & \cdots\cdots & d_{2,T} \\ \cdot & \cdot & & \cdot \\ \cdot & \cdot & & \cdot \\ \cdot & \cdot & & \cdot \\ d_{M,1} & d_{M,2} & \cdots\cdots & d_{M,T} \end{matrix}}^{T} \right. \qquad (1)$$

Where $d_{i,j}$ is the element of matrix $|D|$,subscript i represents spatial position,subscript j means the number of band, so $d_{i,j}$ is a spectral reflectance of ith mixed pixel at jth band.

Based on linear additive principle of mixed pixel

$$d_{i,j} = \sum_{k=1}^{N} a_{i,k} \rho_{k,j}$$

Where subscript k represents ordinal number of independent elements, $a_{i.k}$ means area ratio of kth element of ith mixed pixel. $\rho_{k,j}$ means the spectral reflectance of jth band of kth element.

$$|D| = |A|\,|\rho| \qquad (2)$$

Where

$$|A| = M \left\{ \underbrace{\begin{matrix} a_{1,1} & a_{1,2} & \cdots\cdots & a_{1,N} \\ a_{2,1} & a_{2,2} & \cdots\cdots & a_{2,N} \\ \cdot & \cdot & & \cdot \\ \cdot & \cdot & & \cdot \\ \cdot & \cdot & & \cdot \\ a_{M,1} & a_{M,2} & \cdots\cdots & a_{M,N} \end{matrix}}_{N} \right.$$

$$|\rho| = N \left\{ \overbrace{\begin{matrix} \rho_{1,1} & \rho_{1,2} & \cdots\cdots & \rho_{1,T} \\ \rho_{2,1} & \rho_{2,2} & \cdots\cdots & \rho_{2,T} \\ \cdot & \cdot & & \cdot \\ \cdot & \cdot & & \cdot \\ \cdot & \cdot & & \cdot \\ \rho_{N,1} & \rho_{N,2} & \cdots\cdots & \rho_{N,T} \end{matrix}}^{T} \right.$$

We call $|A|$ area ratio matrix,because it describes area ratio distribution of every independent element for every mixed pixel. We call $|\rho|$ spectral reflectance matrix which describes the characteristics of spectral reflectance of every independent element.

General speaking, $|\rho|$ is not a square matrix. The full rank condition can't be satisfied also,so it is impossible to know $|A|$ through multiplication $|\rho|^{-1}$ for both right hand and left hand of equation (2). ($|\rho|^{-1}$ is an inversion of $|\rho|$). A new way has to be exploited to solve this problem.

Usually $M \neq T$, so $|D|$ is not a square matrix. Let $|Z| = |D|^T|D|$. Where $|D|^T$ is the transfer of $|D|$. We call $|Z|$ a covariance matrix of $|D|$. $|Z|$ is a $T \times T$ dimensional matrix. After knowing eigenvalues and eigenvectors of $|Z|$,it can be expressed by matrix format.

$$|Z||Q|=|\lambda||Q| \tag{3}$$

We call $|Q|$ eigenvector's matrix which consists of every eigenvector. $|Q|=|\overline{Q}_1,\overline{Q}_2,\cdots\cdots\overline{Q}_T|$,where $\overline{Q}_1,\overline{Q}_2\cdots\overline{Q}_T$ are eigenvectors corresponding to eigenvalues $\lambda_1, \lambda_2\cdots\cdots\lambda_T$. eigenvalue matrix $|\lambda|$ is a diagonal matrix

$$|\lambda| = \begin{vmatrix} \lambda_1 & & & 0 \\ & \lambda_2 & & \\ & & \ddots & \\ 0 & & & \lambda_T \end{vmatrix}$$

$$|Q|^{-1}|Z||Q|=|Q|^{-1}|D|^T|D||Q|$$

$$\because \ |Q|^{-1}=|Q|^T$$

$$\text{so } |Q|^{-1}|Z||Q|=|Q|^T|D|^T|D||Q|$$

$$\text{Let } |R|=|D||Q| \tag{4}$$

$$\text{Then } |Q|^{-1}|Z||Q|=|R|^T|R|$$

From (4)

$$|D|=|R||Q|^T$$

$$\text{Let } |C|=|Q|^T$$

$$\text{Then } |D|=|R||C| \tag{5}$$

Formula (5) means that data matrix $|D|$ can be dissolved as a multiplication of two matrixes $|R|$ and $|C|$. We can use a transform matrix $|T|$ to compare (5) with (2).

$$|D|=|R||T|^{-1}|T||C| \tag{6}$$

Where $|T|$ is a transform matrix with $T \times T$ dimensions.

$$\text{Let } |\rho|=|T||C|$$

$\because |C|^{-1}=|C|^T$

$\therefore |T|=|\rho||C|^T$ (7)

Where $|T|$ consists of $\overline{T}_1,\overline{T}_2,\ldots\ldots\overline{T}_N$

$T_j=|\lambda|^{-1}|C^*|^T\overline{\rho}_j$ (8)

$j= 1,2,3,\ldots\ldots N.$

If $|T|$ is known then $|A|$ can be known by

$|A|=|R||T|^{-1}$ (9)

N=?

If we use a spatial vector to represent one band of data matrix,then a T dimensional spatial coordinate system can be formed. M pixels can be represented by M points in T dimensional space. Suppose M pixels only represent a pure stochastic course without any objective inner law of spectrum,then M points should be looked like a ball because of isotropic property of stochastic course, but a fram of remote sensing image contains N independent elements which have own special characteristics of reflective spectrum, so it can be imagined M points shouldn't appear a ball because they were controlled by some inner law eventhough the existence of mixed pixels makes them confused and intuitively indistinquishable. Suppose it looks like a oval ball. The direction of first eigenvector $\overline{C}_1$ in space should be along with the long axis of oval ball. The second eigenvector $\overline{C}_2$ should be in the plane which is perpendicular to long axis of oval ball and direct to long axis of ellipse which was formed by all points in this plane, and so on and so forth. So only linear coordinate system transform has been done by empirical orthogonal function analysis. The new coordinate system has two special properties :

. The new coordinate system is an orthogonal system consisted of $\overline{C}_1,\overline{C}_2\ldots\ldots\overline{C}_T$.

$\overline{C}^*_i\cdot\overline{C}_j=\delta_{i,j}$

Where $\overline{C}^*_i$ is conjugate of $\overline{C}_i$.

. Eigenvalue $\lambda_j=\sum_{i=1}^{M}r^2_{i,j}$ Where $r_{i,j}$ is the projection of ith point (one of M points) to C_j axis, further more

$\lambda_1>\lambda_2>\lambda_3\;\cdots\cdots\cdots>\lambda_T$

That means the scattering range of M points along with direction of $\overline{C}_1$ is the longest one. The scattering range along with $\overline{C}_2$ direction should be less than first one but longer than third one,and so on and so forth. This unhomogeneous property obviously means M points were controlled by inner law. Oppositely for ball the conclusion should be

$\lambda_1\doteq\lambda_2\doteq\lambda_3\cdots\cdot$

So if one image has N independent elements N T,then

$\lambda_1>\lambda_2>\lambda_3\;\cdots\cdots>\lambda_N$

$\lambda_{N+1}\doteq\lambda_{N+2}\doteq\;\cdots\cdots\;\lambda_T\doteq\lambda_0.$

We can form a function IE(n) to judge N=?

$$IE(n) = \left[\frac{n \sum_{j=n+1}^{T} \lambda_j}{M\,T(T-n)}\right]^{1/2} \qquad (10)$$

When n increase from 1 to N IE(n) should decrease,only when $n \geqslant N+1$, IE(n) becomes increasing function,because at this moment

$$\sum_{j=n+1}^{T} \lambda_j = (T-n)\lambda_0 .$$

$$IE(n) = \left(\frac{\lambda_0}{M\,T}\right)^{1/2} (n)^{1/2}$$

Where $\left(\frac{\lambda_0}{M\,T}\right)^{1/2}$ is a constant.IE(n) increase as n increase So N is the turning point of IE(n) from decreasing to increasing tendency.

<u>How to know $|\rho|$?</u>

Formula (7) tells us that if $|\rho|$ is known then $|T|$ can be known, but $|\rho| = |T||C|$. It seems that we had dropped into a dead circle. In fact, $|\rho|$ can't be known by pure mathematic deduction upon data matrix, but some knowledge about $|\rho|$ can be gained by field measurement of reflective spectrum. We refer to this measurement as an initial value symblized by $\bar{\bar{\rho}}_j$, then to substitute $\bar{\bar{\rho}}_j$ into (8) to know T_j using T_j through $|\rho| = |T||C|$ to know $\bar{\rho}_j$, we call $\bar{\rho}_j$ predicted value. $\bar{\rho}_j$ should not be equal to $\bar{\bar{\rho}}_j$. We call the difference $\bar{E}_a = \bar{\bar{\rho}}_j - \bar{\rho}_j$ apparent difference. Suppose the true value which constructs $|\rho|$ can be expressed by $\bar{\rho}^*_j$, then we call the differenc $\bar{\bar{\rho}}_j - \bar{\rho}^*_j = \bar{E}_T$ the target difference and call $\bar{\rho}_j - \bar{\rho}^*_j = \bar{E}_p$ predicted difference.

This formula can be proved

$$\bar{E}^T_a \bar{E}_a = \bar{E}^T_p \bar{E}_p + \bar{E}^T_T \bar{E}_T \qquad (11)$$

$\bar{E}^T_a$ is a transfer of $\bar{E}_a$. $\bar{E}^T_p$ and $\bar{E}^T_T$ are also transfer of $\bar{E}_p$ and $\bar{E}_T$ respectively.

Formula (11) tells us the apparent difference is the sum of two vectors(target difference vector and predicted difference vector)

Suppose $\bar{\bar{\rho}}_j = \bar{\rho}^*_j$

$$\bar{E}^T_a \bar{E}_a = \bar{E}^T_p \bar{E}_p$$

That means eventhough we use true value $\bar{\rho}^*_j$ to know T_j through (8),then to know $\bar{\rho}_j$ through $|\rho| = |T||C|$, the initial value $\bar{\bar{\rho}}_j (= \bar{\rho}^*_j)$ is still different with predicted value $\bar{\rho}_j$, because in any case $|D|$ is inevitable to contain some kind errors

$$|D| = |D^*| + |E| \qquad (12)$$

Where $|D^*|$ means ideal data matrix without any error. $|E|$ represents error matrix ,so $|c|$ and $|R|$ also contain some error, when we use (8) to know T_j the error must be introduced. So if $\overline{\overline{\rho}}_j - \overline{\rho}_j$ is much larger than measurement error,then we can say $\overline{\overline{\rho}}_j \neq \overline{\rho}_j^*$. Through man's interference to readjust $\overline{\overline{\rho}}_j$ .This course is repeated untill $\overline{\overline{\rho}}_j - \overline{\rho}_j$ within measurement error,then we think the true value of reflective spectrum $\overline{\rho}_j^*$ had been found,because at this moment we can say $\overline{\overline{\rho}}_j \doteq \overline{\rho}_j^*$

To review the whole course

The whole course of decomposing method of mixed pixel can be summaried by:

. To form a data matrix $|D|$ using ccT,then to get $|Z|=|D|^T|D|$.

. To perform general principal component analysis of $|Z|$ to know eigenvalues $\lambda_1, \lambda_2, \lambda_3, \ldots\ldots \lambda_T$ and eigenvectors $\overline{Q}_1$, $\overline{Q}_2, \overline{Q}_3, \ldots \overline{Q}_T$.

. Through $|R|=|D||C|^T$ to know $|R|$,where $|C|=|Q|^T$.

. To apply IE(n) to judge N=? .

. To discard all eigenvectors corresponding to λ_{N+1}, $\lambda_{N+2}, \ldots. \lambda_T$. Let $T \times T$ dimensional matrix $|C|$ becomes matrix $|C^*|$ with $N \times T$ dimensions.The same $M \times T$ dimensional matrix $|R|$ becomes matrix $|R^*|$ with $M \times N$ dimensions.

. Through many times readjustment to know $\overline{\overline{\rho}}_{j,k}$.

. Using (8) to know $\overline{T}_j$, then to form $|T|$.

. Through $|A|=|R^*||T|^{-1}$ to know $|A|$.

AN EXAMPLE

We have collected four frams of Beijing images of MSS or TM. The earliest one was taken in May of 1975(MSS). The last one was taken in Oct.of 1984. We chose Northwest suburb Hai-Dian district as an example, because it is a fringe of Beijing city, many things changing rapidly.

If we want to calculate green area of this district,the new problem is how to distinquish forest area and farmland. In May winter wheat is still growing in the field. In Oct.the chinese cabbage is growing well in the field. The reflective spectrum is very similar for forest and farmland. Only the value of MSS 7 or TM 4 of winter wheat or chinese cabbage is less than the value of forest.

Multistep method was adopted. At the first step when the decomposing method of mixed pixel was performed, the average vegetative spectrum was used,the difference of reflective spectral value between forest and farmland was neglected temperally. We only pursue vegetation to be distinquished from soil, road, building and so on. Since water body only occupied a small part of whole image, so it does not join the course.

After knowing the area ratio of vegetation in every pixel,we single out these pixels in which vegetation ratio is larger than 0.6 or so,then we repeat the whole course again for these pixels, in another words,in these pixels the characteristics of vegetation is dominative. If the principal component analysis was performed the difference of reflective spectrum between forest area and crops can be shown.

From theoretical point of view for mixed pixel the sum of total area ratio of verious objects should be equal to " 1 ". as a matter of fact,since the various errors exist,so

$$\sum_{k=1}^{N} a_{i,k} = 1$$

For those pixels whose vegetative area ratio less than 0.6 how to judge the classification of vegetation. We recalculated $a_{i,k}$ using reflective spectrum of forest or crops respectively,then to check the value $\sum_{k=1}^{N} a_{i,k}$, we shoose this one which is closer to " 1 " as a correct answer.

If $\sum_{k=1}^{N} a_{i,k}$ deviates " 1 " obviously, that means some new elements must be within the mixed pixel. These pixels can't be classified. The number of this kind pixels must be small. If the number is large enough their characteristics of reflective spectrum should be considered automatically by principal component analysis. The orthogonal coordinate system $\overline{C}_1, \overline{C}_2, \ldots$ must be different also. In our example water body, lake etc. belong to this situation.Obviously the reflective spectrum of water body is quite different with soil,vegetation and so on, these points deviate main tendency remarkable,but they were treated as an errors because of the small number.

DISCUSSIONS

. Our practice have proven that as long as decomposing method of mixed pixel was performed space-borne remote sensing data such as MSS or TM still can play an important rule in monitoring development and environment of city. From certain point of view people can detect the objects with size less than one pixel,if decomposing method plays well.

. In the past people were satisfied only to know many principal components when principal component analysis method was applied to remote sensing image. Physical interpretation was imposed to principal components. In fact, they have no definite physical meaning. If some one wants to know the results with definite physical meaning a further coordinate system transform is needed.

. Remote sensing data have many advantages to be shosen as one of main data source of GIS,but the physical meaning of remote sensing data is so complicated. If we want to connect remote sensing data to GIS in correct way,the quantitative analysis method of remote sensing data should be solved ahead.

Actually the mixed pixel problem is a basic unavoidable difficulties in quantitative analysis of remote sensing data. Its significancy is by no means limited in estimation of green area of city. In fact, it concerns the evaluation of ability of remote sensing data to environmental monitoring. It is relatively easy to know area ratio of various objects in mixed pixel. The another question of mixed pixel is to retrieve reflective spectrum of every element from mixed pixel,in another words,the question is if we can recover original spectral characteristics of every independent element which had been contaminated by mixed pixel.

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DESIGNING A DIGITAL URBAN TOPOGRAPHIC DATABASE FOR APPLICATIONS IN URBAN PLANNING AND MANAGEMENT

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ABSTRACT

One of the major problems in the implementation of an urban information system is the acquisition of digital data that are acceptable to the computer. Collection of digital urban data and organizing them in a topographic database is an expensive exercise upon which the integrity and quality of urban planning and management are dependent. This paper explains the concepts of a digital urban topographic database and the use of various theoretical models in representing digital data in a database information processing environment. It also examines various applications of digital topographic data in urban planning and management with a view to justifying economically, investment in geographic information technology.

INTRODUCTION

Increased access to computers in the last two decades has allowed many of the information processing functions in urban planning and management to be automated. However, the objectives of computerization have been largely confined to emulating existing manual and clerical procedures in areas such as property tax billing, personnel management, payroll, maintenance of inventories and recording social statistics. The use of what have now become widely known as geographic information systems (GIS) has allowed urban planners, engineers and urban managers to utilize more fully the capabilities of computers to address the many complex information needs of their respective agencies.

Experience has shown that the use of GIS technology to solve the numerous information problems of urban planning and management remain more an expectation than a reality many agencies. There are several reasons that account for this discrepancy but, certainly, the difficulty of obtaining digital data in the appropriate format is a major obstacle to the successful exploitation of this technology. Although use of maps and engineering drawings has always been central to urban planning and management, the use of map and engineering data in digital form represents an entirely different approach to information processing and utilization. In the discussion that follows, we consider the important issue of designing a digital topographic database as an integral component of an urban information system. Moreover, we explore the productive use of such a database in urban planning and management applications.

A digital urban topographic database (DUTD) is essentially composed of data in computer files pertaining to geodetic control points, contours, street fabric, utility infra-structures, lots, parcels, municipal and ward boundaries as well as natural features such as rivers, streams, wetland and vegetation cover which are located within the boundaries of a city. It is different from a mere collection of such data in the following three ways:

(1) the data are collected to serve specific municipal management and engineering objectives, i.e. only data relevant to the information needs of the system users are stored;

(2) the data are logically organized such that individual data items, which are stored only once, can be shared by different users for a variety of applications; and

(3) access to the data base is by means of standard procedures collectively known as a database management system (DBMS).

In a DUTD all individual data items are characterized by a locational attribute. This provides a unique geographical framework by which the physical and socio-economic elements of the urban environment are cross-referenced. It also permits these elements to be spatially analyzed to delineate physical and socio-economic functional zones according to specific criteria, and to obtain a synoptic view of the locational or network patterns of selected urban phenomena. In addition, by comparative analysis of change statistics extracted from the database, the rate and the trend of urban development over a certain time period can be determined. A DUTD, in itself, is not an urban information system. It is an integral component of an urban information system that provides the spatial framework by which data in the system are referenced, manipulated and utilized (Figure 1).

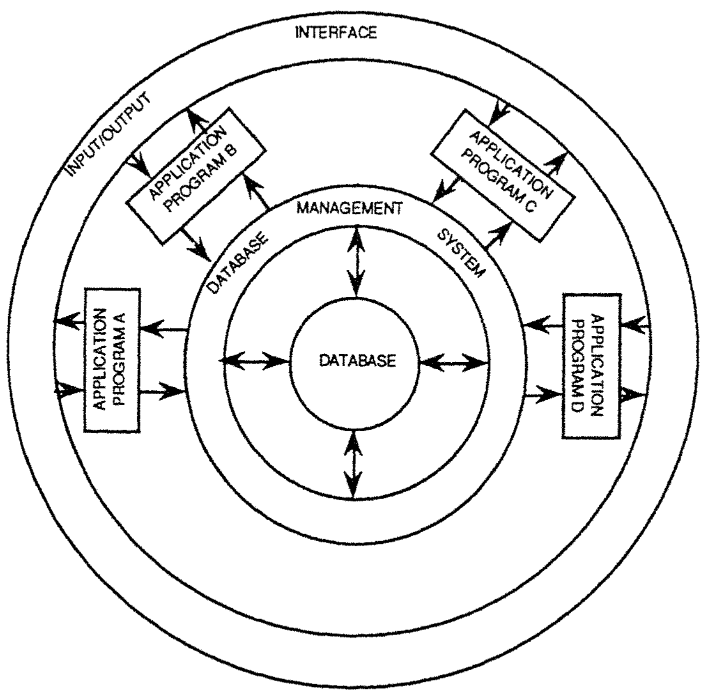

Figure 1: The Concept of a Digital Database

The creation of the DUTD always represents a major part of the capital investment for an urban information system. It is not uncommon, for example, to find in project proposals that only 15 to 20 percent of the total system cost goes toward hardware and software, while the remaining 80 to 85 percent has to be expended on creating the base maps and furnishing the database with attribute information (McLaughlin, 1988; Rust, 1989). The database creation process has therefore to be carried out as a carefully planned exercise. The quality of the database has always to be carefully guarded as a valuable corporate resource. It is also essential for urban planners and managers to make productive use of the database to optimize economic returns from the investment.

URBAN INFORMATION PROCESSING IN A DATABASE ENVIRONMENT

The introduction of GIS for applications in urban planning and management requires much more than the willingness to accept the technology and the ability to purchase the necessary hardware and software. In adopting the information system approach in the work place, it should be clearly understood that:

(1) a system which is unable to satisfy all stipulated user requirements will cause problems rather than help to solve problems;

(2) a poorly managed computer-based information system is probably less productive than a manual data system, and is definitely much more costly;

(3) it is easy to modify database access procedures but very expensive or practically impossible to modify a database structure once it is in operation;

(4) digital database creation is a very expensive and time consuming process. The database is therefore a valuable corporate resource and should always be treated as such; and

(5) a database provides a synergetic effect in information use because considerably more information can be obtained when the individual components are considered in concert than when they are used independently.

The above observations indicate that, among other things, the use of a DUTD requires an entirely new information processing environment, the major characteristics of which are considered below.

User requirements and system design

Experience has shown that urban information systems sometimes fail to generate the functionality expected of them not because of hardware and software deficiencies, but because of the lack of understanding of the information needs of the system end users. The design of all urban databases should be based, first, on gaining a real understanding of how the current operations are carried out within an organisation and, second, on translating the users' needs into specifications for the basic components of a database system (Dangermond, 1988).

Information regarding current data processing practices, and projection of future data requirements, is obtained by a carefully planned user requirements study. Such an exercise involves visits and interviews aiming at the collection of the following kinds of information: basic institutional organization and responsibilities of information users; procedures and equipment used to carry out the responsibilities; inventory and description of geographic information used or generated by the users; existing resources and estimation of the potential for the use of the new technology in the future.

With an understanding of the users' present information needs obtained from the analysis of the results of the study, various spatial data collection, organization, storage and management procedures can be identified. These represent the framework for a 'model' of spatial data which is then used to develop the system design and implementation planning.

Data representation and exchange standards

An important issue in computerized topographic database design is concerned with the representation of digital data and their transfer between different systems. The objectives of establishing a standard for topographic data representation can be understood in two ways: first, to ensure consistency in representation for data collected by different agencies and at different times; second, to facilitate delivery and distribution of electronic digital data between the public, industrial and institutional sectors independent from the media in which the data are carried (Ontario Ministry of Natural Resources, 1987).This standard provides the possibility for wider exchange of digital topographic data, as well as avoidance of duplication in database generation.

Data security and integrity

Methods of data security in a database environment determine the accessibility of different classes of information users to the system. While the concept of data security is, in most instances, more important to attribute data than to topographic data in an urban database, it is still essential that the database designer identify how best to achieve integration of different levels of clearance for users who are entitled to access the database and the operations that can be performed on constituent data.

Closely related to the concept of data security is data integrity. One aspect of data integrity deals with inconsistencies in the database, where specific constraints must be built into the system to detect possible errors in the data. Another aspect of integrity deals with the ability of the system to recover from machine failues, or erroneous updates. The data integrity mechanism of the DBMS maintains different up-date logs and back-up dumps which are used to re-establish a previous state of the database.

User education and system evaluation

The successful utilization of GIS depends at least as much on how the end users understand the technology as on what the system designer can offer. User education on the use of a DUTD includes activities ranging from the training of technicians to perform digitizing; clerical staff who require access to the database in their daily routines; programmers who translate concepts to computer code; to urban managers and policy makers who abstract information for decision making purposes. User education not only provides user groups with the technical knowledge that enables them to grasp the capabilities of the system, but also enables them to communicate effectively with the database designer in system evaluation. Such feedback is an indispensable part of the whole database design process.

A CONCEPTUAL MODEL AND DATABASE STRUCTURE

The task of creating a DUTD is complex. This is partly due to the highly complicated topographic fabric of cities and partly to the necessity to satisfy the different, and occasionally, conflicting, information needs of a multi-user data processing environment. Three theoretical models have been proposed which enable the system designer to determine user needs, to identify possible information flow, to prioritize resource allocation, and to conceptualize the physcial configuration of information systems (Linders, 1983). These models are, namely: the conceptual model; the functional model and the data model.

A conceptual model of digital urban information

The conceptual model shown in Figure 2 helps to identify the constituent database components within an urban information system environment and their interrelationships. In essence, this model comprises two primary databases: the parcel database and the street network database. These two graphic databases together provide the spatial fabric for the description of land-related urban information.

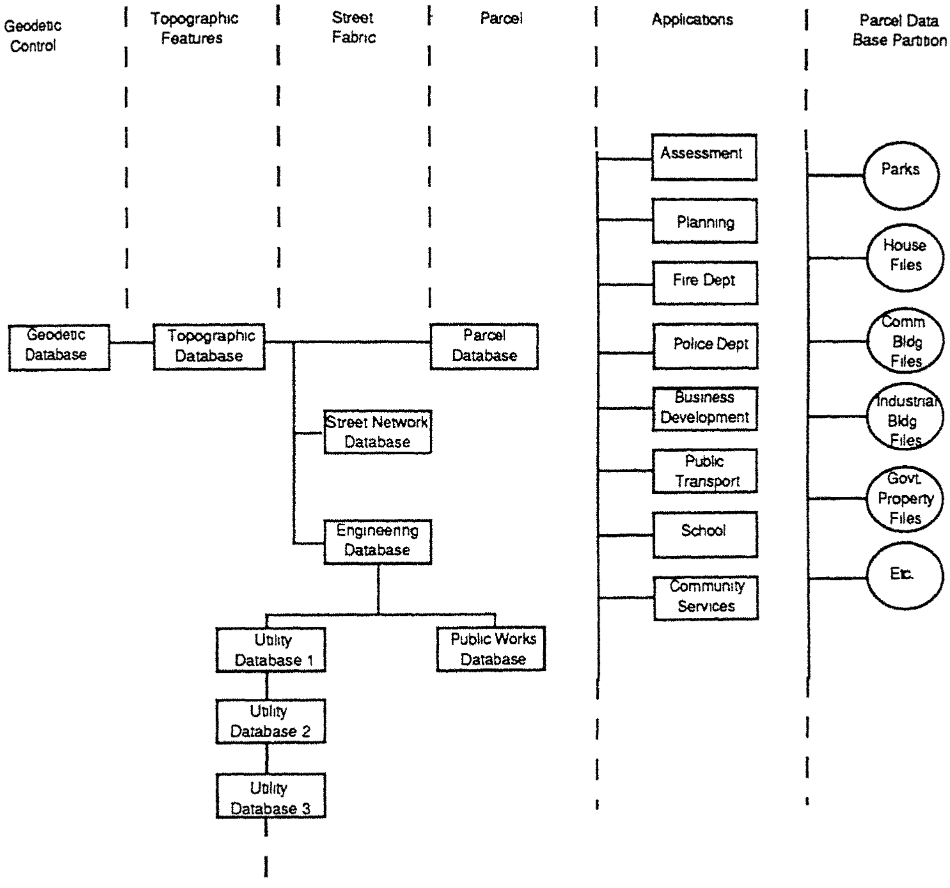

Figure 2: The Conceptual Model of Urban Information
(Source: Linders, 1983, with slight modifications)

A functional model of digital urban information

The functional model in Figure 3 depicts the operation of an urban information processing environment. This model is concerned with three main types of activities: database load, database access and update, and database maintenance. The data which are required for processing are derived from a variety of sources, including the municipal database, external files and application files. The output may include maps, engineering drawings, reports and tabulated summary statistics.

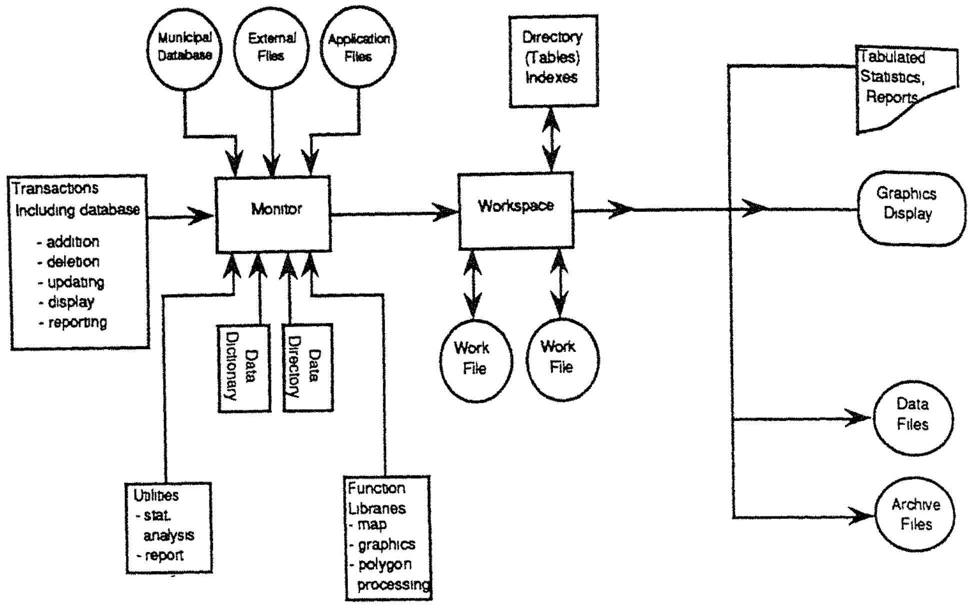

Figure 3: The Functional Model of Urban Information
(Source: Linders, 1983, with slight modification)

Data models of digital urban information

A key difference between a DUTD and the conventional map as a means of storing topographic data is the continuous geographic coverage of the former. A DUTD is not a collection of map sheets, but a common and integrated base for data collected from a variety of sources. A DUTD is therefore always an extremely large data set to which queries are usually made on only relatively small geographic areas that do not necessarily coincide with the boundaries of the origianl input data. In order to facilitate access to the database, it is essential to organize explicitly data elements and to define their interrelationships. This is achieved by using one of the many data models designed for such a purpose (Yeung, 1988).

As the technology stands today, the relational data model is the most flexible and effective for geographic information system applications. In a relational data model, data are organized in a table or relation which indicates a match between two or more entities. A database employing the relational data model can be thought of as a set of tables, with each table representing specific types of relations (Figure 4). The major advantages of the relational database are its simplicity and efficiency. In this model, the relations are expressed explicitly, eliminating the need for cumbersome pointer manipulations used in the hierarchical and network models. A wider range of query applications is also possible. The major drawback of the relational model is the large storage requirement that results from redundancies in data entries. However, this is becoming less problematic due to the rapid reduction of storage costs. Consequently, this data model is gaining importance in practice.

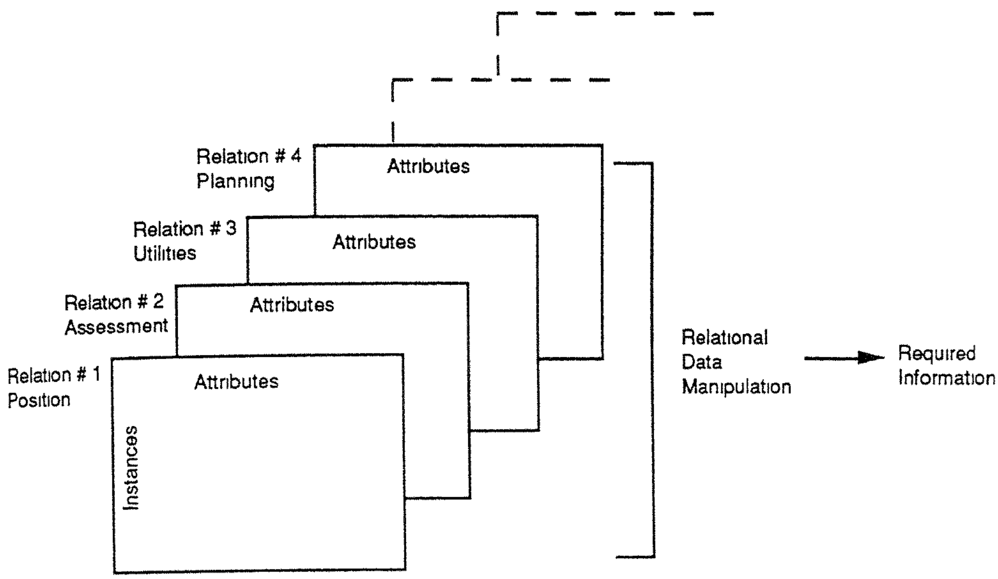

Figure 4: The Relational Data Model of Urban Information

APPLICATIONS IN URBAN PLANNING AND MANAGEMENT

The culmination of the above decisions, which must be made in the course of DUTD design and content, is an evaluation of the **networth** of the final product. In this case networth cannot be defined according to any complex cost-benefit formulation, as no such accounting mechanism can capture accurately the direct and indirect costs incurred in database development and the same savings in database use. Rather, networth can be simply and more informally defined as the difference between the total nonmonetarized costs invested in the care with which a database has been designed and collected minus the nonmonetarized savings derived from the ease of performing standard applications. In general, the more care taken in database design, the greater the ease of use and the greater the networth of the DUTD base. In the case we discuss in this paper, we are interested in two primary areas of database use, namely, database search and retrieval of information and database inventory and modelling capabilities. Each of these applications is now discussed in the context of urban planning and management.

Inventory and Retrieval

Database inventory and retrieval in municipal information systems are typically focussed on two key elements of the urban infrastructure, namely property parcels and the road/utility network. Tied to these two components are numerous information items pertaining to land ownership, land economics, planning, infrastructure maintenance, statistics and management; in short, the foundations of a multipurpose cadastre for the area in question.

Central to the multipurpose cadastre database is a register of land titles that must be accessible, for planning and management uses, with ease and accurracy. A register of urban property titles usually contains two elements, namely a record of the attributes associated with each land parcel and a description of the land to which they refer. The attributes that should be recorded in a relational database structure include the names of the owners, the nature of the tenure (such as freehold or leasehold), the price paid for the land on transfer, and restrictions the use of the parcel (such as covenants or charges where the land is subject to mortgage), exclusive rights to minerals below the soil, and caveats or cautions hich may require a third party to be informed if any dealings in the land are proposed (Dale and McLaughlin, 1988). Not necessarily present in such a register, but assumed to apply, is a category of overriding interests. These include impositions imposed through town and country planning registration such as local zoning by-laws.

Attached to this parcel attribute or title component of the cadastral database is the actual graphic parcel of land, or the cadastre itself. This may be described in the simplest case as a nongraphic entity. That is, an entity which cannot be depicted in graphic two dimensional form on a visual display unit or plotted in two dimensional graphic form on an output device. In this simplest case a property could be retrieved from the database by a parcel reference number (or record) relating to the house, street and town in which the property is located. The accompanying street address would identify a land parcel whose limits can be determined by inspection on the ground. More often than not, certainly in the context of a GIS based DUTD, such a description is insufficient. Optimally, the parcel description would provide additional information, such as the two dimensional shape and size of the property and, at least, the location of its boundaries. It should also provide information about the relative location of the property by providing information about adjoining parcels. This is best achieved by graphical depiction of property boundaries as an integral component of the cadastral database. From such data it is relatively straightforward to produce a description of property boundaries either in terms of graphically connecting co-ordinate points or by reference to the metes (the bearings and distances between adjoining points).

Since each property parcel in the cadastre is unique, the various methods for describing the limits of each parcel must include an element that refers uniquely to the parcel as a whole. Without such a unique parcel identifier (PIN or parcel identification number) cross-referencing between tables within the digital database itself, and, perhaps, other non-digital registers, becomes practically impossible. Given the PIN number, it should be possible to access all details of the parcel including its attributes and its spatial description.

Of the numerous methods for parcel referencing, Moreno (1984), notes that it is desirable for the method to be:

- easy to understand and maintain
- easy to understand so landowners can recall their references
- easy to use for administrators and the public
- easy to process in the computer
- permanent, so the PIN does not change with the sale of a property
- capable of easy updating
- unique so that no two parcels have the same number
- accurate and error free
- flexible so that it can be used for a variety of purposes from title registration through to all forms of land administratio
- economic to produce and maintain

The compilation of such a register and its converson to digital form has significant short term costs. In terms of total cost, some 50% is typically spent on the survey itself and the preparation of the parcel descriptions. The residual cost is accounted for by database design, data input and maintenance. Most commentators, however, agree that medium term cost recovery in long term savings typically justifies the initial expenditures in database development (Joint Nordic Project, 1987).

Modelling Applications

A cadastral database such as that described above forms the foundation for general land administration by providing land-related information in an integrated form. This allows complex forms of analysis to be undertaken and permits a broader understanding of urban land issues.

The spatial frame of reference employed by a DUTD with its base mapping allows cadastral information to be overlain with a series of files relating various types of information to each parcel (Figure 5). The relationships between the various data types can be modelled statistically and graphically to give answers to specific questions or to evaluate 'what if' scenarios for urban futures.

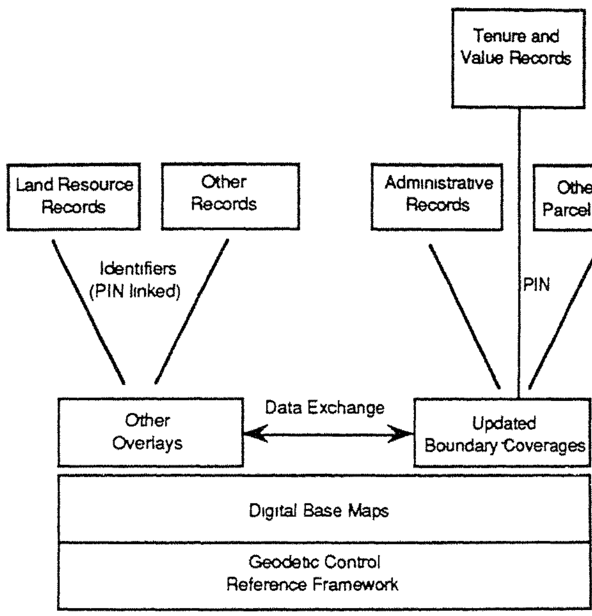

Figure 5: The Components of a Miltipurpose Cadastre

Consider, for example, the case depicted in Figure 6 and Table 1. The data in this simple example can provide information on all themes relating to a given parcel of land; they may provide information on individual themes for all parcels; or the may be combine in relations. Hence, the complexities of urban infrastructure that are land-related can be integrated and processed efficiently within the database concept.

Many types of urban land data can be linked through mapping overlays by reference to x, y co-ordinates or by relations within the database. Data that should be included for case-specific modeling applications cover the following themes: topography; geological and geophysical data; soils; vegetation; housing and buildings; environmentally sensitive areas; administration; areas of historical interest; population; housing and buildings; pollution, health and safety; transportation; water and sewage; gas, electricity and telephone lines; and emergency services among others.

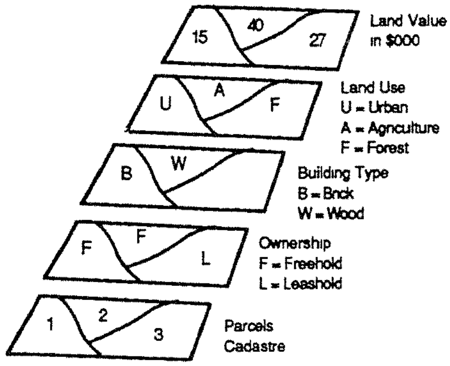

Figure 6: Cadastral-Based Information Layers

Table 1 Relational Records of Property Parcels

Parcel	Ownership	Building Type	Land Use	Value	Abuts
1	F	B	U	15,000	2,3
2	F	W	A	40,000	1,3
3	L	-	F	27,000	1,2

The database can grow in complexity and be adapted to accommodate changing economic circumstances and local needs. As such it is a fundamental entity for efficient and equitable planning and management of the development of urban land.

CONCLUSION

With very powerful data manipulation and information analysis capabilities, GIS have now been widely accepted as an indispensable tool in urban planning and management. A digital topographic database provides the necessary spatial framework within which urban data are cross-referenced and analyzed. The creation of such a database is an expensive enterprise. The design of the database has therefore to be worked out carefully at the stage of system planning. After a system is put into operation, it is important that the topographic database is properly maintained to safeguard the quality and integrity of the data.

Urban planners and managers should have a good understanding of the principles and techniques of spatial database design. This will enable them to play a more active role in the development of information systems that fulfill their needs more efficiently, effectively and economically. The database design concept presented in this paper constitutes no more than a preliminary step toward creating an information system. However, since all future information processing developments within an urban planning agency are contingent upon initial decisions we reemphasize the importance of the above considerations in system design and applications.

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BRISBANE CITY COUNCIL DIGITAL MAPPING SYSTEM: A MAJOR TOOL FOR URBAN PLANNING AND MANAGEMENT IN BRISBANE

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ABSTRACT

The Brisbane City Council is undertaking a major project to replace traditional manual map drafting methods with an innovative digital mapping system This new system is more flexible, cost effective and accurate and provides faster access to up to-date information

A Planner at a graphic work station can for example access data from different sources such as the cadastral base water supply drainage and flood information and combine these to form new maps as required for any Planning Project Hard copy can be produced in minutes for analysis or display

The Project s first major milestone was reached in 1986 when over 500 digitised maps were produced for the new Town Plan These maps are tangible evidence of the system s capacity as a major tool for Urban Planning and Management in Brisbane

BRISBANE

Brisbane is one of the largest and most diverse City Councils in the world It covers an area of some 1220 square kilometres and provides services to almost one million people

These services include buses and ferries traffic control facilities street lighting water supplies, sewerage, heritage protection flood mitigation, pollution control, town planning, roads, engineering, parks and libraries

A number of municipalities were amalgamated in 1924 to form the Brisbane City Council This enables the Council to take a corporate approach to land use planning and the provision of services

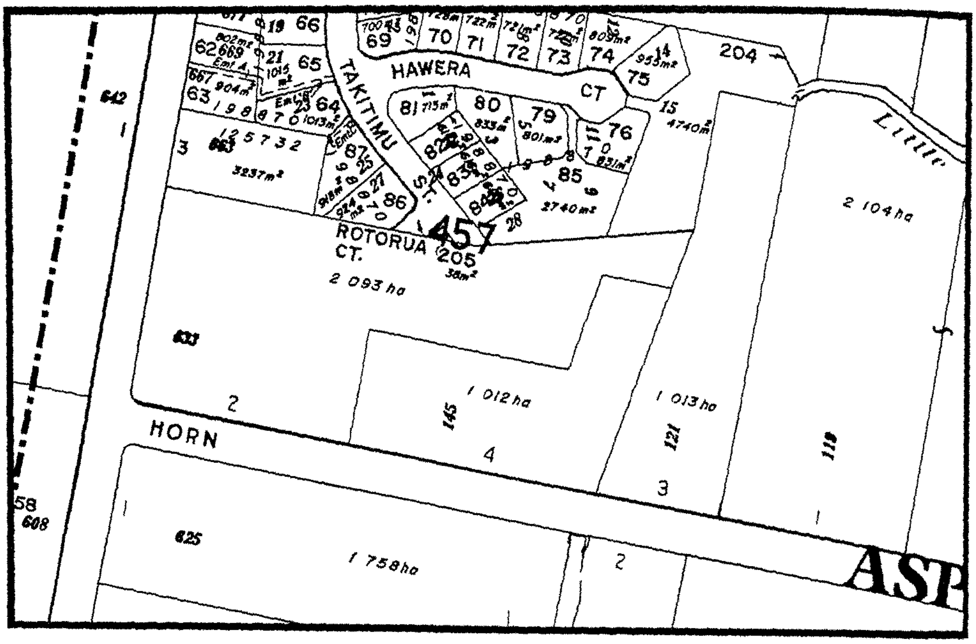
In recent times Brisbane has captured international attention by staging the Commonwealth Games in 1982 and its bid for the 1992 Olympic Games Last year it hosted World Expo 88 In 1992 Brisbane is the venue for the International Lions conference

As well as prominence on the world stage it is also at the forefront in the application of modern mapping technology Residents visitors and prospective businesses all benefit from the installation of an Intergraph Land Information System (L I S) with graphics capability The L I S developed by the Brisbane City Council is one of the most sophisticated mapping and computer information systems used by a local authority anywhere in the world It is proving to be an invaluable tool in the planning and management of the City of Brisbane

THE DIGITAL MAPPING PROJECT

The project began in 1982 when the Council committed itself to the introduction of a digital mapping system The decision evolved primarily from a need to convert thousands of imperial scale maps to a uniform metric standard Map replacement was a pressing issue with many maps more than 40 years old and deteriorating rapidly (Figure 1)

FIGURE 1 Typical map in need of replacement



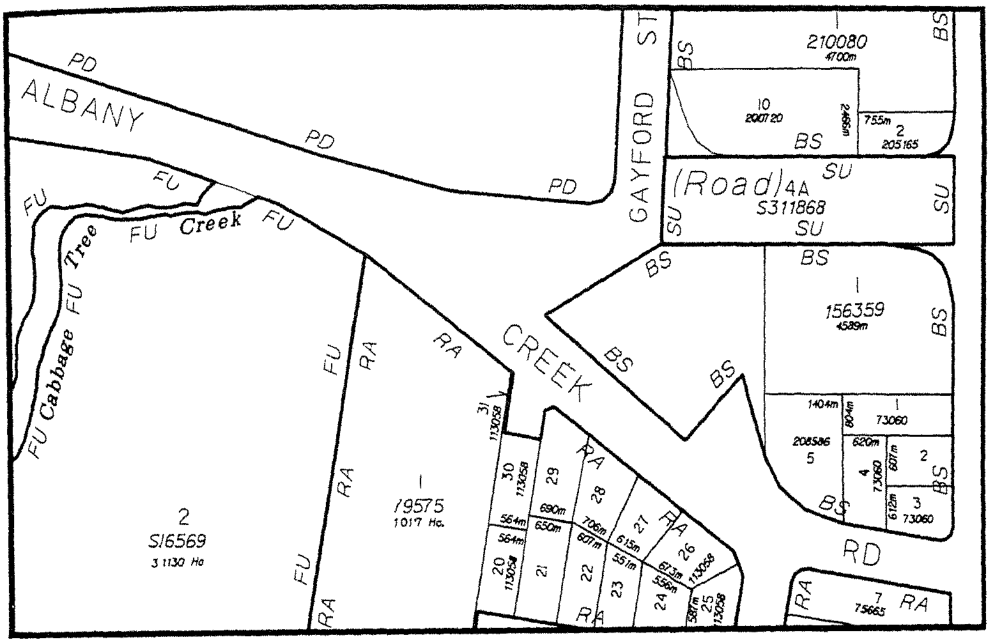
In Brisbane there are more than 300,000 individual land parcels, of which 238,000 are rateable To administer these properties, manage utilities and provide services to the public, the Council needed more than an updated drafting system It needed a system that would link the graphical representations to the administrative and financial systems

As well as being able to handle huge amounts of data, rationalise property information and metricate existing cadastral maps, the system needed to be affordable and practicable A manual system was out of the question - it had been estimated that it would take more than 200 man years to metricate the cadastral maps and more than 400 man years to replace all other old maps

The Council considered its options and decided that the most efficient and cost-effective solution was to use an automated mapping and facilities management system Tenders were called and Intergraph Corporation Pty Ltd was awarded the contract in June, 1983. Development work began when the system was installed five months later

The BCC's cadastral map base was digitized by the state government's Department of Geographic Information in 1986 and updated in 1988 The first milestone occurred in July, 1986 when a complete set of 553 digitized town planning maps for the City of Brisbane was displayed as part of the new Town Plan (Figure 2)

FIGURE 2   A digitized Town Plan Zoning Map



Project Objectives

The project was required to achieve a number of objectives These were

- Convert thousands of existing maps from imperial to metric
- Maintain all maps and attribute data in digital form
- Provide tools for data analysis
- Give users access to the system through a network of review terminals
- Contribute to the development of an integrated Council-wide land information system
- Provide instant up-to-date information to the public
- Reduce costs

Capturing data is often the most time consuming task anyone faces when converting to a computerized system Usually the first few years of any L I S program are spent on putting the necessary information into the system

At the moment the Brisbane City Council is almost halfway through an estimated 160 man years of data capture Currently, there are 40 staff using the Intergraph equipment in two shifts per day The total project should be completed by the end of 1991, but a number of sub-systems are already operational and in daily use The majority are in the Department of Development and Planning at this time due to the necessity for the Project to commence with the digitizing of that Department's cadastral maps as the basis for most applications

The financial stakes are high and this has led to enormous pressures on system design decisions and early implementation of system functions It is important to organise tasks so the greatest savings and biggest advantages are implemented first to get early returns on investment Users are keen to use their sub-systems as soon as data capture for their area is completed and the Council is equally keen to see that it is getting something for its money at an early time

After each sub-system has been implemented, manual maintenance of maps and records is discontinued and replaced by the automated system

Cost Analysis

The estimated cost of Brisbane's LIS is $14 million Over the eight year implementation period this is $14 per head of population or $47 per land parcel The project offers on-going benefits for short term cost The map data stored on the system will serve Council officers and ratepayers well into the 21st century

"Making the system pay" is the focus of the project's management Performance measures are drawn from

- The cost of preparing maps using traditional drafting measures compared to automated map production
- The cost of maintaining the current map series by manual drafting compared to maintaining maps in a digital format
- The time required to answer public counter enquiries by referring to old maps and records, compared to automated system enquiries

Substantial savings will be realised in all areas The revenue earning potential of the system is also being examined

At the moment costs are being offset by selling maps and data to other organisations In the future, it is planned to sell reports and documents produced on the system

Intelligent Maps

As people realise the system's potential, the demand for maps is growing As well as the traditional maps such as the Town Plan maps, new maps that weren't available in the past are becoming available

Recently, a request was received for a coloured map showing the generalised distribution of land valuations in Brisbane This involved assigning colours to a range of valuations and generating a map file with parcels coloured according to their valuation Before automated mapping, this task was unthinkable because of the human effort needed to collect the data and hand colour 300,000 parcels Now, with the aid of modern technology, this task can be completed within a few days and any number of copies of the map produced, all in 'original" condition

Integration

About 80 per cent of transactions, revenues, expenditures and other Local Government management functions are tied to geographic locations, making the integration of land information of major importance

Users are not interested in where the data is stored - in the Unisys land database or in the Intergraph database They want instant access to all information Council has already made some progress in this area Officers can key in a street address, and within 15 seconds a map extract is displayed on screen They can also point to a land parcel displayed on the screen and Rates or general information about that property is displayed on the screen Within a couple of minutes this information can be printed out for use or given to the public

DEPARTMENTAL APPLICATIONS

The system s development and usability relies on the expertise of the in-house users who know their data and their functions Their knowledge of the system's capabilities is essential to its successful implementation It is important to note, however, that a knowledge of the technical details of the system is not required, merely an understanding of what it can produce

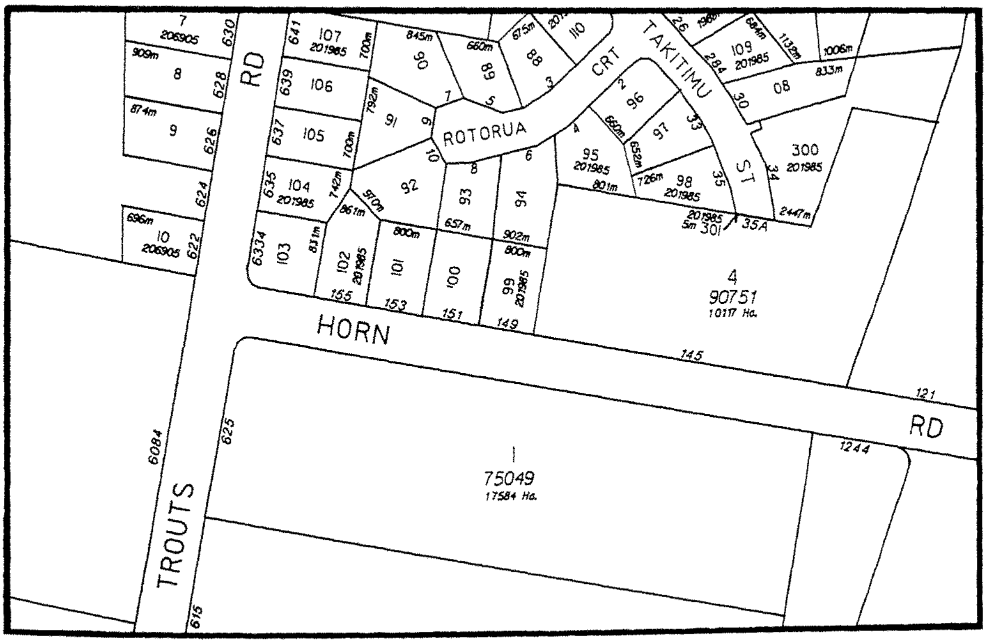
Department of Development and Planning

Town Planning Branch

The Town Planning Branch prepares and reviews strategic, statutory and urban design plans for the city and selected areas It is also responsible for the compilation and maintenance of up-to-date cadastral base maps for use by the whole Council, town planning maps and land data maps These latter maps contain information about land ownership, designated house numbers planning restrictions and development applications While the town plan maps have been maintained in digital form since 1986 the digitization of land data maps was begun only recently

Digital mapping has substantially increased the responsibilities of this Branch and the services provided by it It now receives the digital cadastre from the Department of Geographic Information which it enhances and then produces aesthetically pleasing maps in a variety of scales (Figure 3)

FIGURE 3 A digitized cadastral base map



Also, in February, 1988, a digital mapping service was commenced which provides custom made maps, plans and diagrams. These are requested by the various teams of Town Planners preparing a range of Plans or to assist in assessing development applications. This relieves the Planners of much otherwise tedious and time consuming work and provides high standard display material.

Property attribute data collected by other authorities or other branches of Council for administrative or financial reasons are being used to generate coloured thematic maps based on the cadastre for strategic planning purposes. Data gathering and colouring of these maps in the past have been labour intensive or beyond available resources.

Printed reports combining ownership, land use and development application details and status are initiated by placing a fence around the study area using the cadastre. (The Intergraph system actually stores one enormous map of Brisbane, any chosen part of which can be displayed or printed. No longer is the map user confined to predetermined maps which have to be physically joined together after printing.)

The service is also available to the general public. Real Estate agents have been particularly quick to recognize the potential of this service.

Councils in Queensland are required by State Government to collect a levy to pay for the State funded fire brigade services. Each property has been inspected and allocated a fire service code from a list of 162 codes which are based on land use. A land use map is thus produced by each land parcel in the cadastre being colour filled according to a colour table allocated to 14 groups of the fire service codes. Inspections are ongoing and are updated from the Council's computerized Development and Building System.

An alternative land use code is also provided by the Valuer General for valuation purposes. The four digit Valuer General's land use code provides a better breakdown with the option of secondary uses. Unfortunately updates are not frequent.

The ability to produce reasonably detailed land use maps over a 1200 square kilometre area, at will, has been a major additional benefit of the Digital Mapping Project.

A commercially printed coloured Zoning map of Brisbane City at a scale of 1:50,000 is now also being sold to the public. The 4 overlays for printing 30 colours came from a laser plotter and the digital data was processed from the same digital data maintained on Intergraph for production of the statutory Town Plan Maps at 1:2,500. This new map is of extremely high quality and is proving very popular. It shows at a glance, in detail, the Town Plan zoning of the whole of Brisbane. The last time such a map was produced, it took 2 people 3 months to hand colour 1 copy.

The mapping section is divided into four areas: system development, data capture, data maintenance and mapping. As the manual data maintenance is phased out, manual drafting staff are trained in digital mapping techniques. This has enabled the Council to improve its mapping service without increasing the number of staff employed.

Traffic Planning Branch

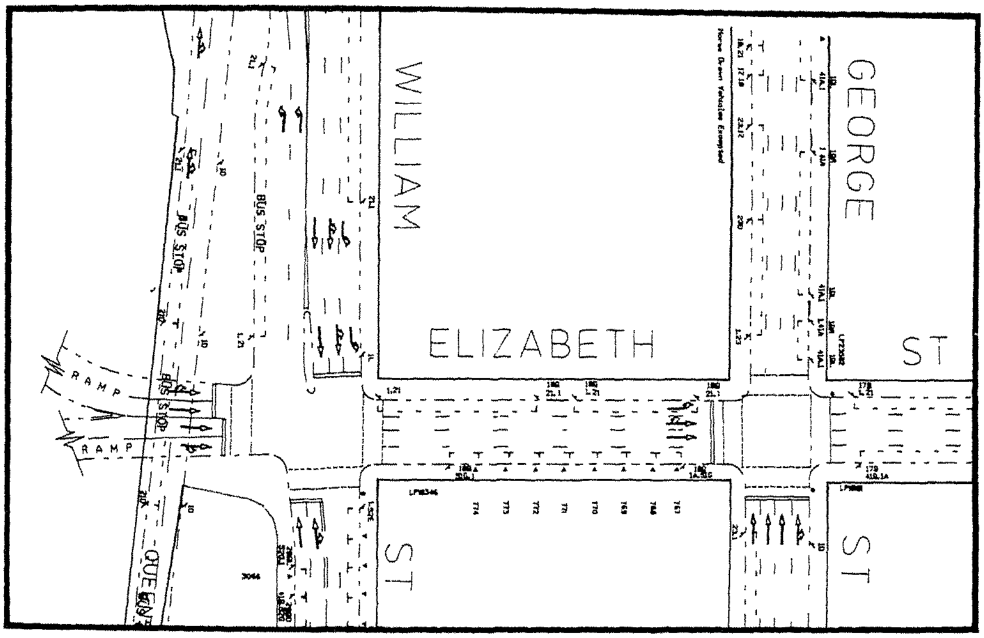
The purpose of this Branch is to develop a safe, efficient and clearly defined traffic system for the residents of Brisbane. The Branch is responsible for the design, installation and maintenance of the various aspects of traffic control. This includes intersection design, traffic management schemes, pavement marking, traffic signs and signals, parking in the central traffic area, kerbspace allocation, traffic counts and road widening proposals. The digital mapping system is assisting with the management of Brisbane's traffic system and is improving productivity.

About 200 solicitor's enquiries are received each day relating to road widenings. Under the manual system each enquiry needed to be looked up on the four chain to an inch map set. Each enquiry took between one and two minutes, a total of five man hours per day.

As well as graphical representation, the digital system flags each land parcel with road widening status. From an alphanumeric terminal the database is searched for a keyed-in land parcel. Its road widening status is returned in 30 seconds - a saving of more than three man hours per day.

Kerbspace allocations, parking restrictions, parking meter locations and information designating different parking types are also stored in the system. Each graphic element has a database occurrence containing information such as the length of kerbspace allocated, parking type, parking meter number and other relevant information. (Figure 4)

FIGURE 4 Kerbspace Usage and Linemarking



Under the manual system, statistical analysis of kerbspace usage was a difficult and time consuming process. It required each of the kerbspace allocations to be measured from a set of 1:500 scale plans. This could take four to five hours. The digital system stores all the lengths of kerbspace allocation types in a database attribute, enabling reports to be generated in minutes.

The linemarking system being developed will be able to generate reports that outline the linemarking maintenance schedule for the Branch.

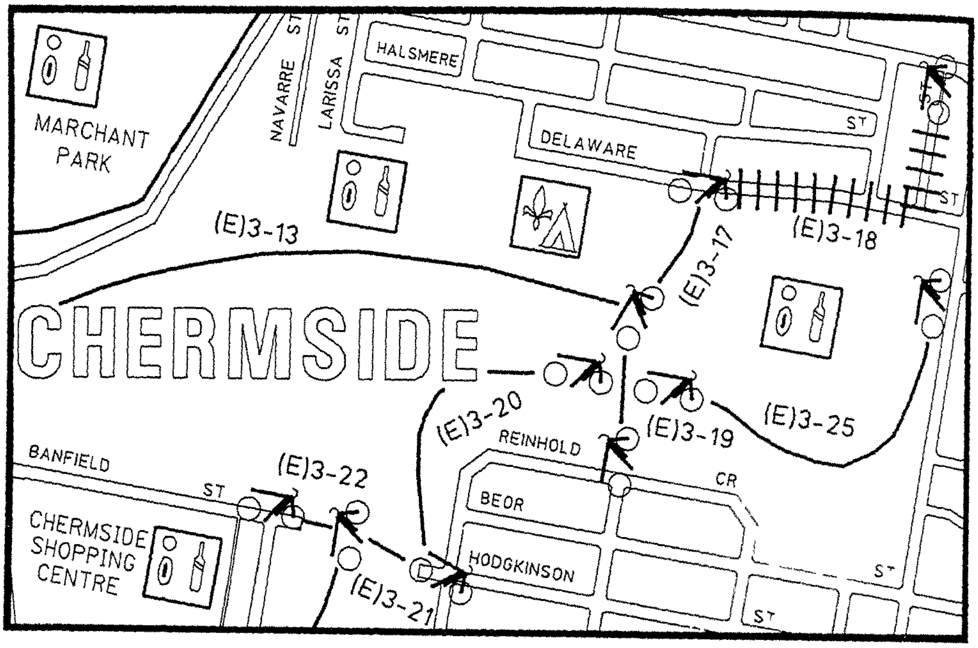
The traffic sign system will enable fast answering of solicitors' enquiries regarding the installation of signs at specific dates (two years of historical records are kept). On average, 1500 signs are repaired or replaced each month This 30 second enquiry can otherwise take up to one hour if maintenance cards need to be searched manually

Department of Works

This Department is responsible for the design, construction and maintenance of engineering works in the broad fields of drainage, road works and bridges

It is also responsible for street lighting and surveying and provides a flood information service Some of the information captured on the digital maps includes stormwater drainage, historical flooding records, location of survey marks and bikeway routes (Figure 5)

FIGURE 5 Brisbane Bikeway Plan



Data Capture

A number of specially designed menus and tutorials enable operators to input graphics and automatically generate database occurrences with the correct hierarchical relationships

System identifiers placed in each occurrence allow for later bulk loading from data files at alphanumeric terminals

The large partitioned database base is maintained by the database forms language command library, using DMRS find and change commands Database partitions correspond to the multi-faceted areas of the cadastral base

Procedures to further integrate the Council's Unisys land database and Intergraph utility files are under development Property flags indicating flooding, proposed easements and stormwater drainage will be loaded into the land enquiry and rating system

This will greatly speed up the processing of development applications and property conveyancing

Benefits

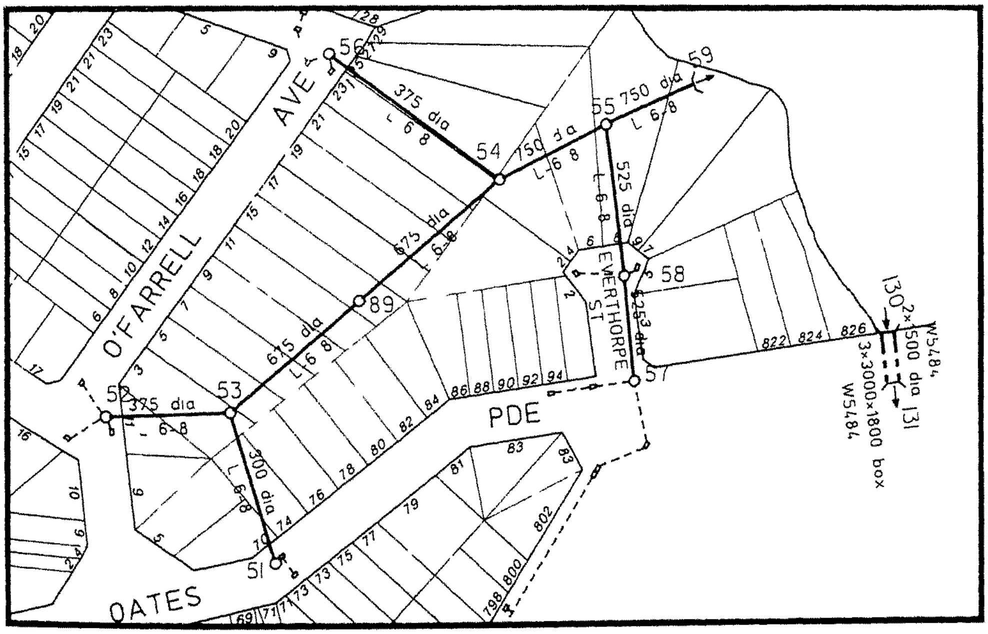
Under the present manual map system conveyancing and land enquiries within the Department can require a search of three or four different plan sets

In this case every enquiry (about 200 per day) takes between four and seven minutes, about 17 man hours per day to search Under the ' one stop ' computer enquiry system, the information will be available within two minutes This reduces search time to seven man hours per day, a manpower reduction of 58 per cent

Other benefits such as drain maintenance and construction scheduling are not available under the present paper map system The digital map system will enable reports and plot locations of badly silted and structurally damaged pipes to be prepared These can then be referred to the Maintenance Branch or tagged for future reconstruction under the current Unisys cost scheduling system

The ability to plot overlays of various maps (eg stormwater sewerage zoning and water supply) will lead to further improvements in engineering investigation and design (Figure 6)

FIGURE 6 Stormwater Drainage Plan



Department of Water Supply and Sewerage

This Department supplies water to Brisbane and some surrounding Shires from three treatment plants and 39 service reservoirs via 429km of trunk/distribution mains and 4,630km reticulation mains. Wastewater is drained from 251,000 properties through 5,600km of sewers and 176 pumping stations to 15 treatment plants.

On average, 52km of new water mains and 68km of new sewer mains are laid each year to extend and maintain the existing systems. The oldest mains still in service are water mains laid in 1877 and sewer mains laid in 1919. More than 75 per cent of the Department's records are in imperial measurements and scales. Most are as old as the installations they represent.

Staff at depots, supplied with microfilm or paper copies of some sets of original maps and plans presently make telephone, fax, radio or messenger enquiries to obtain further or more current information.

Graphical information is being captured for both water supply and sewerage systems by redrawing and digitizing the data. Non-graphical water supply data is being collected onto coding sheets for bulk loading to the database. Non-graphical sewerage data is being entered on PCs and transferred to VAX as ASCII files to be converted and loaded to the database. The department is using two shifts of staff to complete the initial data capture over a five year period.

Due to the time involved in the capture phase, it is necessary and desirable to release the digitized data for general use in stages. Some sections of the existing and new systems will be maintained in parallel during this period.

Maintenance requirements for troublesome water and sewerage mains will be more accurately predicted before a burst or blockage occurs. This will save call out time and inconvenience to the public as maintenance can be planned for low usage periods.

Poor pressure, dirty water and sewerage surcharge problems will be easier to investigate. The database will quickly provide information about water and sewerage mains in the area including levels, ages and maintenance records.

The system will provide up-to-date metric information and improved access times to depot staff, ratepayers, developers and the general public.

Department of Recreation and Health

This Department is beginning to use digital mapping to more effectively administer and maintain the city's parks, libraries, health, sport and recreation facilities.

Department of Transport

This Department maintains information about bus routes, bus stops and bus zone boundaries on the digital mapping system.

This data enables residents to locate their nearest bus stop and see which bus routes service their area.

Other Council departments can use the system to schedule their maintenance work to minimise disruption to bus services.

FUTURE USES

The demand for accurate, up-to-date information is increasing and the Brisbane City Council is constantly expanding its services to cater for this. Plans are now underway to extend its computer network to more than 30 locations throughout Brisbane.

The Council's system will be a vital part of the state-wide land information system based on a hub concept. Progressively, the L.I.S. hub will link all sources and users of land information enabling data to be shared by all who need it.

When the system is fully operational, services will be improved to ratepayers, Council officers, planners, engineers, designers, architects, managers, surveyors, solicitors, developers and people in business.

The system is being implemented progressively and is having a significant impact on the Brisbane City Council's operations and the services provided to the public. The ability of the Council to adequately Plan and Manage this large and complex city has been greatly enhanced by the introduction of this digital mapping system. Already great benefits have been achieved and new applications identified that are well beyond the scope of the original Digital Mapping Project.

As the demands of the 1990s and the year 2000 approach, Council will ensure the potential of the system is fully realised, not only for map production, but also for on-line enquiries, data analysis and Urban Management generally, which will result in cost efficient government to the benefit of all.

APPENDIX

Hardware

Processing units VAX 8530 with 80Mb memory and a VAX 11/785 with 40Mb memory, 27 colour graphic workstations, eight InterView dual screen colour workstations - most with high precision digitizing tables, four Interpro single screen colour workstations, two InterAct 32C colour workstations, four InterPro 32C's, eight InterPro 32 and one InterPro 120 single screen colour workstations, 4.5 gigabytes of disk storage, three tape drive units, 12 alphanumeric terminals with desktop printers, two HP/7585B pen plotters, three Versatec V80 electrostatic plotters, two laser plotters and one colour thermal plotter.

Software

DMRS, IGDS, ACTEM, MicroStation, GPPU, DGS, RANG, HLIN, IPS, 3271 emulator to communicate with Unisys 1100/92, DataView, ISIF Converter.

THE APPLICATION OF LAND INFORMATION SYSTEMS IN PLANNING IN WESTERN AUSTRALIA

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The overall objectives for establishing the State Planning Commission's Industrial and Commercial Land Information System for the Perth Metropolitan Region are to:

i) Provide an accurate assessment of land zoned and/or used for industrial and commercial purposes.
ii) Ensure that a dynamic and compatible system is maintained in which land information can be stored, accessed and updated on a continuing basis.
iii) Establish a data base to assist in the review of strategies and policies for the optimal location and development of Industrial and Commercial activities.

Over the last four years the Commission has developed and implemented a comprehensive Industrial and Commercial Land Information System. This system contains some 40 variables including information on land use, land title details, floor space and employment for approximately 50,000 land uses. The Commission undertakes a bi-annual resurvey of Industrial and Commercial complexes and/or activities within the Perth Metropolitan Region and because of the various efficiencies which have been built into the monitoring system re-surveys can be completed on the basis of approximately 15% of the original survey costs.

This system is now recognised as the most comprehensive Industrial and Commercial land data base currently utilised in Australia today. This system was designed to not only benefit the Commission and other Government agencies but also to allow easy access to the private sector for such purposes as business feasibility studies, land development, land use information and commercial real estate research. This land information system was also implemented with an idea of establishing a charging system (or credit for contribution) for release of selected data without compromising confidentiality and to allow for a contribution towards the data collection and maintenance costs.

The benefits which have accrued to the Western Australian State Planning Commission from the establishment and maintenance of this land information system have been numerous. However, more importantly the data which has been collected and stored offers many benefits and advantages to other users such as:

- consistency and accuracy;
- low cost collection and maintenance;
- flexibility to different types of users;
- development and integration of other user applications;
- sharing and linking with other computer systems.

The methodologies and techniques used to establish the Commission's Land Information System are a substantial innovation in computerised Land Information Systems using the latest technology available. Most importantly these type of systems provide mechanisms which facilitate the accessibility of information as well as allowing for the maintenance of data bases for both Industrial and Commercial land within the Perth Metropolitan Region.

Information Systems are powerful mechanisms for marshalling and interpreting data. However, the success of the implementation of the Commission's land information systems will ultimately be measured by the impact it will have on assisting both the government and the private sectors in their decision making processes.

PLANNING AGENCY EXPERIENCES WITH AUTOMATED MAPPING AND GEOGRAPHIC INFORMATION SYSTEMS

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PLANNING AGENCY EXPERIENCES WITH AUTOMATED MAPPING AND GEOGRAPHIC INFORMATION SYSTEMS

ABSTRACT: Within the past decade powerful computing tools have been developed for producing maps and manipulating geographic information. These systems include geographic information systems (GIS), computer-aided design (CAD) and thematic mapping packages. Since these systems perform a number of functions that are quite useful in urban planning applications, various types of computer assisted mapping systems have been incorporated into planning practice. Past research by the authors shows that a significant number of local planning agencies in California either had or were planning to implement some type of mapping system in 1989 or 1990. The experience of agencies that have already developed automated mapping systems can greatly benefit those just beginning to move into this new technology. To document current agency experience with developing and using various types of mapping systems and to more carefully describe the characteristics of the systems now in use, a mail survey of city and county planning agencies in California was conducted in March 1989. Based on the results of this survey we show that there are a large number of minicomputer systems and stand alone microcomputers used for mapping purposes by these planning agencies. We show that a majority of the systems in place are some type of GIS and that most of the thematic mapping packages are in agencies with larger systems. We identify the major software packages being used in California planning agencies and attempt to see how hardware and software configurations are changing over time. Land parcel mapping and traditional planning tasks related to the general plan appear to be the most important urban planning applications of these existing mapping systems. We also explore implementation and development problems encountered by the agencies based on hardware, software and institutional factors. The respondents were either very pleased with their investment in this technology or thought it was too early to tell. A few had experienced some cost overruns, generally in the area of base map preparation or attribute data acquisition. The results reported here are intended to serve as a guide to those planners who may be considering or are now undertaking the development of a mapping system.

Introduction

Interest in automated mapping and geographic information systems has been rapidly increasing among city and regional planners in the United States in recent years. To better understand the role of geographical information systems and automated mapping in public planning agencies and to provide useful insights for those firms and agencies likely to be considering some type of mapping system in the near future, the authors undertook a mail survey in March 1989. The purpose of this paper is to provide an initial summary of the results of that survey. This is the third in a series of surveys undertaken by the authors to track the adoption and use of computing technology in urban and regional planning.

Based on the results of a more general survey conducted in February 1988, a list of California city and county planning agencies thought to be using or developing some form of a computer mapping system was extracted[1]. From this list 36 agencies indicated that they currently had some form of computerized mapping system in operation. The responses received from this sample of California city and county planning agencies are reported in this paper[2] .

The procedure used to identify the study population produced a fairly comprehensive list of agencies that are currently using these systems, but since the sampling is based on the 1988 survey responses, the newest innovators may be somewhat underestimated. Those that have recently purchased fairly inexpensive mapping programs which may not have been anticipated in 1988 may be particularly underrepresented. Therefore, the sample is probably already dated with respect to some of the most recent technology innovations (e.g. graphics workstations). This data can therefore be seen as a snap shot of automated mapping use in California planning agencies in a single point in time. Such problems are common when dealing with a rapidly changing technology, so the reader is encouraged to view the data in light of these limitations.

The recency with which automated mapping and geographic information systems have entered the planning arena is demonstrated in Table 1. Well over half of the respondents had acquired their mapping systems in 1987 or later. Thus, it appears that any description of mapping systems in urban planning must realize the current volatility in the hardware and software base. Continued rapid change seems to be likely in this area for the foreseeable future.

Table 1. Mapping System Acquisition by Years

	Number of Agencies	Percent of Agencies
1982 or earlier	4	11.8
1983-1986	10	29.4
1987-1989	20	58.8

N = 34

In the following sections we first describe the configuration of the systems being used by these planning agencies. This description characterizes the types of hardware and software

[1] For a more detailed discussion of the overall use of computers in planning agencies, see French and Wiggins, 1989.

[2] This research was supported by Lincoln Institute of Land Policy and California Polytechnic Sate University.

used. We then consider the types of applications being pursued by the agencies and the characteristics of the staff operating the systems. We then turn to the question of system development including data acquisition, institutional linkages and particular problems encountered in building the systems.

System Configuration

There is a wide variety of hardware and software available to support mapping activities in a planning agency. Such systems can range from thematic mapping packages which cost less than $1,000 and run on standard microcomputers to systems costing many thousands of dollars and requiring a dedicated minicomputer.

There are several kinds of hardware configurations available for an agency to choose from. The most common type of hardware configuration found in the agencies surveyed is stand alone microcomputers (63.9% of the agencies). The second most common hardware configuration is mini/mainframe systems. Overall graphics workstations were not widely used, even though it is clear that many of the vendors intend for this to be a major hardware platform for GIS and CAD applications in the near future.

This is clarified if we consider for a moment how system configurations are changing over time. Using the adoption variable discussed earlier, Table 2 characterizes hardware configurations for three distinct time periods. Clearly, the number of agencies selecting minicomputers has declined markedly in recent years. Microcomputers show a long history of mapping applications in these planning agencies and continue to play a major role in computer mapping hardware environments in the most recent time period. The proportion of graphics workstations used in mapping applications had not shown a strong upturn at the time of the survey, but in the future these machines may attract some of the agencies who would have used a minicomputer in an earlier time period.

Table 2. Hardware Configurations by Time Period

(Column Percentages Shown in Parentheses)

	1982 or[1] earlier	1983-1986	1987-1989
Minicomputer	3 (75)	6 (60)	5 (25)
Microcomputers	3 (75)	8 (80)	15 (75)
Graphics Workstations	1 (25)	1 (10)	4 (20)
Other	0 (0)	2 (20)	1 (5)
	N=4	N=10	N=20

[1]Note: Percentages do not add to 100% due to multiple installations in some agencies

Fully 69% of the agencies were using some type of geographic information system to support their mapping activities. This is rather surprising given the relatively high cost of such systems. The lower end systems showed much less penetration into public planning agencies. While only 33% of the agencies are using a CAD system, thematic mapping packages could muster only 19% of the agencies. Although Duecker (1987) and others have clearly pointed out the advantages of GIS over CAD systems, a number of authors have shown that CAD and thematic mapping systems can be very useful in some specific applications (Wiggins, 1986; Landis, 1986; Brown and Schoen, 1987).

A total of 25 of these agencies had acquired some kind of geographic information system. As Table 3 shows the GIS market currently appears to be very fragmented. Surprisingly, the most popular type of GIS package was not one of the commercial packages, but custom software. Of the GIS packages, ARC/INFO was the most frequently used with 20% of the installations. The microcomputer version of this package accounted for another 8%, giving the software in both forms a substantial market share. It is interesting to note that agencies either had the minicomputer or the PC version of ARC/INFO; none of the agencies had both versions. Most of the remaining GIS packages were used by only two or three agencies. A number of well known mapping packages were not present at all in our survey. One can only assume they are being used in other parts of the country or are being used by other types of departments (e.g., tax assessors or public works) not included in this study population.

Table 3. Market Share of Various GIS Packages in California, 1989

	Number Using	Percent of Agencies[1]
Custom Software	7	28
ARC/INFO (Mini)	5	20
PC ARC/INFO	2	8
Intergraph	3	12
Vango	2	8
MacDonnell Douglas	2	8
Ultimap	1	4
LandTrak	3	12
URS Geographics	2	8
MapGraphix	1	4

N=25

[1]Note: Percentages do not add to 100% due to multiple installations in some agencies

The computer aided design and thematic mapping markets appear to be less fragmented than the GIS mapping. AutoCAD clearly dominated the CAD installations with 50% of the 12 installations reported by our respondents. Atlas*Graphics similarly dominated the thematic mapping category with 57% of the thematic mapping installations in this sample. With one exception the thematic mapping packages were being used by agencies which also had a more powerful CAD or GIS system.

Table 4 shows how the software chosen has varied somewhat over time. From these data it appears that custom software is declining and being replaced by microcomputer based systems. Although many of the recent acquisitions seem to be microcomputer-based products, ARC/INFO and Intergraph still seem to be selling their minicomputer based systems quite well. Two of the newer systems (MacDonnell Douglas and Ultimap) are designed to run on a graphics workstation.

Table 4. Software Selections by Time Period

(Column Percentages Shown in Parentheses)

	1982 or earlier	1983-1986[1]	1987-1989[1]
Custom Software	2 (50)	2 (20)	3 (15)
ARC/INFO (Mini)	1 (25)	1 (10)	3 (15)
PC ARC/INFO	0 (0)	1 (10)	1 (5)
Intergraph	0 (0)	1 (10)	2 (10)
Vango	0 (0)	2 (20)	0 (0)
MacDonnell Douglas	0 (0)	0 (0)	2 (10)
Ultimap	0 (0)	0 (0)	1 (5)
LandTrak	0 (0)	3 (30)	0 (0)
URS Geographics	0 (0)	1 (10)	1 (5)
MapGraphix	0 (0)	0 (0)	1 (5)
AutoCad	1 (25)	0 (0)	5 (25)
Atlas*Graphics	0 (0)	1 (10)	3 (15)
	N=4	N=10	N=20

[1]Note: Percentages do not add to 100% due to multiple installations in some agencies

System Applications and Users

The predominant types of applications being undertaken by these planning agencies were land parcel mapping (61.1%) and related activities such as permit tracking and vacant land inventories. There was also a large amount of use in the area of traditional planning activities such as general plan preparation, zoning review and growth monitoring.Table 5 shows the number and percent of agencies which have undertaken various applications with their mapping systems.

Table 5. Mapping Applications in Public Planning Agencies

	Number Using	Percent of Agencies[1]
Land Parcel Mapping	22	61.1
General Plan Preparation	21	58.3
Zoning Review	18	50.0
Vacant Land Inventory	15	41.7
Monitoring Growth	11	30.6
Census Mapping	11	30.6
Permit Tracking	9	25.0
Transportation Modeling	8	22.2
Environmental Impact Analysis	8	22.2
Facility Management/ Utility Mapping	7	19.4
Event Mapping	6	16.7
Capital Improvement Planning	6	16.7
Natural Resource Inventory	5	13.9
Land Suitability Analysis	3	8.3
		N=36

[1]Note: Percentages do not add to 100% due to multiple installations in some agencies

It is somewhat unexpected that relatively few agencies were using their systems for environmental planning applications such as land suitability analysis, natural resource inventory or environmental impact assessment. It was quite surprising that only 3 of the agencies were doing land suitability analysis, given the popularity of the McHargian paradigm. This is all the more difficult to explain given the large number of users in our sample that had GIS systems with the polygon processing capabilities needed for many types of environmental analysis. The low level of interest in environmental applications warrants further study.

There is a wide range of staff support in the study population. While the average number of full time staff members working specifically with the computer mapping systems is 2.7, staff size ranges from 0 to 22. Only half of the agencies have not found it necessary to hire any new specialists to help operate the systems. Most of the agencies indicated that their staff has been either self-trained (63.9%) or had some type of in-house training (61.1%). Only 16.7% of the respondents indicated that any of their staff had college training in operating an automated mapping system.

Given the expense and complexity of these systems there is often an imperative to share the system with other departments. A majority of the respondents (55.6%) share their mapping system with the public works/engineering department on their jurisdiction. Another 38.9% of the agencies indicated that their mapping systems are shared with the building department. Only 5.6% reported that their systems are shared with the school board or with other levels of government. Many departments expect to begin sharing their systems within the next two years with either fire/police, engineering/public works, the building department or other levels of government.

System Development

A number of problems can occur in implementing a mapping system. One of the most interesting aspects of the survey is to see what types of system development problems the agencies have encountered in building their systems. The respondents were asked to rate their return on investment of funds and staff time in their mapping systems and operations. As would be expected given the recent development of many of the systems, most stated that it was too early to tell (51.4%). Those who were able to evaluate the quality of this investment either thought there were large positive returns (28.6%) or small positive returns (20%). It is important to note that no one in our sample suggested that their system was not a good investment.

As a basis for initial base map construction, most planning agencies are using both assessor maps and planning maps (66.7%). Nearly all of the base maps contained streets (88.9%) and parcel boundaries (86.1%). Features such as topography and soils information are not typically included in base maps, but this may be due to the expense of collecting such data or to a larger lack of interest in pursuing environmental applications..

A majority of the agencies reported that they have had some type of problem in building their system (58.3%). The most frequently cited problems include: Lack of staff and staff training, lack of management support, lack of cooperation, problems with data input and conversion, maintenance of database, difficulty of system implementation, lack of adequate software, complexity of software, and time costs (many indicated that it has taken much longer to implement than expected). surprisingly few said cost overruns had been a problem.

Conclusions

The survey documents a small but vital collection of public planning agencies actively using the new mapping technologies. The rapid advance of this technology and its effects on hardware and software configurations are clearly documented by the survey. Nearly half of the agencies have had systems three years or less. This rapid infusion of new technology is expected to continue and we may well double the number of systems in place again in the next three years.

A large proportion of planning agencies are selecting GIS over other automated systems. The obvious power of these systems makes them desirable, but in the comments section of the survey a number of respondents mention some of the complexity in using these systems effectively. There are a significant number of CAD installations and further analysis will be conducted to see if their applications differ from the GIS users. It is hard to explain the lack of thematic map users. In this group they are largely used to support larger systems.

Quite a few of the agencies are currently using minicomputers. At present the graphics workstation is relatively unimportant. However, some of the newer software packages are intended to run on this platform. The continuing importance of microcomputers in this area is also evident. As these smaller systems get more speed, memory and storage they are becoming more viable platforms for GIS and CAD applications.

Most of the applications tend to be parcel related or tied to traditional plan making activities. These mapping systems do not seem to be widely used in capital improvements programming or utility mapping. This should be explored further in light of the public works department's involvement in mapping in the various jurisdictions. Relatively few agencies are focusing on environmental and natural resource mapping issues. This is particularly interesting in light of the traditional applications of GIS technology. It appears that planners are primarily using this new technology to make plans and to support some administrative activities such as zoning review.

Although there is little evidence of serious cost overruns, staffing and training seem to be fairly common problems. Many of the newer installations say that it is too early to tell if they have made a good investment by adopting this new technology, but those who have made an evaluation of this type indicate that their system was a good investment and is producing positive returns. Let us hope this optimism is warranted by the experiences who may be just beginning the process of developing a mapping system.

Less clear from the survey is the long range impact of shared information systems on urban planning and management. For the first time many of these planning agencies are sharing their system and certain information with a public works department. Many more intend to share their systems with the police and fire departments and other agencies as well. Unfortunately, understanding how the sharing of a common database will affect the practice of urban planning requires careful attention beyond the scope of this research.

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BUILDING OF MICRO-GIS TOOL AND ITS APPLICATION

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ABSTRACT

Establishing geographic information system (GIS) on microcomputer, called Micro-GIS, has been proven fast, practical, economical, and flexible. That is being well accepted by more & more GIS users in the world. One reason for this situation is that the designers and programmers of Micro-GIS Tools have solved and overcome many problems and limitations of microcomputers, which makes it much easier to build GIS on microcomputers. PURSIS (Peking University Remote Sensing Information System—temporal name) is just such a Micro-GIS tool built by us. Supported by PURSIS, some experimental systems have been created since 1987,and some of them are gradually being put into practice.

In Part One of this paper, we will introduce and discuss micro-GIS tool building. Although we have paid great attention to techniques of software engineering, which may be interesting to GIS tool builders, it must be useful and helpful to GIS users, especially to GIS managers. In Part Two, we will introduce an experimental system.

INTRODUCTION

PURSIS is used for collecting, storing, managing, analysing and displaying geographic (or spatial) data and information. When it is organically combined with certain application programs, the thematic Micro-GISs for special problem can be established. Here, we first brief you on some characters of PURSIS:

1. Two kinds of data, vector and raster are used for digit map data. Their relationships can be found in Section 1-5.
2. Run Length Code (RLC), one of compressing encoding methods, is used to less amount of raster. Statistics suggest that the compressing rate for raster can reach about 1:10 on the average. In this paper, although most discussions for digit map processing are based on raster, PURSIS really stores these data, except DEM, in RLC form rather than in raster form.
3. Programs for fast data converting between vector and raster have been developed.
4. COLOUR-136 program can expand 16 colours supported by variours COLOUR / GRAPHICS Adapter, like EGA,CGA,VGA, etc., to 136 colours, which make it easier for users to distinguish from different entities in map with different colours.
5. DTM (Digit Terrain Model) Operation Module provides a lot of functions, such as producing DEM (Digital Elevation Model), making slope map, aspect map, land roughness map, 3-dimetion model, illumination map, profile map, etc.
6. Logical Operation Module have users be able to simultaneously control & process attributes and digit map, which has greatly amended conventional DBMS to perform spatial data.
7. PURSIS library contains a great many of subroutines and functions. They can be directly called by users' programs to access PURSIS data, to utilize most of system functions such as displaying, menu controlling, mapping, etc.
8. Three application models have been provided.
9. In addition to plotter mapping, a fast, economical, flexible,and powerful mapping tool with colour printers has been built.

—— PART ONE TOOL BUILDING ——

SECTION 1. PURSIS GENERAL DESIGNING

The logical design is based on Information System Designing Theory and the tool tasks. The physical design decides data structure & accessing strategy.

1. PURSIS ARCHITECTURE

PURSIS is divided into 8 modules (Fig.(1.1)).

```
           ┌──── Data Pre-processing Module
           ├──── Digital Map Editing Module
           ├──── Attribute Data Base & Management ──────┐ Spatial
           ├──── Operation Module for Graphics Data     │ Database
PURSIS ────┼──── Operation Module for DTM Data          │  and
           ├──── Logical Operation & Analysis Module ───┘ Management
           ├──── Application Models
           ├──── Digital Mapping Module
           └──── Interface Between PURSIS and User Programs
```

Fig.(1.1) PURSIS Architecture

2. BASIC HARDWARE CONFIGRATION

. IBM PC-XT, AT, IBM 80386 and compatibles, with at least 640 KB memory.
. 30 MB or larger hard disk, and two floppy disk drivers.
. High resolution CRT with graphics adapter like EGA, CGA, etc.
. At least two RS-232 ports, and one parallel port.
. 8087, 80287,or 80387 coprocessor had better be installed.
. Digitizer, Plotter, and Printer (Color Printer will be best).

3. COMPUTER LANGUAGES FOR PURSIS PROGRAMMING

We built PURSIS with three computer languages, FORTRAN-77, CLIPPER (compiler of DBASE III), and 8086 / 8088 ASSEMBLER. FORTRAN programs serve numerical calculating, the system mastering, and assembler subroutines invoking. CLIPPER programs are used to manage attribute database & perform Logic Operation along with some FORTRAN programs. In addition, we have studied DBASE file structures so as to create or access DBASE files with FORTRAN-77 programs directly.

4. PURSIS DATA STRUCTURE

(1). Vector data are stored in following structures (Fig.(1.2))

48-word head	
Separate Mark	Arc 1
Left-polygon No.	Right-polygon No.
X1 Coordinate	Y1 Coordinate
......	......
Separate Mark	Arc 2
Left-polygon No.	Right-polygon No.
X1 Coordinate	Y1 Coordinate
......	......
Ending Mark	

(A). Vector Structure for Polygon

48-word head	
Separate Mark	Value of Arc 1
X1 Coordinate	Y1 Coordinate
......	......
Separate Mark	Value of Arc 2
X1 Coordinate	Y1 Coordinate
......	......
Ending Mark	

(B). Vector Structure for Linear

Fig.(1.2) Vector Structures

It is found that arcs are separated, and each of them is as one recording unit. Each unit contains polygon numbers/line value, and x,y coordinates of the arc.

(2). Run Length Code (RLC) Structure

RLC is one of methods to compress raster data. It maps all of points at a line to some pairs of integers. Each pair is called a Run Length (RL), and the first integer in a RL represents value or code of points; the second expresses number of points, called Length. Fig.(1.3) shows RLC data structure:

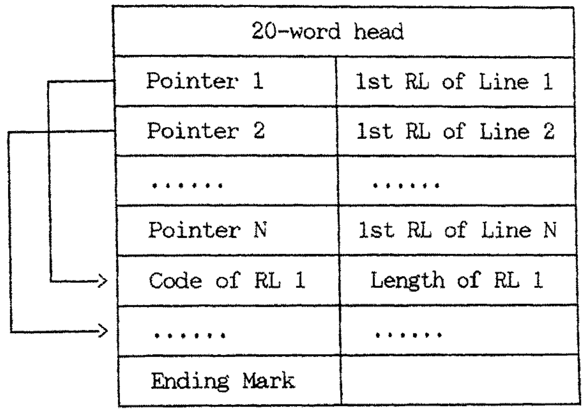

Fig.(1.3) RLC data structure

Each line has a pointer, which points to the logical address of 1st RL at the line so that program can directly access data from RLC file very quickly.

(3). DEM Data Structure

Because elevations of any two adjacent grid cells in DEM matrix probably are not equal, so usually we can not use RLC to compress this kind of data. In PURSIS, only DEM data are organized in raster form.

(4). Attribute Data Structure

Attribute data are recorded in ASCII format and logically organized as a relational table, which is required by DBASE III.

5. DIGIT MAP DATA FLOWING IN PURSIS

The data flowing is shown in Fig.(1.4); V: Vector, R: Raster or RLC.

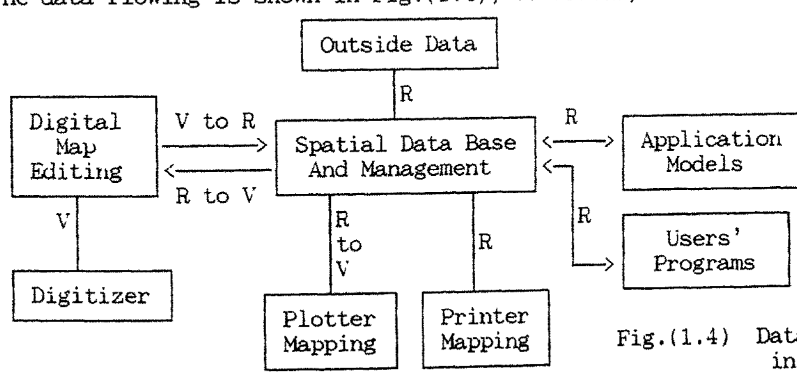

Fig.(1.4) Data Flowing in PURSIS

6. INTERFACES BETWEEN PURSIS AND USERS

Besides menu interface for every module, PURSIS provides a function library, in which there is a group of subroutines & functions. We only list some of them dealing with data accessing, and the others can be found in SECTION 5.

. decoding subroutine, it converts RLC to raster.

. encoding subroutine, it converts raster to RLC.

. DBASE I/O subroutines to access record from/to attribute database.

Statements & rules of calling these subroutines & functions form a "language". It is similar to Host Data Language, one of data manipulation languages, which can be embedded in host language to write users programs.

SECTION 2. DATA PRE-PROCESSING

1. OUTSIDE DATA PROCESSING

Outside data specifies processed remote sensing digit image, which can be obtained by communicating with digit image processing systems or magnetic tape unit. Because this kind data has become classified map, PURSIS organize them in RLC form shown in Fig.(1.3).

2. GEOMETRICAL REGISTERING

Spatial data logically form a multi-layer structure. each plane represents a map, and all of planes must be geometrically registered so that analysis can be done on a correct basis.

3. CONVERTING RLC DATA TO OUTSIDE DATA

Sometimes, users need to take their digit map data out of PURSIS for other purpose, so PURSIS provides a operation to convert RLC to raster.

4. CONVERTING VECTOR TO RLC

In GIS & Computer Graphics, converting vector to raster (or called polygon filling), is an important and complicated operation. Here, we introduce a new method based on algorithm called Boundary Algebra Filling (BAF).Comparing with conventional algorithms, BAF is not point-by-point but arc-by-arc, and is not from point to boundaries but from boundary to points. It uses only additions & subtractions, so the program runs very quickly.

```
Given:  PL(i), code of polygon on left of ARC i ,
        PR(i), code of polygon on right of ARC i ,
        PN(i), total amount of points on ARC i,        (i=1, 2, ..... , N).
        V(x(k),y(k)), value of point k, and its coordinate is x,y.
  BAF start:(a) initiate array V                 (f) V(x,y(k))=V(x,y(k))+DP
            (b) LOOP i from 1 to N               (g) NEXT x
            (c) DP=PL(i)-PR(i)                   (h) NEXT k
            (d) LOOP k from 1 to PN(i)           (i) NEXT i
            (e) LOOP x from x(k) to 1, step=-1   ! end of BAF.
```

From the algorithm, we can find that when tracing each arc, BAF add a DP (DP=PL(i)-PR(i)) to all horizontal grid cells on its left. After all of arcs are processed as above, the convertion is over.

5. CONVERTING RLC TO VECTOR

This convertion is called Two-Boundary Tracing (TBT). Its basic procedure can be described as follows:

(1). Boundaries Extracting (taking polygon map as example)

Because every boundary is shared by two polygons, two parallel lines along inner edges of their own polygons can be extracted,which are so called the two boundaries.

(2). Seeking Knot Dots

When logically moving a 2x2 matrix window on the raster data plane & boundary data plane, if at least 3 points of the four captured by the window are different, or two of them different but they rank like a cross, at this time, the 4 points are all defined as knot dots (Fig.(2.3)).

a	b
c	d

a	a
c	d

a	b
a	d

a	b
c	a

a	b
b	a

Fig.(2.3) Possible Situations for Knot Dots

(3). Vectors Seeking

Starting from a knot, converting program regularly moves the window in one of four directions, reads polygon codes from the raster file to get values on the left & right, also at the same time, determines tracing directions according to the boundaries captured by the window, and then traces a vector in certain direction until encountering any other knot. As tracing, obtained data are coordinates of points that center of the window passes through, and the data, along with the codes of left and right polygons, are recorded into a vector file in the form shown in Fig.(1.2). For those points on boundaries, once the window passes them, they are erased. After finishing above processing in all 4 directions, this knot dot is also erased, and the program will turn to a new knot dot to go on above procedure.

SECTION 3. DIGITAL MAP EDITING

1. DIGITIZING

(1). Coordinate Transforming

Digitizing deals with three coordinate systems: digitizer system, map system, and computer CRT system. The user will be asked to digitize four corner points of map to determine relations between the map system and digitizer system. In regard to CRT system, we use it only for displaying graphics when digitizing for the user to monitor the procedure.

(2). Polygon Map Digitizing

Invoking digitizing program, user should choose a threshold diameter for point-merging; that is because point (knot) connecting 2 arcs may be digitized becoming two points when double-digitizing. If dislocation is smaller than the diameter, the two points are merged. Before digitizing arc, the program first asks the user to input left code & right code of the arc,which will be used to creat a topological table for graphics modifing and convert vector to raster later. When digitizing an arc, any two digitized points on the arc are treated as two terminal points of a straight line. All of digitized points and inputed polygon codes are organized in vector form file (Fig.(1.2 A)).

(3). Linear Map Digitizing

Difference from Polygon Map Digitizing is that before digitizing, the user should input one number, which may represent grade of road for transportation map, elevation of contour for land form map, and so on. All lines collected by digitizer are also stored in a vector file (Fig.(1.2 B).

2. GRAPHICS MODIFING

Modifing mainly includes deleting, adding an arc, changing value of a line and code of left / right polygon. Before modifing, a topological table should be created. From it, we can quickly get information: (A) left & right polygon codes of an arc, (B) how many & what arcs consist of a polygon,(C) coordinates of two terminal points of each arc, and (D) all point coordinates from Vector File. The program works in interactive mode to modify displayed map on the CRT.

SECTION 4. ATTRIBUTE DATA BASE AND MANAGEMENT

Spatail information includes geometrical data and geo-attribute data. The former specifies geo-entities often represented by computer graphics with x, y z coordinates. The latter mainly specifies non-graphics data, which are called geo-attribute or attribute. A digital map is related to an attribute database.

1. INITIAL DATABASE CREATING

Area of polygon and length of line are very useful quantities in GIS, and they had better be calculated based on vector to get highest accuracy. So PURSIS automatically creates initial database to store area of every polygon or length of every line, which are got during converting from vector to raster. In this database, there are only two segments; one is for codes, the other for the area or length.

2. DATABASE MANAGEMENT ROUTINES

(1) Menu Control Routine (MCR)

We have written a group of database management routines with CLIPPER, and they are all mastered by MCR.

(2) File Checking and Receiving Routine (FCRR)

(3) Database Structure Displaying Routine (DSDR)

(4) Window Control Routine (WCR)

WCR provides 3 windows for the conversation between the user and system. These three windows are database structure managing window, command inputing window, and information displaying window.

(5) File Structure Management Routine (FSMR)

In database structure managing window, user can append, delete, and modify database structure under the support of FSMR.

(6) Data Editing Routine (DER)

DER helps the user append new data, modify and delete old data, registrate record pointer, and so on.

(7) Database Operation Routine (DOR)

DOR provides addition, subtraction, multiplication, division, statistics, restart sorting, functional operations, sum, classfication, etc.

SECTION 5. OPERATION FOR GRAPHICS DATA

Discussions in Section 5 mainly deal with geometrical operation. GIS users have their data geometrically changed very often, which rarely involves attribute. Therefor, we developed the module specially to process graphics.

1. STRUCTURE

The module is divided into six parts, (1) PURSIS Library, (2) Data Control, (3) Display, (4) Transformation, (5) Statistics, (6) Inquiry.

2. MASTER CONTROL PROGRAM (MCP)

Receiving command, MCP interpretes it and timely invokes relative program.

3. PURSIS LIBRARY

PURSIS Library consists of assembler subroutines & FORTRAN-77 subroutines. These subroutines are as a Functional Library to serve both PURSIS itself and GIS users (including any other computer users). PURSIS Library contains:

(1) Functions by Assembler

. CRT clearing,
. setting CRT in text mode,
. setting CRT in graphics mode,
. setting cursor at any position,
. windowing on CRT in text mode,
. system pause or waiting response,
. checking keyboard buffer,
. getting scan code from keyboard,
. getting ASCII code from keyboard,
. computer sounding,
. reading character & attribute on CRT,
. reading color code of a dot on CRT,
. writing character with colors on CRT,
. writing a dot with color on CRT,
. scrolling text page on CRT,
. roaming digit map on CRT,
. DOS files managing,
. initiating RS-232 & parallel port,
. printer driving,
. digitizer driving,
. reading data from digitizer,
. plotter driving,

(2) Functions by FORTRAN-77

. drawing straight line on CRT,
. drawing circle on CRT,
. drawing rectangle on CRT,
. drawing triangle on CRT,
. moving digit linear map on CRT,
. controlling a cross cursor on CRT,
. menu controlling,
. RLC encoding,
. RLC decoding,
. graphics data reading in,
. graphics data writing out,
. accessing record from DBASE file,
. expanding colors of some CGA,
. changing the order of colors,
. converting between any two kinds of data types.
. PURSIS files managing.
. users' programs connecting.

4. DATA CONTROL PROGRAM (DCP)

DCP controls only graphics data. It provides a channel connecting graphics data with all routines of this module. DCP can access both RLC and raster.

5. DISPLAY PROGRAM (DP)

Most of color/graphics adapters in microcomputers support only 16 colours, which is too few to display multi-colored digit map on the screen. In order to distinguish from variours types in the map with different colours on the CRT, we designed a progarm, called COLOUR-136, which can expand 16 original colours to 136 colours.

Colour of each pixel can be represented with an integer (colour code) that ranges from 0 to 15. COLOUR-136 program interlacing-regularly assigns some two colour codes to pixels to produce a "new colour". In fact, it is visual effect by mixed-colour stimulating. According to the cross-rank principle, utilizing the 16 original colours, the program can make 120 "new colours", plus the 16, total amount of colours can reach 136. However, we must stress that the mixed-colours are just available to display polygon-filled maps, but not to image or linear map.

6. TRANSFORMATION PROGRAM (TP)

Geometrical and digital transformation is very useful to GIS user. TP provides follwing operations:

. windowing,
. cutting,
. rolling,
. moving,
. zooming,
. boundaries extracting,
. buffering,
. overlaying boundaries onto displayed map,
. adding,subtracting,multiplicating,and dividing constant to/from digit map,
. functional transforming: triangle, exponent, mathematical power, etc.,
. two maps adding, subtracting, multiplicating, and dividing,
. symbols editing,
. drawing on displayed map,
. polygon code changing.

7. STATISTICS PROGRAM (SP)

Using SP, users can do or get analysis with histogram, maximum and minimum of codes in digit map, root-mean, average, variance, regression analysis, etc.

8. INQUIRY PROGRAM (IP)

IP is an assistant tool for analysis. It mainly used to answer questions:

. what is the code of a polygon or line ?
. what is the size of the map (lines and columns) ?
. what is the scale of the map ?
. further information for operations in this module.

SECTION 6. OPERATIONS FOR DTM DATA

DTM is important data in GIS, and is widely used in a lot of field such as survey, remote sensing, agriculture, forestry, transportation, geology, military, etc. DEM is basic data for making other data, it must be produced first according to digitized contours.

1. DEM PRODUCING

One of high accuracy methods for DEM producing is Point-by-Point Weighting Linear Interpolating. Suppose point P is unknown-point, Z1, Z2, ..., and Z8 are 8 known-points, which locate on the contours nearest to point P in 8 directions, and d1, d2, ..., and d8 are distances between known-ponits and unknown-point P. Then,

$$Zp = [\sum_{i=1}^{8} Zi/di] / [\sum_{i=1}^{8} 1/di] \qquad (6\text{-}1).$$

As we have metioned that the main problems of microcomputers are their low speed and small internal memory, which greatly affects velocity to search the eight known-points because accessing data has to be done between hard disk and internal memory. To solve the problems, DPP first cuts land form map into some sub-maps that can be fully arranged in the memory, and the sub-maps are partly overlapped each other. Loading a sub-map into memory, in turn to each unknown-point in a central rectangle in this sub-map, DPP sets out from it to search known-points in eight directions respectively. Once searching ray-line encounters a nearest contour, DPP records the elevation of the contour, calculates the distance between the two points. After completing 8 directions searching, DPP calculates elevation of the unknown-point according to (6-1). Processing all of unknown-points in the rectangle as above, DPP turns to another sub-map. Because of the overlaps, known-points in these parts are shared by those two adjacent sub-maps, therefor there are no any gaps or errors on the border between any two sub-maps.

2. DTM PRODUCING (Except DEM)

Following thematic maps can be produced in this module. Detail about them has been introduced in "BUILDING OF MICRO-GIS TOOL — Part One".

(1) Elevation Grading Map
(2) Relative Elevation Map
(3) Slope Map
(4) Aspect Map
(5) Land Roughness Map
(6) Slope Shape Map
(7) Valley Density
(8) Illumination Map
(9) Land Form Map
(10) Profile
(11) 3-Dimention Model
(12) Others

SECTION 7. LOGICAL OPERATION AND ANALYSIS

PURSIS utilize compiler DBASE III, CLIPPER, to create and manage attribute database. However, as a spatial database, it includes not only attribute, but digit map. A management system for spatial database should controls these two data effectively. Conventional Data Base Management Systems (DBMS), including DBASE III, have been proven to be insufficient to model & perform spatial information systems, CAD/CAM, etc. To amend DBASE III, we designed Logical Operation & Analysis Module (LOAM) with CLIPPER & FORTRAN-77 programs, which are used to perform attribute and graphics integrally.

1. CONCEPTION MODEL OF SPATIAL DATABASE

All of digit maps in spatial database can be regarded as layer structure, which consists of some planes (data planes). Each plane represents a map, and it is a collection of features with x, y coordinates. The key codes, which are numbered for different type of entities in the map, forms z-coordinate. They connect the entities with relative records in the attribute database. For the purpose of inquiry & analysis, PURSIS strongly requires that data at the same x,y coordinate in all data planes apply to that x,y coordinate; that is to say, all digit maps in the spatial database must be of same character of map projection, same map scale, and must have been geometrically registered.

2. TECHNIQUE TO CONTROL SPATIAL DATA

(1) Logic Instructions

Logic instructions or expressions are composed of variables (attributes), constants, and operators. The operators include " ( ) ", " .and. ", " .or. ", " .not. ", " > ", " < ", " = ", " ≥ ", " ≤ ", " + ", " - ", " x ", " ÷ ", etc. In fact, the variables, constants, operators, and grammars are all depended on rules of DBASE III. What we have done is just designing an interface that can timely receive and interpret logic instructions inputed by the user.

(2) The Technique

Key of the logical operation is to set up a connection between the CLIPPER program (CLP) and the FORTRAN program (FOP), or say how to tell the results of running CLP to FOP. As you have known, codes assigned to different entities in digit map do point to different records in attribute database, in other words, each entity in the map relates to a record in the attribute database. Therefor, LOAM regards the codes as key-words (key codes). Processing logic instructions, CLP produces a new attribute database, and data in this new database come from other database based on the logic expressions. These data may be results of logic selection, logic operation, or mathematical transformation. At that time, LOAM also makes a look-table that consists of some key codes according to the results, and the FOP with some ASSEMBLER subroutines are called in. Finally, the FOP optionally accesses entities from relative digit maps according to the look-table, displays them on the CRT, organizes and stores them into a new digital map file.

3. LOGICAL OPERATION FOR SPATIAL DATA

(1) Working Windows

Interface of LOAM provides three windows;

. Window 1, to display database structure,

. Window 2, for user to input logic instructions,

. Window 3, for user to converse with the system, to respond to user qestions, or to display attribute results of the operations and necessary information.

. Window 4, to display graphics/map. Only the FOP uses this window, and it will cover over all above 3 windows. As returning from FOP to CLP, the 3 windows are appear again.

(2) Files Opening

LOAM first ask user to open spatial data files.The maximum number of files is 20. All opened files are logically arranged as a layer structure.

(3) Logic Operations and Inquiry for Analysis

If the user inputs logical instructions in the window 2, LOAM first checks and interprets them, and then performs relevant attribute databases, displays the results in the window 3. Once the user go to window 4, all names of opened files are vertically listed on right of the CRT layer by layer.Then a controllable pointer is pointing to a name of plane, which called current plane, and map at this plane is simultaneously displayed. Now the user can obtain much information about the displayed map and its attributes. LOAM uses some keys on the keyboard to support the work in the window 4.

. [Esc] : to return to CLP.

. [F1]: to move the pointer up, which can shift planes.

. [F2]: to move the pointer down, which can also shift planes.

. [Shift] + [Arrow]: to move displayed map up, down, left, and right.

. [Arrow]: to move a cross cursor to point to any entity in the map.

. [F3]: to overlay boundaries of a map onto displayed map.

. [F4]: to display size of the digit map.

. [F5]: to display code of the entity pointed to by the cursor.

. [F6]: to display attributes of the entity pointed to by the cursor.

. [F10]: to save results.

Here is an example to further illustrate logic operations.

Given a region, the user wants to make a vegetation distribution map that must meet conditions: (a) elevation – H is higher than 40 metre and lower than 240 metre, and (b) soil type — S is limestone drab or alfisol drab soil. Now, the user should perform as follows:

step 1: opening administrative map of the region.

step 2: opening elevation map.

step 3: inputing logic expression, $40 < H < 240$.

step 4: opening soil map.

step 5: inputing logic expression, S = "limestone drab".or."alfisol drab".

step 6: opening vegetation map.

step 7: extracting boundaries of the administrative map.

step 8: executing with operator, ".and."

step 9: displaying results in window 3 and window 4.

step 10: saving results.

SECTION 8. APPLICATION MODELS

On frequently used application models, we designed three programs.

1. EXPERT ASSIGNING WEIGHT MODEL (EAW)

EAW is a system analysis model, and a combining qualitative & quantitative analysis method used to solve complicated geo-problems. Its basic principle is similar to the level analysis. Geo-problem deals with a lot of complex factors. They are of certain independence,and sometimes confine each other. So building an exactly mathematical formula to describe some geo-model is very difficult.

In order to solve this kind of problem, we should use geo-experts' experiences. Experts sort the factors according as their relative importance, and assign weight values to them. For subclasses belonging to some factor, the experts further sort them and assign weights. Finally, EAW composites these factors and subclasses to obtain sorted results. EAW can be expressed with (8-1).

$$R(x,y) = \sum_{i=1}^{m} W(i)\ C[i,j(x,y)] \qquad (8\text{-}1).$$

Where, C(i,j): weight of subclass j of factor i,or weight of type j in plane i.
j(x,y): type j at x, y coordinate in plane i.
W(i) : weight of factor i, or weight of data plane i.
m : total amount of factors (planes).

EAW operations are separated in two steps. First, for every involved database, the user should add one segment, in which the weights assigned by experts will be recorded, and then append all weights W(i)xC(i,j) to the segment of all records. The second step is composition. At that time, a FORTRAN-77 program is invoked. It accesses data with same x, y coordinates in different planes, and according to their type codes, the program can get weights from relative databases. Finally the program adds the weights together and stores them into result file. Until all points of the planes are processed, EAW is finished.

2. EXPERT PROPOSITION MODEL (EP)

Let's take an example to explain Expert Proposition Model.

Given agricultural experts' propositions for rice planting are

(1) accumulated temperature (T) must higher 3200°C,
(2) amount of rainfall (R) greater 800 mm or having irrigation conditions (W) in the region,
(3) slope angle (S) smaller 8°,
(4) frostless season (F) longer 200 days.

Those propositions can be represented with proposition expressions as

$$P \longleftarrow (\ P1 \cap (\ P2 \cup (\overline{P2} \cap P3)\ )\ \cap P4 \cap P5\ ) \qquad (8\text{-}2)$$

$$\left.\begin{array}{llll} P \longleftarrow \text{fit for planting rice}, & \overline{P2} \longleftarrow R < 800\ \text{mm}, \\ P1 \longleftarrow T > 3200^{\circ}C, & P3 \longleftarrow W \\ P2 \longleftarrow R > 800\ \text{mm}, & P4 \longleftarrow S < 8^{\circ}, \\ & P5 \longleftarrow F > 200\ \text{days}. \end{array}\right\} \qquad (8\text{-}3)$$

We take distribution map of accumulated temperature, rainfall map, irrigation map, slope map, and frostless distribution map to join the calculation. For regularly accessed data with same x,y coordinates from different data planes, EP uses (8-2) and (8-3) to verifie them. Points agreeing with the expressions are classified to class P, or else to class NOT~P.

To produce some thematic map such as soil erosion map, user can input many propositions one time, and processed by EP, a new multi-type map will be made.

3. OVERLAYING CLASSIFING (OC)

Users frequently want to put some maps together (overlay) for analysis. In result map of overlaying, many new types are produced by compositing types of original maps. Because the number of new types may be great, especially when a lot of maps join this operation, or some maps have a great number of types, cluster processing had better be adopted before or after the overlaying. Division of new types can be done by setting up a look-table. For each point with same x, y coordinate coming from different data planes, OC program composites them as a new combination, and compares it with all combinations in the table, which are added in just before. If the new combination is different from any one in the look-table, it is also added, as a new type, into the table. At the same time, the program assigns the type code and attributes of original map to the point, and stores it in result files. The procedure will be repeatly carried on, until last point is processed.

SECTION 9. DIGITAL MAPPING

In Section 9, we will introduce two mapping methods; one is mapping with (colour) printer, and the other with plotter.

1. PRINTER MAPPING

TOPRINT is a program we developed as a mapping tool, with the characters: low cost, easily controlling, being able to be widely used, high accuracy (can reach 0.141 millimetre), and available timely to produce informal maps.

(1) Master Control Program (MCP)

When user call TOPRINT, Master Control Program first displays all elements, boundaries of polygons, lines, points in map, and map borders on computer CRT, and then the user can choose several operations: inquiring code of the entity that cursor points to on the CRT, overlaying other linear map on displayed map, invoking Graphics Library Managing System, invoking Symbol & Illustration Editing Module, invoking Printing Module, and providing help information.

(2) Graphics Library Management System (GLMS)

We have built a graph library that has 1350 graphics. For colour printer, except black, other six colours combined with the 1350 graphs will be able to produce 6x1350 different graphics, i.e. 8100 different types in the map can be distinguished. However, the most important thing is that GLMS allows user to append more new graphs into the library. At this point, for 10x10 dot matrix used to make a graph, possible number of graphs can reach 100!. GLMS provides eight operations;

(a). making or appending new graph(s) to the library,
(b). modifying existing graph(s),
(c). deleting existing graph(s),
(d). replacing a graph with another one in the library,
(e). comparing whether there are same graphs in the library or not,
(f). changing the order of colours,
(g). enlarging any one of the graphs,
(h). and storing or renewing the library.

(3) Symbol and Illustration Editing Module (SIEM)

One of characters of map is that it has lots of symbols,illustrations, and legend. As a mapping tool for Micro-GIS, we design SIEM to perform edit, which works in interactive mode. The results are automatically stored as a disk file called S-I file (Symbol & Illustration).

(4) Printing Module (PM)

After choosing one of three printing modes, 8, 12, and 24 needle mode, PM accesses variours disk files: (1) digital map file, (2) Graphics Library, (3) overlayed linear map file if the work has been done under MCP, (4) S-I file if editing work has been done or S-I file has existed on disk. All files can be organized in raster or RLC form so as for PM scans them point by point.If current point is on boundary of a polygon, line, the map bordors, symbol, or character for illustration, PM will drive the head of printer to hit certain needle on black part of the ribbon.If current scanning point is inside some polygon, PM first accesses a graph from the library according to polygon code, and then PM makes judgements whether this point should be printed or not depended on its relative coordinate in the 10x10 graphics dot matrix; if it overlaps at any one of points of the graph, PM will drive some needle to hit on certain color part of the ribbon, or else not drive any needle. Because every polygon has a code, polygons can be distinguished by filling with different graphs.

2. PLOTTER MAPPING

Crucial problem for computer mapping is how to edit symbols with interactive mode. We have introduced its basic principle for printer mapping. Though differences between plotter mapping and printer mapping are obviously existing, the principle can be shared by them. Here, we mainly introduce how to add symbol to polygon map (filling polygon with symbols), which is of the most common sense for plotter mapping.

(1) Graphics Symbol Library

Plotting classified map often uses variours linear/spot graphical symbols to fill polygons. As printer mapping, we have also built a Vector Symbol Library (VSL) for plotter mapping. Some spot symbols were obtained by digitizing, and all of symbols of VSL are orderly numbered with integers as codes. Besides the codes, for each symbol, there are variours parameters to describe its some characters. For example:

parameters for linear symbol: direction (α),
space length (d),
linear type (T).

parameters for spot symbol : space length (d),
coordinate (x,y).

(2) Symbol Locating Algorithm

We will introduce one of algorithms that fits to fill polygon with single direction lines. Mp means the number of arcs which consist of polygon M, Na is the number of points at arc, NUM & TEMP are two arrays, and B is a big enough number.

```
Start !
      For arc=1 to Mp
          For point=1 to Na-1
              x0=x(point)*cos(α)-y(point)*sin(α)
              y0=x(point)*sin(α)+y(point)*cos(α)
              x1=x(point+1)*cos(α)-y(point+1)*sin(α)
              y1=x(point+1)*sin(α)+y(point+1)*cos(α)
              k=(y1-y0)/(x0-x1)
              For x=x0 to x1, Step=d
                  NUM(x)=NUM(x)+1
                  TEMP(x,NUM(x))=k*(x-x0)+y0
              Next x
          Next point
      Next arc
      For x=1 to B
          call collate(TEMP(x,NUM(x))
          For num=1 to B, Step=2
              lx0=x*d*cos(α)+TEMP(x,num)*sin(α)
              ly0=TEMP(x,num)*cos(α)-x*d*sin(α)
              lx1=x*d*cos(α)+TEMP(x,num+1)*sin(α)
              ly1=TEMP(x,num+1)*cos(α)-x*d*sin(α)
              call drawline(lx0,ly0,lx1,lx2,color,T)
          Next num
      Next x
 END !
```

(3) Symbol Editing

The editing for plotter mapping is almost similar to that for printer mapping. Please refer to "Graphics Library Management System (GLMS)" in this Section. Results are stored in a file called EF (Editing File).

(4) Plotting

After editing, including adding symbols, illustraions,and legend, plotting program can be invoked. Because all of data, which are digit map and EF, are recorded in vector form, the program orderly reads them from relative file and transferes them to plotter for drawing.

—— PART TWO APPLICATIONS ——

SECTION 10. INTRODUCTION FOR CORPIS

Building CORPIS (COunty and township Regional Planning Information System) is a co-operation project, taken by Institute of Urban Planning of Beijing and Institute of Remote Sensing, Peking University since 1988. Purpose of the project is to build a computer system for county & township planning and managing. Ping Gu County, in Beijing district, was chosen as the experimental region for this project. CORPIS, as a regional information system, is supported by Micro-GIS tool PURSIS. Besides general functions that a GIS should have, it has been asked to complete special task, plans selecting & evaluating. This task should consider economic, social, enviornmental factors, and total benifit, so as to help local government to make some decisions for the region's development. The basic supply installation plans and land use plans evaluating is an important task; the former is for railway, road, power, communication, drainage, etc., and the latter for industry, agriculture, forestry, animal husbundary, fishery etc.

1. DATA COLLECTING

For a 2000^2km region in Ping Gu County, it took us two months to input 28 kinds of maps with the scale 1:25000, land form, geomorphic, soil, hydrometric, geologic, land use, administrative, vegetation, mineral, trasnportation, environmental, disaster distribution maps, etc., and their relative attibute databases were created. All of data come from statistics, surveys, and aeorphoto / satellite image interpreting, and they cover 1960s, 1970s, and 1980s.

2. ANALYSIS FOR CROP GROWTH ENVIORNMENT

Considering relationships between the factors: soil, soil fertility, climate, irrigation, transportation, population, levels of production, Using EAW Model (please refer to Section 8), and making enviornment map for crop growth, the user utilize input-output model to analyse and evaluate the conditions for crop growth, find out some inconvenient distributions of plant, and make better plan according to crop growth and economic rules.

3. FOREST PLANNING

On the basis of general plan for this region, forest planning is based on the analysis to the factors, elevation, slope, aspect, illumination, soil type, and climate. Depending on characters of different trees and distribution of the natural conditions,the plan was made by the interactive computer graphics, and timely mapped.

4. EVALUATION FOR TOWN LAND USE

Town land use planning is important to the project. Past work reveals that many plans may be made by different planners with different methods. We will introduce one of evaluations, called Matrix of Influence (MI). It is based on

$$G = \sum_{i=1}^{n} W(i)\, g(i,j). \qquad (10\text{-}1).$$

where, W(i) is weight assigned to factor i,

g(i,j) is influence degree between factor i and factor j.

The influences are divided into 6 degrees (table (10.1) and (10.2))

0 — means no influence, 1 — means small influence,
3 — means general influence, 5 — means big influence,
7 — means significant influence, 9 — means the most siginificant influence.

*** In part two of original paper, several application systems were briefly introduced. But as a paper presented at this Conference, we only extracted the Section on Urban Planning from the original paper. Section 10 was provided by Mr. Xie K. Qing, Engineer of the Institute of Urban Planning, Beijing, and Mr. Sui D. Zhi, M.S., of Institute of Remote Sensing, Peking University.

In this region, living land use and industry land use were evaluated, and the indexes are:

Living land use:
- environment (g1)
- transportation (g2)
- education (g3)
- hospital (g4)
- amusement (g5)
- population (g6)
- trade (g7)
- water supply (g8)
- drainage (g9)
- ges (g10)
- foundation (g11)

Industry land use: environment (g1), transportation (g2), population (g6), water supply (g8), drainage (g9), foundation (g11)

MI is different from EAW Model. Main character of MI is that it considers not only weight (W(i)) of factor itself decided by AHP Method, but also influences between factors. Matrix of the influence calculated by MI is shown as follows:

	g1	g2	g3	g4	g5	g6	g7	g8	g9	g10
g1	0	1	7	5	3	9	7	1	1	1
g2	1	0	3	7	5	9	9	1	1	1
g3	1	3	0	1	1	1	1	3	1	1
g4	5	5	1	0	1	3	1	1	1	1
g5	5	7	1	1	0	7	3	3	3	3
g6	7	9	7	7	9	0	9	7	7	5
g7	5	1	1	3	5	9	0	5	3	3
g8	1	1	3	5	5	7	7	0	5	1
g9	7	3	5	7	3	9	7	3	0	1
g10	5	3	1	1	1	7	3	1	1	0

table(10.1) matrix for living land use

	g1	g2	g6	g8	g9	g11
g1	0	3	7	9	9	3
g2	1	0	5	9	7	5
g6	1	3	0	9	9	3
g8	3	7	5	0	9	7
g9	1	0	0	7	0	3
g11	3	5	7	9	3	0

table(10.2) **matrix for industry land use**

According to these values in above tables, the weights assigned by the experts, and (10-1), we can obtain results of the evaluation.

CONCLUSION

Procedure of problem solving with computer can be infered by induction as double-levels of abstract; the first is abstract from problem to formal logic, and second from formal logic to computer instructions. As GIS tool, PURSIS has been able to complete most of logical operations that are regarded as the second abstract, which is easier than first level abstract because the abstract from problem to formal logic requires that GIS users and creators fully understand and use formal logic which mainly means SET and COMPUTATIONAL LOGIC. If people are not aware of that, the GIS may become only data inquiring system or computer cartography system. An excellent GIS should tell people not only what they can do, but how they should do. We will further improve the interface of PURSIS with the powerful weapon, LOGIC, to make modelling and analysing more useful and helpful.

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VALUE ADDED OF A GEOGRAPHICAL INFORMATION SYSTEM

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A geographical information system - or any other information system for that matter - is not an end in itself. Nor does it render its services in isolation but, instead, the information system operates within a specific context. A fundamental question may be formulated as regarding to the functions the information system is expected to perform. Or, in other words, what is the value that the information system may add in this respect? Any practical work in designing and appraising an information system should address these questions.

In addition to this, geographical information systems trigger the question about the specific value added by spatial data and information.

By adopting an economic perspective - in the form of relative simple economic views (concepts) - an analytical framework can be developed to facilitate exploring the domain of a geographical information system. Among other aspects, these views pertain to

- efficiency: optimal versus maximum amount of information;
- information as an economic good: private and/or collective;
- other than economic values: e.g. organizational and group-formative;
- functional analysis: value in relative rather than in absolute terms.

Such framework must have a practical significance and aiming at to facilitate the interpretation and definition of the complex reality of management and utilization of information rather than to provide a means to valuate information in absolute monetary terms.

The purpose of these brief and preliminary notes are to invite critical comments. Subsequently, an elaborated analysis of this field is envisaged.

Introduction

The last two decades have shown a remarkable development of geographical information systems into a stage of technical maturity. Recently, contextual concerns with respect to the applicability of geographical information systems step forward. In particular, issues of designing and planning of geographical information systems in their organizational setting have received some attention. In these notes an attempt will be made to explore the notion of value of information and, hence, the potential value of an information system. Special attention will be given to geographical information systems in handling spatial data and information.

A geographical information system - or any other information system for that matter - is not an end in itself. Its value arises out of the usefulness of its resultant information products. In other words, to what extent is the information system functional towards its context or environment. These functions - manifest and latent - ultimately determine the value of the invisaged information system. The major functions of any information system are in its ability to accept, process and present data, to update and modify data, to combine data sets originating from different sources and to integrate them for effective use, thereby providing genuinely new information. Consequently, the actual value of the information system depends on the need to accomplish these functions; that is to say, the necessity to exceeds presently available capabilities in these respects and the extent to which the envisaged information system can satisfy these needs.

The usefulness, utility or value of information must be understood against the background of scarcity. Information is not a free-good. Costs and expenditures are needed in order to obtain certain information. Although the required information might exist, accesibility to it may be limited and this will further increase its scarcity. In addition, the attentional resources required to cope with the produced information are scarce as well. For example, specific skills and experience may be required to interpret the information correctly. Information, in short, is an economic good. And viewed in this way several points for attention can be formulated to be considered in order to facilitate management and utilization of information, particularly with respect to information systems.

In the following sections an attempt is made to sketch some of them.

<u>Efficiency; optimal versus maximum amount of information</u>.

The very concept of information implies that (potential) users of this information exist. Information without the perspective of being utilized is meaningless and should not be called 'information' at all.

Assume that a prospective user is able to identify the information he really needs. This information (I-max) has the highest utility or value for the user and, consequently, less or more information will have a lower value to him. Assume moreover increasing marginal costs in obtaining the information. It follows that when costs in obtaining information are considered as well, the optimal amount of information where the difference between value and costs are maximum (I-opt) will be less than the amount of information with the highest value for the user. Obviously, the difference between I-opt and I-max depends partly on the shape of the utility function; the steeper this curve the closer I-opt will be to I-max. Why can a user accept less information than he really needs. One explanation may be that the user is able to supplement the 'lacking' information with information obtained from other sources and particular with information residing in his mind already in the form of knowledge, experience, etc. However, a steep utility function indicates that such substitution is hardly possible.

The difference between I-opt and I-max relates to efficiency in obtaining information; is this last bit of information really worth the (extra) costs in obtaining it. Seen from the side of supplying information the foregoing suggests the tendency to produce too much information. This is similar to the theory of Niskanen for the supply of collective goods where governmental departments and bureaucracies tend to maximize their budgets ('bureaucratic optimum').

In practice, however, quite often the choice is between a package of information or no information at all. For example, if one wants to employ a certain model, sufficient data has to be applied even if the resulting information is more than what is actually needed. Still, the above tendency to produce too much information is a real problem.

<u>Is spatial information always necessary</u>?

In the foregoing, a simplified view of information has been used. However, if we add different qualitative aspects to the concept of information the conclusions remain essentially the same. For example, the necessity to provide information with an explicit spatial dimension is not selfevident. It all depends. Does this extra qualitative spatial component add something which is worth the costs in obtaining it? Or is it possible to employ a-spatial information supplemented with knowledge in the form of mental spatial models and topology residing in our minds already?

Of course, these critical remarks do not deny the potential value of handling spatial data in general and by a geographical information system in particular.

Often, handling spatial data is a complex task; particularly if the data originates from multiple sources. For example, many empirical studies have revealed serious shortcomings in human ability to develop and maintain topologically correct mental maps. This leads to the conclusion that although spatial information and geographical information systems are not needed under all circumstances, our human capabilities are limited in developing and applying mental maps and therefore need to be supported by spatial information and geographical information systems.

Analytical capabilities and modelling add to an information system the capability to structure, analyse and interpret data in relation to specific users' fields of application. Particularly in the case of spatial data handling and geographical information systems, the development of relevant analytical and modelling techniques is lagging behind developments in database design and handling. Here is a challenging domain of future research and development.

Information utilization system as context for the information system

Speaking in general terms, an information system does not render its services in isolation but, instead, it operates within a certain and given (though influenceable) context. This context consists of the whole of data and information flows, their channels, creators, collectors, users, and so on, oriented towards (end-) uses and will be referred to as the 'information utilization system'.

This notion of information utilization systems brings the envisaged information system into a relative position. Its value relates to the extent in which it is able to solve informational problems and fill data and information gaps in the existing information utilization system. In order to perceive and assess the potential value of the envisaged information system a simple 'with-and-without'-type of analysis will give a more realistic picture than focussing on technical sophistications only.

Apart from the intrinsic value of information, in that it supports managerial functions like planning and decision making, an information system has an organizational impact or value as well. It may offer an integrative framework for a wide range of activities. The possibility to employ sophisticated technical possibilities may pose a challenge and therefore may contribute to a stimulating working environment. In short, an information system may contribute to organizational development.

Information facilitates sharing of mental images

The resulting information products of an information system are being interpreted and integrated by the user of that information with the help and to the extent of an already existing mental frame of reference or models residing in the user's mind. This is how each individual user copes with informational stimuli. When interpreted and integrated, the external information adds to the existing mental frame of reference.

Individuals do not act in isolation but, instead, they work within a social context. They relate their behaviour to their perception of the behaviour of others. The essence of a group is a shared consciousness which may be viewed as shared or common mental images. This social dimension adds a element new to the value of information and, hence, the potential value of an information system. In a social or group context, information which can be shared facilitates the creation and unification of shared mental images. And this, in turn, may reinforce group consciousness.

This social role of information implies the necessity of accessibility of data and information with the obvious exception of matters like privacy, etc. Moreover, if public or popular participation is aimed at, the public should have full and free access to data and information as well. Withholding and manipulating information may easily jeopardize this social function.

The issues of sharing information and having free access to it raise a number of questions when information is viewed as an economic good. For instance, public and private values of the information may differ. Often, public authorities and firms consider information as a resource next to land, labour and capital, whereas individuals consider information as guidance for consumption. Changes in accessibility of information may have income distributional impacts.

Information: private or collective good?

It has been mentioned before that information is an economic good. The foregoing sections lead to the question whether information must be considered as a private or as a collective good. Information reflects properties of both types of economic goods.

When information is considered as a (pseudo) collective good, emphasis is on sharing information and hence, on sharing the costs of obtaining the information. Consequently, information is viewed as a collective asset for the society as a whole. When information is considered as a private good, emphasis is on exclusive use that an individual user can make out of this information excluding other users. Now, information is viewed as an asset for individuals operating within a market economy.

In practice, one may easily observe an expanding market where 'sellers' and 'buyers' of certain types of information meet. This supports the idea that at least those types of information must be considered as private economic goods. Since many data within society are available with the help of public financial resources, the question concerning the extent to which information must be regarded as private economic good is highly relevant as seen from the point of view of the society at large.

Often, a (free) market is considered as an information system for individual suppliers and consumers within that market with respect to price-quantity relationships of their goods. When data and information are considered as economic private goods in the above sense it follows that they provide the user with a relative advantage over other participants within that market. This relative advantage, however, will fade away due to the market mechanism. Consequently, information as a private economic good has a high decay rate and need continuous updating. For this, special mechanisms are indispensable.

Unequally distributed abilities in collecting, processing and utilizing data and information do have distorting effects on the free market principle and, hence, contribute to so-called 'market failures'. In order to restore the market, essential data and information should be accessible to agents all operating at this market. These and similar arguments at least provide a rationale for considering data and information as (pseudo) collective goods to the extent where they relate to public interests in the widest sense.

Preliminary conclusions

Viewing information from a point of view of its value this opens up new perspectives for management and utilization of information rather than those limited to technicalities in collection and processing of data.

This perspective, however, should not replace other and more traditional views. To the contrary, an approach to information which comprises many facets will certainly stimulate creative thinking in finding solutions to contemporary problems in management and utilization of information as a basic resource for development.

APPLICATION OF GEOGRAPHIC INFORMATION SYSTEMS IN AN URBAN ENVIRONMENT

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ABSTRACT

Geographic information systems (GISs) are designed as general-purpose systems to manage spatial information. They are similar to commercial database management systems except for their strong spatial context. This recent technology has inspired many users who have, for generations, been faced with the difficult task of making decision based on spatial information.

This paper first reviews the development, design, and functions of GISs. It then evaluates the effectiveness of contemporary GISs in managing spatial information in an urban environment. In particular, special problems caused by high data density and multi-layer organization will be examined. A solution to these problems demands special display, database query, and data organization components of a GIS.

Finally, the paper will present an application using CARIS (Computer Aided Resource Information System), a GIS developed in Fredericton, New Brunswick. This application illustrates the concept of a multi-layered GIS with which databases of progressive detail can be vertically linked to facilitate data query.

THE APPLICATION OF THE GEOTECHNICAL DATA MANAGEMENT SYSTEM 'STRATA 3' TO URBAN PLANNING

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ABSTRACT

The STRATA 3 data management system provides a means for storage, retrieval and graphical representation of geological and geotechnical information; it comprises two elements, a database and a graphics package. Geological and geotechnical data from boreholes and trial pits are recorded and stored within the database element of the system. The graphics package performs interpolation between these known data points and permits output of multi-surface, isometric projections and geological sections. The database can be interrogated to provide information on data availability: viz. what exists, who holds it, where it is held or summaries of the records themselves. The application of the system to urban planning is discussed in respect of land-use planning and development control.

INTRODUCTION

In developing STRATA 3 the principal objective was to achieve multi-surface graphical representation of geology by tailoring existing and relatively cheap software packages. It was considered that multi-surface isometric projections would be a valuable asset in the urban planning process when it is often necessary to provide explanations of complex geotechnical conditions to non-specialists.

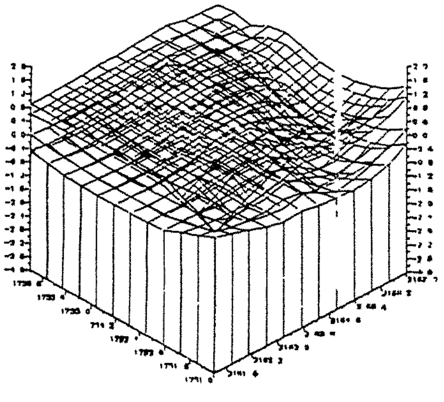
The utilisation of existing software to create geotechnical data management systems has been undertaken by other academic researchers, notably Day (1983) and Wainwright, Wood and Tucker (1985). GEOSHARE, described in full by Raper and Wainwright (1987), is a geotechnical database developed at Queen Mary College, London.

STRATA 3 is one element of a R & D programme presently being undertaken at UWCC to explore the applications of information technology to engineering geology. Other elements of the programme include the design of expert systems and the computer-aided preparation of environmental geology maps.

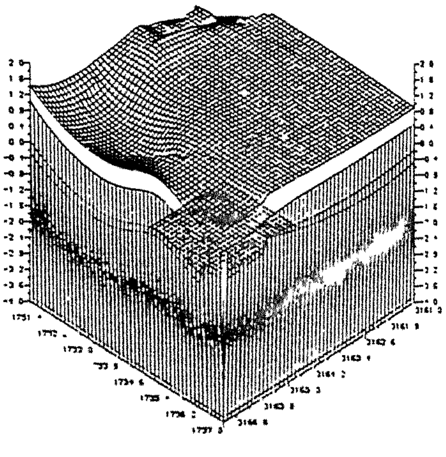
This paper describes the development of Strata 3, the input requirements, operating procedures and output capabilities; the utility of the system in planning practice is discussed and references are made to a case study undertaken in the docklands of Cardiff. Future research and development work is itemised with respect to up-dating the present system and providing links with other software packages, notably geographic information systems.

SYSTEM DEVELOPMENT

Development work on STRATA 3 has been performed in the School of Engineering at the University of Wales College of Cardiff, and has been sponsored by Wallace Evans and Partners, Consulting Engineers, Penarth; work commenced in October 1987. The aim was to establish a geotechnical data management system by utilising software that was available on the UWCC VAX network. Some preliminary work was carried out using DATATRIEVE but later ORACLE was chosen to fulfil the database function for the system. From the outset multi-surface graphical capabilities were considered to be an essential requirement for the system. Some previous experience with GINO-F and GINOSURF indicated that this suite of programs might be the easiest to tailor in order to provide multi-surface representations. The main problem was to simplify the picture obtained by superimposing a number of geological surfaces in a single isometric projection. The solution was achieved in a number of stages, and some early representations are shown in Figure 1a and 1b.



1a



1b

Figures 1a and 1b. Illustrations of the difficulties encountered in tailoring GINO to produce multi-surface isometric projections.

OPERATING PROCEDURES

STRATA 3 is operated on the UWCC VAX computer network and on the Apollo system of Wallace Evans and Partners. Although STRATA 3 has not yet been mounted on a PC, appropriate versions of ORACLE and GINO are available.

ORACLE is a modern Relational Database Management System which uses Standard Query Language, this is being adopted by most advanced database systems in order to allow interactive use with more than one specifically tailored program suite.

ORACLE is set up to be a menu driven database which prompts the user to enter specific items of information from borehole records. For a case study in south Cardiff these items included:

- Grid reference,
- Reduced level,
- Organisation holding record,
- Location of record,
- Reference number,
- Depth to lithological boundaries,
- Depth to water table,
- Standard penetration test (SPT) depths and 'N' values,
- Other test depths and test results.

Information on mapped strata boundaries, faults and even historical data can also be included. Clearly, the database can be designed to store as much or as little data as is required. Once entered facilities allow editing, up-dating of the data and conversion to metric units. A formal quality control check is desirable at this stage; also, it is often useful to review the data elements selected and confirm that they are both adequate and necessary. Output from the database is obtained using simple call statements. Specific boreholes can be recalled and their records reproduced in a borehole format; reliability of data is often a function of the age of the records, selectivity is also possible in this respect. Parcels of land, defined by their national grid co-ordinates, can be searched: for borehole records reflecting particular ground conditions. Some examples are shown in Table 1.

The main graphics package belongs to the GINOSURF library, this enables the automatic plotting of 3-D data as contour maps, single isometric surface views and cross-sections.

Input data take the form of x, y and z co-ordinates. For any borehole the national grid co-ordinates are input together with the reduced level of a lithological boundary or water table. Initially data input files for each surface were established manually from the borehole records but the interfacing with ORACLE has enabled the creation of input files directly from the database. The automatic contouring routine within GINOSURF performs an interpolation function between the randomly spaced data points and generates height values for the nodal points of a regular grid. The user can effect a measure of control on this interpolation function in order to enhance accuracy and avoid gross discontinuities (Greenshaw, 1989). One of the drawbacks of interpolating between data points to provide representations of continuous geology is that accuracy is directly proportional to data point concentration. This is not a shortcoming of the system rather a limitation that would apply to any interpolation procedure.

BOREHOLE LOCATION

CONTRACT NO 7099 BH ID NO BTL 9
EASTINGS 318314 NORTHINGS 173840 M AOD 2.20
LOCATION BUTETOWN LINK, CARDIFF
WATER TABLE -4.90 DATE START 18-MAR-83 END 21-MAR-83
CLIENT SGCC METHOD CABLE TOOL/ROTARY CORE

GEOTECHNICAL TEST RESULTS

CONTRACT NO 7099 BH ID NO BTL 9

STRATA	DEPTH	LL %	PL %	MC %	SPT
ALLUVIUM	1.00	70	31	61	
	2.50	38	35	49	
RIVER GRAVEL	4.85				16
	6.05				16
	7.00				
GLACIAL GRAVEL	8.65				19
	10.30				17
KEUPER MARL	13.20	37	26	24	
	15.10	28	18	19	
	16.25	23	14	13	61
	21.15	24	19	16	40

LITHOLOGICAL BOUNDARIES

CONTRACT NO 7099 BH ID NO BTL 9

DEPTH	STRATA DESCRIPTION
4.25	Alluvium: Very soft black slightly fine sandy clayey SILT.
8.00	River Gravel: Medium dense overall black clayey sandy GRAVEL.
13.10	Glacial Gravel: Medium dense to dense, overall brown dark green/grey, red brown becomming very sandy with depth rounded GRAVEL with cobbles up to 150mm many with depth.
14.60	Keuper Marl: Sub-zone IVa.
22.70	Keuper Marl: Sub-zone III.
23.40	Keuper Marl: Sub-zone II.
24.10	Keuper Marl: Sub-zone I.
41.65	Keuper Marl: Sub-zone III.
42.40	Keuper Marl: Sub-zone II.
47.25	Keuper Marl: Sub-zone III.

Table 1. Some examples of selective output from the database of geotechnical information.

Graphical output requires site definition using national grid co-ordinates; presently these have to be taken from O.S. plans. Output can take three forms:

A location map showing data points (borehole and trial pit locations) and grid co-ordinates: these can be produced to any scale and are most meaningful when copied onto acetate sheets and used as overlays on O.S plans. It is also possible to draw onto the location plan contours of chosen geological surfaces, for example: topography, rockhead, water table (Figure 2).

- Geological sections: by default, these are taken diagonally across the defined site but there is flexibility to select any required line of section (Figure 3).
- Multi-surface isometric projections showing the layered geological structure underlying defined sites (Figure 4). The system permits a number of variations, viz. the projection can be viewed from two diametrically opposite corners and the upper geological layers can be stripped off to afford details of the morphology of, say, a particularly important bearing stratum.

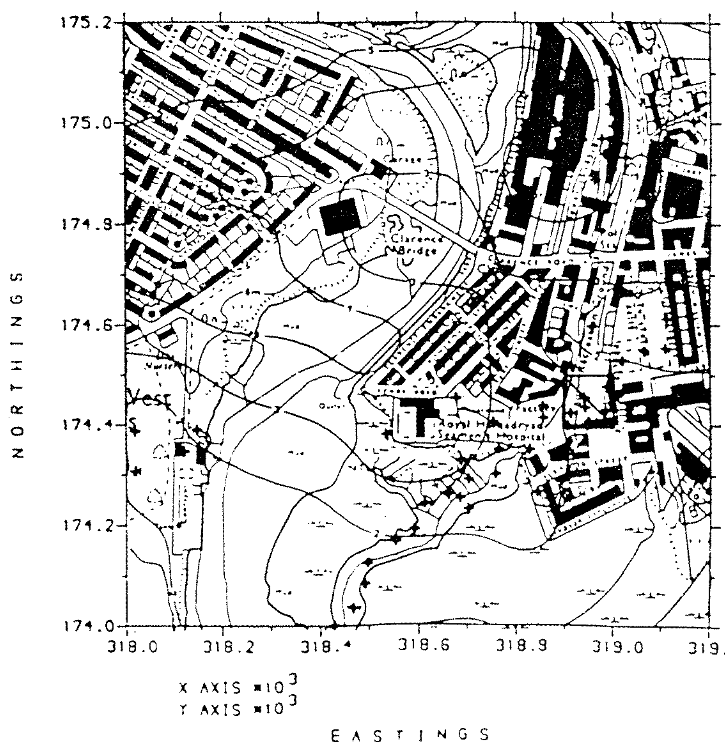


Figure 2. Location plan showing the site as a window, data points and contours of depth to water table; an example from south Cardiff superimposed on OS plan.

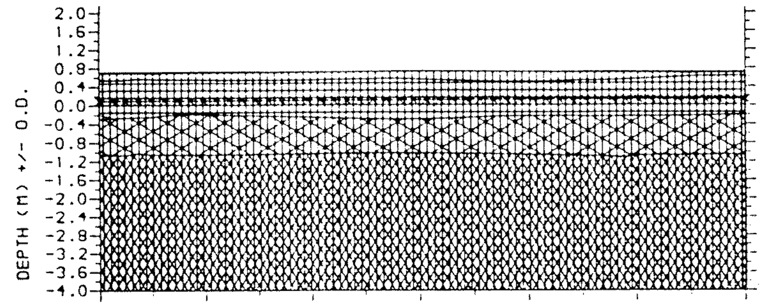


Figure 3. Geological section showing lithological units and water table; see Fig. 4 for legend.

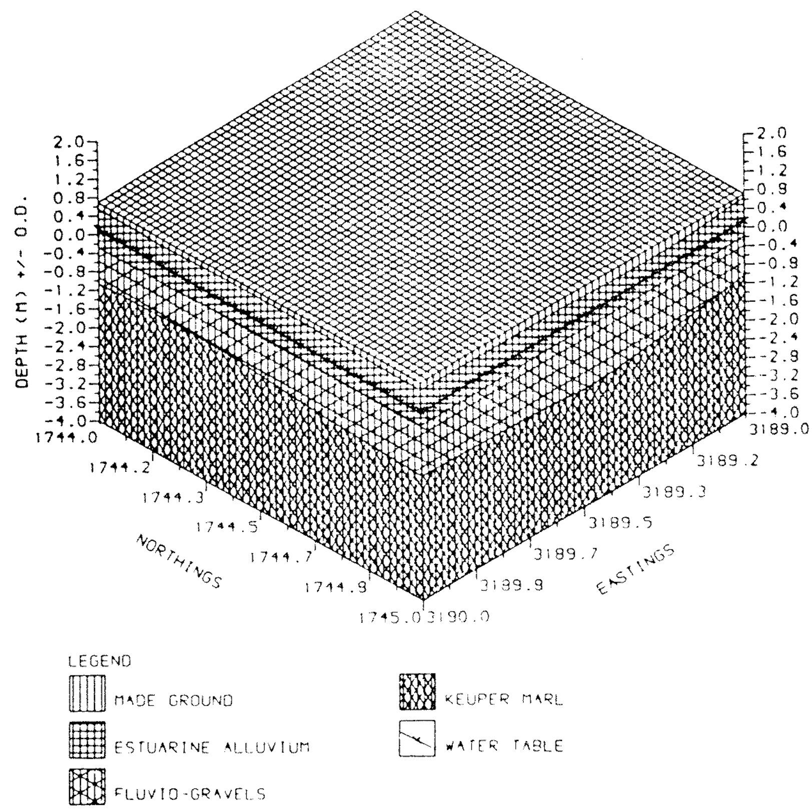


Figure 4. Final format of the multi-surface isometric projection; an example from the low relief docklands of south Cardiff.

The extent of the location plan and the site under consideration are defined separately, so that the site appears as a window on the location plan. As all data points are shown, this format enables the validity of the interpolation to be gauged by a visual assessment of data-point concentration. As necessary, data-point concentrations can be used formally to prepare quantitative statements on quality assurance.

APPLICATIONS OF STRATA 3

As a geotechnical data management system, STRATA 3 has a wide range of applications in both urban planning and civil engineering practice. From a planning viewpoint, an important advantage of this system is the provision of 3-D graphics which permit enhanced appreciation, by developers, planners and other non-specialists, of complex geological and geotechnical conditions. In the field of urban planning and management the main applications are in:

- The rapid provision of geological and geotechnical data to potential developers.
- Land-use planning, where the influence of ground conditions on development costs can be taken into account. Local ground conditions can be optimised when planning the layout of structures within individual sites and, if appropriate, a similar logic can be applied to the selection of sites for particular types of developments (viz. car parks, green belt/recreational land, subsurface structure, multi-storey structures etc.).
- Development control in hazardous environments. STRATA 3 can be used to gauge the degree of hazard from natural phenomenon such as landsliding or flooding. For example, such hazards may relate to the distribution of steep topography and particularly unstable geological sequences or to the occurence of a high water table. STRATA 3 highlights the individual factors that might be detrimental to the long-term security of developments and permits an interpretation of their effect, or combined effects, in the absence of speciality hazard maps.

To a large extent the utility of STRATA 3 as an urban planning tool will depend on the geological setting and the management role of the planning authority. However, in many urban scenarios geotechnical data management systems could provide, not only cost benefits to developers, but long-term advantages to planning authorities.

Although not of principal concern to this conference STRATA 3 also has utility in civil engineering practice; substantial cost benefits could be gained in the fields of:

- Site investigation.
- Preliminary foundation design of buildings and highway structures.
- Preliminary costing of ground works and earthworks.

FUTURÉ DEVELOPMENTS

Future research and development work will concern: (1) the periodic updating of the database and graphics facilities and (2) the automated provision of factual and interpolated data from STRATA 3 for use with other software.

A number of R & D activities are already being addressed, these include:

- The replacement of GINO with a more modern contouring graphics package. The requirements of the new software are that it offers a number of different interpolation methods and a facility for the incorporation of geological faults as well as improved quality of the graphics and annotations.
- The linkage of STRATA 3 with geographic information systems and computer mapping packages so that data sets which define continuous 3D geology can be used directly to prepare thematic maps. In the simplest cases, contours showing depth to rockhead, depth to water table or thickness of compressive stratum can be superimposed onto maps showng surface geology. For other purposes the combined effect of two or more factors could be represented by summing numerical ratings given to each factor zone. Linkage to geographical information systems will also be necessary in order to utilise digital Ordnance Survey data.
- The preparation of fence diagrams, which incorporate borehole logs, for end-users who require factual rather than interpolated information.
- The representation of underground services on the graphical output.

CONCLUSIONS

STRATA 3 is a geotechnical data management system which comprises a database and a graphics package. The database (ORACLE) provides a means for storage and retrieval of existing borehole information, also, it directly provides input files for the graphics package (GINO). GINO performs interpolation between these known data points and permits output of geological sections and contour/location plans; modification to this software has enabled the production of multi-surface, isometric projections.

The 3D graphics offer important advantages to developers, planners and other non-specialists as they permit enhanced appreciation of complex geological and geotechnical conditions. The main applications of STRATA 3 to urban planners are in the rapid provision of geological and geotechnical data, land-use planning and development control in hazardous environments. STRATA 3 is now being used under contract to the Department of the Environment for the management of geotechnical records in an environmental geology study of the Severn Levels.

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THE DEVELOPMENT OF URBAN AND REGIONAL INFORMATION SYSTEM IN MEDIUM SIZED CITIES OF CHINA

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ABSTRACT

This paper presents the development and application of the Urban and Regional Planning and Management Information Systems in China, especially in the medium sized cities.

INTRODUCTION

The Urban and Regional Information System (URIS) have been developed for about twenty years, since it came into being in the late 1960's. The Urban and Regional Information Systems Association (URISA) was organized at the Fourth Annual Conference on Urban Planning Information Systems and Programs, held at Berkeley (California, U.S.A.) in August 1966. URISA is an international organization dedicated to the advancement of information systems capabilities relating to urban areas (John E. Rickert, 1972). When urban information systems were first being conceived and started under development, it was assumed by many that they would provide the answers to virtually all urban ills (Robert E. Joyce, 1972).

There is no clean dividing line between urban analysis and regional analysis (Richard Rhoda, 1982). The former is actually a special case of the latter with focuses on patterns and processes within individual urban of metropolitan areas. It may even turn out that patterns within a city may result from processes operating elsewhere.

Over the past two decades, computer-based URIS have been developed to assist in the very difficult problems, specifically in transport, utilities, facility and distribution planning. A 1982 paper (Raker, D.S., computing mapping and geographic information system for market research), listed 26 companies providing either GIS services or geographical data, or both, in this area.

Facing the challenges of the information area, the China have adopted a vigorous attitude to catch up with the international progress in the eighties with great effort. It is clear about that there is still a longer way for us to go not only in the technology. Further more great discrepancy either in social requirements or ideology exists (Chen Shupeng, 1987). The URIS has still been looked upon as a new one of high technology. But, since the eighties, Chinese scientists and urban planners have made great effort to the establishment of URIS in China.

The urbanization is very strongly problem in China for next twenty or more years for the economic developing (Guifa Cao, 1987). What are the development objectives of the national government and local government? How do these objectives impact on urbanization and regional development? How much leverage does government have on urban and regional growth processes? The national and local government should answer these. So they give some supports for to develope the URIS. Several of the issues have already been addressed, and some projects have been prosecuted in China.

A. <u>The World Bank Project of URIS in Medium-Size Cities</u>

In 1987, the Chinese government (SPC -- State Planning Commission) requested a loan of the World Bank for a project to improve the efficiency of medium size city governments in urban planning and municipal management (Alain C. Bertaud and Guifa Cao, Te project design, 1988). Three medium-size cities were selected for a pilot study: Changzhou city in Jiangsu province, Shashi city in Hubei province and Luoyang city in Henan province. The appraisal mission of the World Bank visited the three cities in August -- September 1988, and asked the city agencies to collect several types data, such as, population data by city district, subdistrict, and areas under neighborhood committee; the employment data of large industrial units; establish method to collect and update employment projection from all employers, etc. The appraisal mission of the World Bank visited the cities again in November -- December 1988. These data have been collected. The employment data were needed for up to date projections of employment situations.

According to the World Bank's guidelines, the pilot study should consist of three components:

1. The establishment of a geographic information system for urban planning and municipal management. A variety of data should be collected by appropriate city agencies concerning the city Characteristics and function (fig. 1).

2. The development of methods to analyze these data and models for carrying out urban planning and projections, such as, landuse planning; population projection; housing planning; employment projections, etc.
3. The dissemination of findings of the study to city agencies so that immediate applications can be made in urban management and socio-economic projections. The data collected and the tools developed to analyze the data will be disseminated to governments of other cities to up grade their planning and management skills.

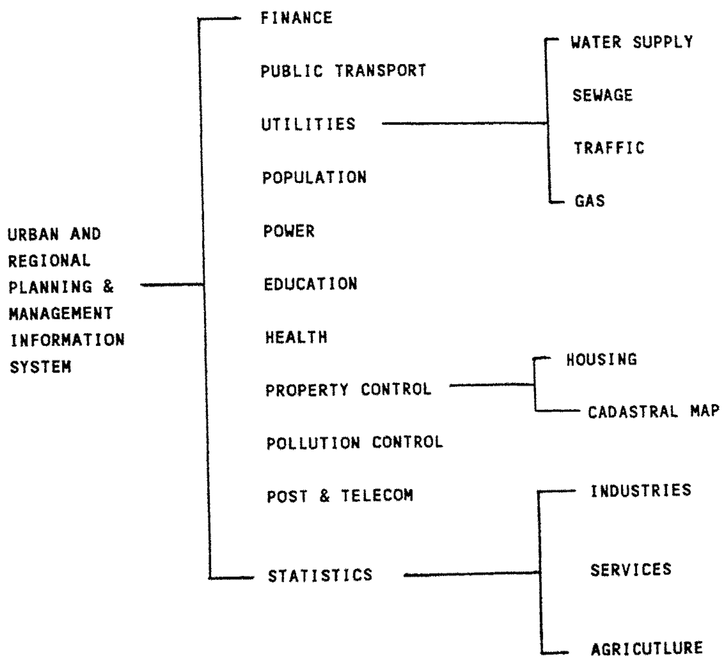

FIG. 1 THE STRUCTURE OF ORGANIZATIONS

According to the schedule, the following tasks of the pilot study should be completed by July, 1989.

1. The design of a geocoding system
2. The derivation of the data information dictionary

And some tasks should be beginning, for example, the base map digitizing (1:1,000 landform maps, landuse maps, 1:500 utilities maps, etc.); the data collecting by geocode system.

B. <u>The Project of Department of Urban Planning and Management in URIS in Suzhou City</u>

A plan has been set up to substantively reconstruct the heart of the old city area of Suzhou city in Jiangsu Province. Since 1987, the Department of Urban Planning and Management, State Ministry of Construction has asked the Institute of Urban Planning, Tongji University in Shanghai to assist Suzhou city government to construct a cadastral information system of the 14 km^2 area in old city. The following tasks are near completion, and the project has proved to be useful:

1. The completion of 1:500 cadastral map of the 14 km^2 area of the old city in Suzhou.
2. The development of a cadastral information systems and automated system of cadastral mapping system.
3. The adoption of the standardized housing classification system of used in the national housing census, originally designed by the State Ministry of Construction.

Since housing classification is essential to urban management and planning, we should take this opportunity to reexamine the above mentioned classification method. It divides the housing into six classes on the basis of construction materials (table 1).

Table 1

classes	construction materials
1	steel structure
2	steel and reinforced concrete structure
3	reinforced concrete structure
4	reinforced concrete & brick-wood structure
5	brick and wood structure
6	others

Obviously this classification scheme does not provide sufficient information for carrying out comprehensive housing planning. For example, it does not give any information about current conditions of housing. Families of difference income and size need different housing facilities; the age of housing is critical to the projection of demands of new housing and requirements of housing maintenance. Thus the Authors believe that the housing classification method should be included three classification normalization; (a) classification on the basis of construction materials, (b) classification on the housing facilities (see table 2); (c) classification on the years of housing construction (see table 3).

Table 2

classes	facilities in house
1	kitchen, bathroom, heating system, water supply, sewer, etc.
2	kitchen, toilet, water supply, sewer
3	kitchen, public toilet, water supply
4	public kitchen, public toilet
5	public kitchen
6	only bedroom

Table 3

classes	construction times of house
1	new, < 5 years
2	6 to 25 years
3	26 to 50 years
4	51 to 75 years
5	76 to 100 years
6	more than 100 years

CONCLUSIONS

The URIS is a tool for urban and regional planning and municipal management. How to use the tool and how to develop the tool that have some different ways in China.

1. The users of the URIS are the city planners and municipal managers, or leaders of the city government. It will be very important for URIS developing that the output and menu system of the URIS should be in Chinese.
2. The urban and regional developing models are the policy models. The policy models study and policy analysis should be included in the developing of the Urban and Regional Information System.

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A KNOWLEDGE-BASED COMPUTER SYSTEM FOR ZONING

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ABSTRACT

Zoning is considered as a main instrument of urban land use planning. A zoning project is a complicated decision-making process, which is related not only to natural, social and economical factors but also to the senses of values of people. Therefore, it is very difficult to make the alternative rational due to limited knowledge and ability of planners. To solve these problems many studies on computer-aided systems have been done. But most of the developed systems are no more than programs of mathematical models in planning process. The experience of planners, which should be considered essential in land use planning, is not always utilized for the decision process. The efficiency of planning might be improved to some extent by these kinds of systems. But they are not sufficient to support planners in making a satisfactory alternative by considering a variety of factors, such as strategies for regional development, the demands of inhabitants and etc..

The objective of this paper is to develop a knowledge-based computer-aided system for zoning in urban land use planning. This system can support planners in making an alternative by using various knowledge stored in the knowledge base in form of IF-THEN rule. We focus our attention on two problems. One is how to acquire knowledge from experts, and the other is how to utilize acquired knowledge efficiently. To the former, we make IF-THEN rules from the " knowledge structure graph", which is obtained by structuring the consciousness of experts or inhabitants. In the graph nodes represent promises or conclusions of rules, and links between any two nodes represent rules. The most important problem about the utilization of knowledge is how to combine ambiguous rules in inference in order to obtain a reasonable conclusion. For this purpose, we develop a new model. This model, improving on traditional fuzzy inference, can describe the variation of certainty factor of a conclusion by the number and the relation (dependent or independent) of the rules to be combined. So human inference mechanism can be expressed more appropriately. An application is also given and its applicability is discussed.

A DECISION SUPPORT AND EXPERT SYSTEM FOR RETAIL PLANNING

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ABSTRACT

An important issue in the Dutch retail planning practice is to predict the likely impacts of new retail developments on consumer demand and assess the feasibility of new projects.

In practice, a planning team has to decide which retail plan out of a number of alternative plans has to be implemented. A decision support system for retail planning can facilitate this decision.

The decision support system consists of three modules. The first module is used to manage the required data. The second module is used to model consumer choice behaviour while the third module summarizes and evaluates the predicted impacts of the alternative retail plans.

AIMS AND NATURE OF RETAIL PLANNING IN THE NETHERLANDS

Physical planning has traditionally played an important role in the Dutch society. The lack of space, fast urbanization and the open nature of its society have increased the need to control land development very carefully. Over the years a detailed set of plans and regulations have been approved which regulate future land use. Such plans require the approval of democratically chosen councils while the public can also participate in the planning process at various stages. Consequently, there has been a strong tendency for the last twenty years to base planning proposals partly on the results of scientific analyses. For example, the Dutch law states that a general survey should be conducted before municipalities can start the preparation of their plans.

In practice, the importance of scientific research in the planning process differs considerably between planning sectors. Retail planning is one sector of urban and regional planning with a traditionally strong input of research in the planning and design process. Until a few years ago, municipalities were obliged by law to conduct some kind of retail planning research whenever a new plan was developed. Although this situation has changed somewhat, this law is not existing any longer as a result of the economic crisis and a consequent deregulation, every day practice still demonstrates a considerable amount of applied research especially when the envisaged changes in the retail structure are substantial.

Perhaps the most important issue in this respect is to predict the likely impacts of new retail developments on consumer demand and assess the feasibility of new projects. The results of such studies are used also to decide on the amount of space and location of new retail facilities. Traditionally, such decisions were made on the basis of a set of normative ratios between the amount of retail space and the number of inhabitants of the plan area, adjusted according to the type of residential zone involved. It soon became evident however that such simple procedures were inadequate to justify the retail plans. Especially the larger scale developments and the peripheral shopping centres had impacts that were beyond previous experience. These developments stimulated the use of more complex research strategies, starting in the late 1970s, to assess the viability of new retail developments on the one hand and the likely impacts of these new developments on the existing shopping centres on the other hand. It resulted in an official governmental report and a series of guidelines for the Dutch provinces and municipalities, which suggested in a very detailed manner the kind of research these planning agencies had to conduct to substantiate their decision making.

The research effort typically involves a large-scale in-home interview to determine consumer orientation patterns for different types of goods, an inventory of available floor space in the various shopping centres, disaggregated according to type of firm, and an interview witn the entrepreneurs. Recently, information about the supply side of the retailing system is stored in a national geographical information system, which covers most of the country and is developed specifically for retail planning purposes. The consumer interview is used to construct mathematical models of consumer shopping behaviour to predict the likely impacts of policy decisions related to building programs, transportation and retail developments, on the level of retail turnover in the various shopping centres of the study area. The assessment of these effects is typically accomplished by comparing the predicted retail turnover per square foot floorspace with a normative planning standard, which is derived from a national survey, sometimes adjusted to the local circumstances. If changes in the retail structure are predicted not to have substantial negative impacts on the level of turnover per square foot floorspace, that is, the predicted level of turnover is not lower than the norm, it is generally concluded that the proposed changes in the retail structure can be justified.

MODELLING CONSUMER CHOICE BEHAVIOUR

To predict the likely effects of policy measures concerning the retail system, the likely effects of those measures on consumer choice behaviour need to be predicted. For this purpose, it is common practice to construct a mathematical model of consumer choice behaviour. In such a model, consumer choice behaviour is explicitly related to a number of features (attributes) of the shopping centres, including the distance between residential location and shopping centre location. After deciding which type of consumer model will be used and which attributes are incorporated in the consumer model (model specification), the exact relationships between choice behaviour and attributes have to be determined (model calibration). Model calibration finally results in a number of parameters which can be considered as weigths for the selected attributes. Next the performance of the model has to be investigated. Only if the model reproduces the consumer choice behaviour used to calibrate the model satisfactory, the model can be used to predict consumer choice behaviour at future moments in time conditional upon the assumption that consumer choice behaviour is stable over time. To predict the likely effects of policy measures on consumer behaviour, the policy measures have to be translated in terms of the attributes of the shopping centres used in the model. Using the adjusted attribute scores, consumer choice behaviour under new circumstances can be predicted.

In the context of Dutch retail planning, the models used are generally based on observed consumer choice behaviour. In several regions the conventional spatial interaction model has been used. Further, the multinomial logit model has found ample application. Recently, individually based choice simulator systems based on conjoint measurements have been developed. In contrast to spatial interaction and discrete choice models which are derived from observed behaviour, the simulator system is based on individuals' expressed or intended behaviour given a number of hypothetical choice alternatives.

Models based on observed choice behaviour

Spatial interaction models are based on observed flows of consumers between residential zones and shopping centres. In practice, the origin-constrained version of this model is used to predict the distribution of consumers over the alternative shopping centres, given their residential zone. According to this model, the number of consumer visiting a particular shopping centre depends on the (relative) attractiveness of the shopping centre and the (relative) distance between residential zone and shopping centre. The attractiveness of the shopping centres is generally represented by some surrogate variable like the amount of floorspace or number of outlets per shopping centre. Sometimes, the model is generalized to incorporate more explanatory variables in the attractiveness component.

In contrast to spatial interation models which are based on aggregate flows of consumers, discrete choice models are based on observed choice behaviour of individual consumers. The well known multinomial logit model is the most frequently used discrete choice model. According to this model, the probability that a consumer chooses a particular shopping centre depends on the relative utility of that centre. The utilities of the shopping centres are assumed to be individual specific and depend on characteristics of the shopping centres as perceived by each individual. Further, discrete choice models take into account individual choice sets: only those shopping centres a consumer is familiar with can be chosen by that consumer.

From a theoretical point of view, a discrete choice model is preferable to a spatial interaction model. In practice however, predicting the likely effects of policy measures using a discrete choice model requires the specification of two additional submodels. First, a submodel to construct individual choice sets is required. To determine the set of available shopping centres for each individual consumer, logistic regression analysis may be used (see for example Van der Heijden & Timmermans, 1984). The second submodel is necessary to relate attribute scores as perceived by the individual to objective characteristics of the shopping centres. Curve fitting procedures may be used to determine such relationships.

Models based on expressed or intended choice behaviour

In a transportation planning context, this approach has become known as the stated preference approach. The approach has gained increasing popularity in retailing, marketing, recreation, transportation, housing, migration, etc. (see e.g. Golledge and Timmermans, 1988). The model system involves generating hypothetical shopping centres by combining shopping centre characteristics, some of which may be beyond the domain of experience, and then requesting consumers to express some measure of preference for the resulting set of shopping opportunities. Individual preference structures may then be derived from these data and choices may be simulated by implementing some decision rule, for example, that a consumer will choose the alternative which received the highest preference. Since these preference structures relate to hypothetical shopping centres, the effects of retail change on individual choice behaviour and turnover levels of the shopping centres in the study area may be predicted by generating new alternatives which reflect these changes and then simulating choice behaviour by applying the derived preference structures and decision rules to the resulting choice sets.

More specifically, the approach involves the following steps (see Timmermans, 1984). First, some measurement model is specified. Next, the hypothetical choice alternatives are generated. This step involves identifying the attributes which are considered important in influencing the choice behaviour of interest, defining these attributes in terms of attribute levels, and then combining these into hypothetical choice alternatives according to some experimental design. The choice of design is largely dictated by the chosen measurement model because especially the complex measurement models cannot be estimated on the basis of simple experimental designs. Subsequently, subjects are requested to express their overall evaluation or preference for the resulting set of choice alternatives. These preference measures are then decomposed into the so called part-worth utilities associated with the various attribute levels, given the a priori specified measurement model. The validity of the decomposition may be assessed by calculating some goodness of fit measure. Having derived the preference structures, the next step involves specifying a decision rule which predicts an individual's choice behaviour given the position of the choice alternatives on his subjective preference scale. In general, different types of decision rules may be considered. The first rule states that an individual will invariably choose the alternative included in his choice set which received the highest preference score. The second rule is not deterministic and states that choice probabilities are systematically related to preferences.

The simulation works as follows. First, the shopping centres are described in terms of the attributes included in the preference experiment. Next, for each individual separately, a choice set is identified using some submodel. The consumer's preference score for each shopping centre is then calculated by applying his part-worth preference function to the description of the shopping centres in terms of attribute levels. Given these preference scores, actual behaviour is simulated by implementing the decision rule. These predicted individual choices are then aggregated to yield an estimate of aggregate retail turnover. Impacts are simulated by defining retail plans in terms of the attribute levels included in the conjoint measurement model. This results in adjusted attribute levels of the shopping centres involved and hence in changes in preferences and subsequent choice behaviour. This process is repeated iteratively for some fixed time horizon.

Recently, Louviere and Woodworth (1983) have developed an alternative approach. Basically, this approach involves measuring choices directly rather than constructing choices from preference ratings. Essentially, their approach amounts to estimating random utility models from experimental design data, that is choices among hypothetical alternatives. These choice designs differ from preference designs in that the hypothetical choice alternatives should now be placed into choice sets. This can be done in a number of ways (Louviere and Timmermans, 1987). Because one now deals with choices per se rather than preferences, the estimated choice model can be used directly to simulate consumer choice behaviour.

A DECISION SUPPORT SYSTEM FOR RETAIL PLANNING

The application of choice models to problems of retail planning commonly involves research institutes or universities to collect the data, estimate the model and run a fixed number of scenarios. Retail planning processes usually involve a number of representatives of various parties (local government, local retailers, national chains, Ministry of Economic Affairs, consumer groups, etc.). In practice, this planning group proposes a number of scenarios to be considered and the analyst then runs his model to assess the impacts of such scenarios. His findings are then used to support the decision making process as an input to the discussions or negotiations or as a way of formulating additional scenarios. Due to this formalized nature of the planning process, it can often take several weeks before the next meeting is held. Perhaps more problematic though, is that many research contracts include a limited number of runs, which will often frustate the planning process in that additional analyses require additional funding. Moreover, to assess the impacts of plans of local retailers later on, the model has to be used several times afterwards. Hence, a need was felt to develop user-friendly computer software that can be considered as a decision support system for retail planning.

We will now describe some computer software that has been developed by the authors. The software consists of three main modules. First, the information base includes software to manage the necessary information. Second, the modelbase contains software to model consumer choice behaviour. Finally, the third part contains software to summarize the results of different scenarios and evaluate those scenarios on a series of criteria or system performance indicators to assist the planning team in the decision making process.

Module 1: Database

The database module enables users to input and manage the required data. This module can be used to simulate policy measures by changing, deleting or introducing shopping centres in future time periods, or by changing the number of inhabitants per residential zone or even changing the number of residential zones. The required data contains the following information.

The supply side

This part of the information base includes data about the location, size and type of shops. To calculate normative turnover figures for each shopping centre, normative turnover-to-floorspace levels, disaggregated to type of shop are required. In addition, characteristics of shopping centres like the amount of parking facilities, type of shopping centre, etcetera are required.

The transportation network

To calculate travel times between residential zones and shopping centres, a transportation network has to be specified, including future alterations. Alternatively, a matrix of travel times is allowed as well.

Population figures and expenditures

To predict the turnover in each shopping centre in the future, the development of the number of inhabitants per residential zone and their expenditures need to be known. In addition, the outflow of expenditures to shopping centres in external zones and the inflow of expenditures of consumers living in external zones must be assessed.

Choice behaviour

To estimate the parameters of the model, one requires data concerning consumer choice behaviour. The required data depends on the type of model used. If a spatial interaction model is used, a so-called observed interaction matrix should be constructed. Each cell of this matrix contains the number of times a particular shopping centre is being visited by consumers living in a particular residential zone. In the case a discrete choice model is used, much more information is required. First, for each respondent, the set of available shopping centres has to be identified. Second, the number of times a respondent visits each available shopping centre is required. Third, the attribute scores of the available shopping centres as perceived by the respondent are needed. In the case of the simulator system, depending on whether a preference task or a choice task is being applied, individual preferences or intended choices are required. To assess the applicability of the simulator system in practice, observed choice behaviour is required as well.

Module 2: Modelbase

This part of the decision support system contains software to calibrate a consumer choice model and to predict consumer choice behaviour using the calibrated choice model. For each type of model, an independent computer program is available. In addition, a program to determine the goodness-of-fit between observed (or intended) choice behaviour and choice behaviour predicted by the model is available. Each program runs on personal computers under DOS.

Spinmo

The SPINMO (SPatial INteraction MOdelling) program (Borgers and Timmermans, 1988) uses the scores of the shopping centres on one or more attributes and a matrix of distances between residential zones and shopping centres to model the observed flows of consumers. Several distance functions can be specified, e.g. a power function, an exponential function or a combination of both. SPINMO minimizes the sum of squared deviances between observed and predicted flows by means of a gradient search method and/or a sequential search method.

Caldis

The CALDIS (CALibration of DIScrete choice models) program (Borgers, 1985) was developed to calibrate several types of discrete choice models. The pc-version of CALDIS, however, only contains the multinomial logit model. The program estimates the weights of the attributes given the number of times each individual chooses each available shopping centre and the attributes scores as perceived by the individuals. The program uses the log-likelihood as optimization criterion. Like the SPINMO program, CALDIS uses a gradient and/or a sequential search method to find the optimal point in the parameter space. After predicting individual choice frequencies, both observed and predicted individual choice behaviour can be aggragated into flows between residential zones and shopping centres.

Giant

The GIANT (Generation, Implementation & ANalysis of Treatments) system (Timmermans & Borgers, 1989), part of which is still in a developing stage, can be considered as an expert system to assist the analyst in constructing and analyzing conjoint-based simulator systems. The design of experiments, which is required in using such a modelling approach demands some expert-knowledge which is often not available. This program aims at filling this gap. It should be emphasized that the system is thus not specifically developed for retail planning applications. It is a program to support the formulation of decompositional preference and choice models and analyze human decision making and choice behaviour in general. The program may thus be of use in all possible kinds of planning and policy-making contexts related to preferences and choice behaviour.

The program is menu-driven. It allows the user (a) to construct designs and generate experimental tasks, (b) to input and control subjects' responses to such experimental tasks, (c) to estimate preference functions and choice models from these experimental designs data, and (d) to simulate actual choice behaviour using the estimated preference functions or choice models.

The most difficult part in developing these models is the construction of experimental designs that allow estimating the required model. GIANT allows addressing this problem at four levels of sophistication and expertise. The unexperienced user can choose from a number of typical problems for which the modelling approach may be used. Depending upon the chosen option, the program then raises some additional questions and finally constructs the required designs. This option might also be used by an experienced user to deal with standard problems. At the next, more sophisticated level the system can be used to answer a series of questions and the system then determines whether a suitable experimental design can be constructed. A third option allows the user to use an experimental design from the data base of the program. Finally, the program contains an option to contruct one own's design. Evidently, this option requires sufficient knowledge on the part of the user, but the system provides a number of analytic modules to assist the user in understanding the properties of the constructed design.

Several standard problems are incorporated in the system design. One such problem is that of conjoint preference measuring. This option should be chosen if one wishes to measure individual preferences for hypothetical choice alternatives. The program enables the user to construct the hypothetical choice alternatives so that individual overall preference measures can be decomposed into part-worth utilities for the attribute levels. Another standard problem concerns the estimation of the impacts of possible modifications in existing alternatives. In this case, the program generates a number of treatments. The proposed modifications and their levels are varied over the treatments so that the effect of each modification can be assessed. Still another problem concerns the prediction of market shares in so-called variable markets. Choice sets varying in size and composition are constructed to get insight in expressed choice behaviour.

To deal with such problems, several decisions have to be made. In the most simple mode, decisions are made by the system which confronts the user only with those options that leave some freedom of choice. All decision that are logically required to deal with a certain problem are made automatically. In the other modes, these decision have to be made by the user. The system only warns against inconsistencies and improper solutions and provides some additional information.

The most important decision in this respect is whether the user wishes to implement a preference design or a choice design because this decision dictates much of the subsequent decisions, schemes of analyses and simulations. If a choice task is selected, the user has to decide whether to use a paired comparison design or a multiple comparison design. A paired comparison design has often some advantages, but a multiple comparision design should be chosen whenever one wishes to examine extended choice sets. The system has several options to construct such multiple comparison designs. In particular, it allows the construction of single fractional factorial design, split plot designs, foldover designs, and randomized designs. If required, the statistical properties of the design are displayed and the user is guarded against faults. The system allows also the user to include a base alternative to each choice set and to construct either fixed or varying choice set designs.

Having generated a design, the program can be used to output the experimental tasks. The user is requested to name the choice alternatives, attributes, and attributes levels assumed to affect consumer behaviour. In addition, the system permits inputting additional texts introducing the experimental task or specifying the measurement scale. A simple text-processing routine is written to help the user in describing the design and the experimental task. Important for many applied research projects is that the system allows the user to randomize the choice sets, choice alternatives, attributes and/or attribute levels across subjects. This is a very time-consuming task if the designs are constructed by hand and therefore this option is often omitted in practice at the risk of introducing different kinds of biases in the measurement.

The next main part of the computer program allows the user to input the responses to the constructed experimental tasks. Again, several options are available. Ranking, ratings, single choice and allocation data may be inputted, and whenever possible, the inputted data are automatically checked. The system contains also a number of routines to convert data. Ratings may be converted into rankings; rankings may be exploited to generate choice data; allocation data can be converted into single choice data.

Once the response data are available the preference or choice model can be estimated. Several estimation procedures may be used, depending upon the scale properties and the kind of model one wishes to use (for details, see Timmermans, 1984). A necessary step in the estimation involves the construction of a design matrix. That is, the design has to be coded in terms of a series of indicator variables. GIANT allows a choice among four coding schemes: dummy coding, effect coding, orthogonal polynomials and a scheme suggested by Louviere (1988). Part of the coding depends upon the model specification and the problem studied. This part of the coding is handled automatically. The coded data can then be used in routines that analyze the data and estimate the specified model. To assist the user in interpreting the results of the analysis, the program generates a couple of summary statistics such as mean coefficients, graphical plots, analyses of monotonicity and tabulations of goodness-of-fit measures.

Finally, the system can be used to perform the simulation and assess the likely impacts of designated policy options or plans. The system allows the use of deterministic choice rules, various probabilistic choice rules, and several direct choice models. Information about market shares is provided.

Gof

Before using the specified model to predict the likely impacts of retail plans, the validity of the model has to be determined. This can be done by comparing predicted flows of consumers between residential zones and shopping centres with observed flows of consumers. The program GOF calculates several goodness-of-fit measures (see Borgers & Timmermans, 1985) between predicted and observed flows of consumers and between predicted and observed number of consumer per shopping centre.

Module 3: Evaluation

In practice, several alternative plans concerning the spatial retail system are considered. The planning team has to decide which plan is most desirable. Given the likely impacts of each plan on several criteria, the selection process can be supported by some multi-criteria evaluation system. The evaluation-system uses a number of system performance indicators as criteria (Van der Heijden, 1986). The indicators compare the impacts of a specific plan to the impacts of the so-called trend (when no policy measures are realized). Alternatively, the impacts of a specific plan may be compared to normative figures. In addition to the indicators, user determined criteria can be used to evaluate the alternative retail plans.

The evaluation technique implemented belongs to the category of mixed data evaluation techniques (see Voogd, 1983). The advantage of mixed data multicriteria evaluation techniques is their ability to process both quantitative criteria and qualitative criteria. Although the system performance indicators are quantitative criteria, the user may wish to add criteria of a qualitative nature. In addition to a matrix of scores of each retail plan on the criteria, a vector of weigths has to be specified. These weights reflect the importance attached to the various criteria. In practice, the weights have to be specified by the planning team.

The system performance indicators can be distinguished in three types. Indicators of retailers interest refer to the economic functioning of the shopping centres. Indicators of consumer interest concern the availability of shopping facilities for consumers living in the residential zones. Finally, indicators of public interest concern items like equality and waste of resources.

Indicators of retailers interest

It is important for the planning team to get insight into the development of the turnover-to-floorspace ratio given some plan as compared to the development according to the trend. The turnover-to-floorspace (T-t-F) figures are considered as a surrogate measure of efficiency. The first indicator of retail interest is determined by calculating the ratio T-t-F(plan)/T-t-F(trend) for each shopping centre at each time period. A ratio less than 1.0 indicates a negative impact for the retailers in the specified shopping centre in the specified time period. By calculating the mean value over all shopping centres and all time periods, an average indicator for the plan under consideration results.

Another indicator of retailers interest is based upon the number of times the T-t-F(plan) is lower than the T-t-F(trend) for a particular shopping centre over all time periods. Averaging over all shopping centres and dividing this average value by the number of time periods gives a second indicator for the proposed plan.

Indicators of consumers interest

For consumers, the available shopping opportunities are important. Therefore, indicators of consumers interest are based on the available amount of floorspace and number of shops for consumers living in a particalar residential zone. To determine which shopping centres are available, some (residential zone specific) distance threshold has to be specified. The available shopping opportunities for consumers living in a specific residential zone according to the proposed plan can be compared to the available shopping opportunities according to the trend by calculating the ratio between both figures. An overall indicator can be determined by averaging the ratios over all residential zones and time periods. Such overall indicator can be calculated for the availability of floorspace, floorspace per branche, number of shops, number of shops per branche, number of different branches, etcetera.

Changes in the local access of the shopping centres can be measured by summing the expenditures in the nearest shopping centre over the residential zones and time periods. Dividing this sum of expenditures by the sum of expenditures in the nearest shopping centres for the trend gives another indicator of consumer interests. Of course, this indicator can be disaggregated according to several branches.

Indicators of public interest

In general, minimizing travel distances is considered as a planning objective. For a plan under consideration, the average distance travelled by consumers can be calculated. The first indicator of public interest equals the ratio of the average distance under condition of the proposed plan and the average distance for the trend.

Another general planning objective concerns the equality in the retail system. Policy measures should pursue equality between retailers and between consumers. Equality between retailers can be assessed by calculating some measure of deviation in the vector containing the averaged turnover-to-floorspace ratio for each shopping centre. Equality between consumers can be determined by calculating a measure of deviation in the vector containing the averaged amount of available shopping facilities per residential zone.

EPILOGUE

In this paper, we described a decision support system for retail planning. The computer package, parts of which are still in a developing stage, contains a database manager, a modelbase and an evaluation module. So far, the system is being used both in a scientific environment to get more insight into spatial choice behaviour, and in an applied planning environment.

In two main cities of the Netherlands, the so-called PEARL system (Borgers & Timmermans, 1986) is used to predict the effects of retail plans proposed by the local government or by local retailers. PEARL is an abridged version of the system described above. The modelbase contains software to predict consumer choice behaviour at the aggregate level. The models were calibrated at our department using observed consumer choice behaviour. The evaluation module only relates predicted turnover-to-floorspace figures to normative turnover-to-floorspace figures.

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TRAFFIC PLANNING BY A 'DESKTOP EXPERT'

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ABSTRACT

Personal computers provide transport engineers with new and powerful means to use computer-based information systems and modelling procedures in their work. The battery of desktop planning tools now available means that modelling can be gainfully used in the planning, design and analysis of transport systems. Models are now easy to use in the design office, and may have a role in community participation and information exchange.

This paper describes the need for a systematic approach to transport and traffic modelling and analysis for understanding travel demand and to provide insights into the traffic and environmental impacts of transport systems management and land use developments. It suggests that a hierarchical system of models and techniques is a valid and useful approach to adopt in these circumstances.

INTRODUCTION

The personal computer and its attendant software, especially GIS for managing transport data sets and PC-based interactive traffic and transport modelling packages provides practising transport planners and engineers with unparalleled opportunities to use the most advanced modelling and information systems management techniques in their work. This paper describes the development of an integrated modelling system (the 'Transport Planning Microscope', TPM) for the identification of road transport user needs and the prediction of the traffic and environmental impacts.

TPM is an integrated, PC-based system that includes geographic information systems (GIS) software and a set of traffic and transport modelling packages in an interactive, design-oriented environment. It provides powerful means for the capture, display, analysis, retrieval, modelling and interpretation of data relating to the way people use transport systems, and the performance of these systems. The resulting system may be seen as a 'microscope' for the planner or engineer, enabling studies of regional, metropolitan and local area road networks and individual road sections and activity sites to be made. The system consists of a connected hierarchy of models and software packages, that enables the analyst to shift the focus of an investigation between the broad and detailed levels. There is a useful analogy with the biologist's use of a microscope in studying a specimen at a series of levels of magnification.

TPM includes two transport network models, MONTRANP and MULATM, for strategic and dense road network analysis, together with an interactive transport data analysis and display package (DIAMONDS) for the examination of travel demand data. DIAMONDS is an interpretative tool for use with a combined physical, demographic and transport database constructed in a GIS framework. The system also provides links to other models, such as TRANSTAT for statistical analysis of transport data, POLDIF for estimating environmental impacts of road traffic, MULTSIM for analysis of arterial road flows, and SIDRA for intersection analysis and design.

The system offers provides new opportunities for desktop analysis, planning and design, with the ability to use a variety of data sources within an integrated framework. It provides a powerful means for understanding of travel behaviour and the impacts of transport systems. The TPM system outlined in this paper may be seen as an integrated database and modelling system for transport planning, which spans all facets of the analyst's work from the identification of user needs to network planning, detailed design and impact assessment.

COMPUTERS IN TRANSPORT PLANNING

The computer is essential in modern transport planning. Computer-based models provide the only practical means for the study and analysis of flows on transport networks. Since the 1950s, engineers and planners have been involved in the development of powerful modelling systems for the study of the component elements of transportation networks, and of the networks themselves. Until recently, however, these models remained in the domain of the specialist and were not suited to widespread application in engineering design and analysis. The advent of the personal computer (PC) drew computer modelling into the design process:

(1) by making computing capacity readily available to the engineering profession at large;
(2) by providing a readily accessible means for the application of the latest computer-based methods (e.g. CAD and GIS) in the design office, and
(3) by providing interfaces (e.g. through interactive graphics and CAD systems) that planners and engineers can use directly in their work and in their communications with other parties and the community.

A full account of the new roles of computer-based methods in transport engineering is given in Young, Taylor and Gipps (1989).

This paper examines some of these recent developments in the state-of-the-art in computing for transport planning, and indicates the development of a unified framework to connect these developments. The following levels of interest are highlighted:

(a) the <u>sketch planning</u> level, where a 'broad-brush' approach that reveals the needs of transport users and provides simple answers to broad, 'ill-defined' questions is sought;
(b) the <u>strategic level</u> network, representing the metropolitan or sub-metropolitan level network of classical transport demand modelling;

(c) the local area (or 'dense') network, which is the detailed representation of a small part of a (typically) urban network. This level represents the transition between traffic engineering and transport planning, and has assumed great significance in contemporary transport analysis;
(d) the individual link or junction in a road system, where questions of operational and design details are important, and
(e) the impacts of transport systems, notably environmental impacts, represented by the air and noise pollution loads carried by a region.

In addition, the heightened interest in computer-based modelling of transport systems has led to developments in the interactive analysis of model outputs, and the assessment of the impacts of transport system operations.

In all of the above areas, PC-based packages involving interactive graphics and database management have provided the impetus for the general introduction of computer-based tools into transport planning practice in the design office. Some examples are cited:

(1) DIAMONDS and TIP (Taylor, Young and Newton, 1988), which provide means for the interpretation of travel demand data and the extrapolation of trends and developments in transport, land use and other interacting systems;
(2) MONTRANP, an educational and practical tool for the analysis of strategic level transportation networks;
(3) the MULATM local area traffic package for local area network studies (Young, Taylor and Gipps, 1989);
(4) SIDGRA, a graphics-based interface for data entry, editing and interrogation of model outputs in the SIDRA package (Chung, 1989);
(5) the POLDIF model for environmental impact assessment, and its linkage to MULATM (Taylor and Anderson, 1988), and
(6) TRANSTAT, a special-purpose statistical package for the analysis of transport data (Thompson, Taylor and Young, 1988).

These packages are connected into an integrated unit through TPM, the 'Transport Planning Microscope'. The means by which TPM can function depends on the availability of GIS software.

GEOGRAPHIC INFORMATION SYSTEMS

Wigan and Kenyon (1988) defined two principal requirements for a transport database management system:

(1) the system should have an interactive graphics interface, so that the geographic dimensions of the data can be clearly (and quickly) seen, and
(2) care is needed to ensure that the information system and its data files may be easily applied in the widest number of environments, i.e. the information system should be able to run without modification on a wide number of host computers (e.g. IBM and Apple microcomputers, workstations, minicomputers and mainframe computers). The use of a standard query language (such as the Structured Query Language, SQL) is also necessary.

There are already commercially-available GIS that meet these requirements. ARC/INFO (see Zwart and Williamson (1988) and Newton, Davis, Simberg and Crawford (1988)) is already finding widespread application in land use and environmental planning. MAPINFO is another GIS package that has already found application in transport planning (see Kurt and Connolly, 1989). Besides providing an established and proven data management system with powerful graphics interface, such systems also offer flexibility in zone definition. Restriction to a pre-determined zoning system has been a substantial problem for the analysis and application of travel data from previous surveys, and has limited the opportunities for cross-comparisons between alternative data sets.

GIS structures allow the representative of the exact site of each data record (e.g. household), say on the basis of digitised co-ordinates), and thus the ability to superimpose a range of zoning systems on the data. A significant feature of the interrogation and display of the GIS is an ability to overlay maps of the distribution of a number of variables in the database, which provides enhanced opportunities for data analysis and the development of an understanding of behaviour and characteristics in the study area.

Zwart and Williamson (1988) defined the requirements of a GIS in terms of two sets of procedures, refinement and manipulation of data and data analysis. The refinement and manipulation procedures transform data, to facilitate handling or analysis by subsequent operations. No analysis functions are performed, the process is that of editing and transformation. In many cases this is all that may be required to provide valuable planning information. The new forms of the data may be valuable in their own right, or may be more readily comprehended visually. Typical operations include classification of both the spatial and attribute data elements on a map, aggregation of the spatial (zonal) elements to provide simplified data sets, interpolation (e.g. to make contour displays more informative), and map projection changes to permit the merging of regions or highlighting of sub-regions.

The data analysis procedures involve the extraction of data from a system for use in decision making. This may be merely the retrieval of the contents of all or part of a data file, or involve complex space-time-attribute queries to such questions as size of area, attribute combinations, distance separation, shortest route, etc. Table 1 provides a list of desirable data handling capabilities for GIS applications in transport planning.

An example of the application of the GIS concept is given in Figure 1. This diagram shows a set of individual databases (topography, land ownership and use, transport network, socio-economic and demographic data, transport system use, and environmental impacts (e.g. noise contours)) that can be combined within the GIS framework. The GIS software enables the user to isolate particular elements from the available data, or to fuse combinations of elements, so that a picture of the performance and structure of particular parts of the transport system can be gauged. All of this is done whilst keeping the spatial perspective of the study area in full view. The GIS package also allows the user to focus on small sub-areas within the full region, or to take the broader regional perspective. In the case of Figure 1, the types of models that may be applied with the particular databases are also indicated.

Table 1 Desirable Data Handling Capabilities of a GIS for Use in Transport Planning

Data Refinement and Manipulation

Reclassification of attributes (add, remove, select and join)

Coordinate manipulation (shift, rotate, scale)

Projection change

Generalise
- dissolve, merge and eliminate boundaries
- line thinning
- line smoothing

Generate (points, lines, corridors, polygons)

Data Analysis

Overlay
* point in polygon (union, join identity, intersect, clip)
* line in polygon (union, join identity, intersect, clip)
* polygon on polygon (union, join identity, intersect, clip)

Measure
* count (number of items)
* distance (between points, along network, along curvilinear alignments)
* areas
* calculate (arithmetic and Boolean conditions)

Network Analysis
* route selection (shortest path, quickest path, optimum tour)
* allocation (acceptable separation between centres, location of facilities and resources)

[source: Zwart and Williamson (1988)]

The ability of the GIS to examine and display transport-related data for a full study area, or any sub-region within it, provides essential support for the concept of a connected hierarchy of transport models.

HIERARCHICAL APPROACH TO MODELLING

Modelling provides a powerful means for understanding the needs of the users of transport systems, and for assessing the ability of a given system to cope with the demands placed upon it. The new generation of transport models provides unparalleled opportunities to use models in project design and evaluation (Young, Taylor and Gipps, 1989). There is no one universal model. Different problems and applications require different models, because the level of detail needed in model output and the demands for valid input data vary between applications.

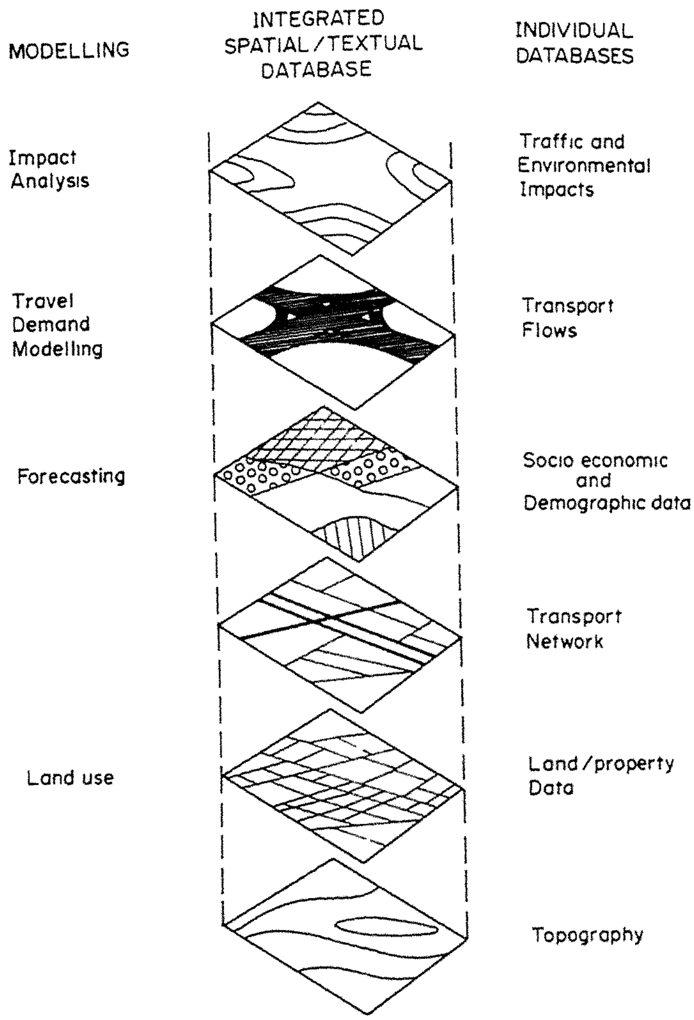

Figure 1: The Geographic Information System provides a framework for integrating several transport-related databases

A useful perspective from which to view modelling strategies is that of a hierarchy of models, as described by Taylor (1988) and Young, Taylor and Gipps (1989). The hierarchy combines:

(a) relevant model theories and concepts, to identify the ideas and relationships that are directly applicable to a given problem;
(b) appropriate levels and detail of input data;
(c) appropriate choice of computing methods and capacity, and
(d) relevant model outputs that describe the performance of the system under study at an accuracy commensurate with the validity of the theories used and the input data.

The following seven-level hierarchy has been found useful for traffic analysis and modelling. Starting at the most detailed (micro-) level, the hierarchy is:

(1) microscopic simulation of individual units in a traffic stream, e.g. for the assessment of vehicle performance in at a junction or along a link;
(2) macroscopic flow models in which the flow units are assumed to behave in some collective fashion on some element of a transport system, e.g. aggregate models of flows on a link or at an intersection;
(3) simulation models of flows in networks for the optimisation of network performance for fixed route choice (i.e. fixed level and distribution of travel demands);
(4) dense network models, including both trip assignment models and models for creating synthetic O-D matrices. This level of the hierarchy introduces a direct demand response to changes in system performance (e.g. deviations in route and destination choice as the characteristics of the transport system are modified);
(5) strategic (or large scale) network models, typically involving the 'four-step' process of trip generation, trip distribution, mode choice and trip assignment. This level is that of the typical transport network analysis package;
(6) land use impact assessment models for the analysis of the local and regional impacts of new or revised facilities, such as retail centres, and
(7) sketch planning models of land use-transport interactions. At this level the spatial connections between system elements need only occur as notional representations.

This hierarchy provides a means of classifying and comparing transport models. Its levels may be distinguished on the basis of spatial aggregation and time duration, with both area and duration increasing as one moves from level 1 to level 7. Areas increase from the isolated junction or road section (individual site), to areas of several hectares (district centre), to several square kilometres (dense network), and to an entire metropolitan area. Study period durations for the microscopic simulations are generally of the order of a few minutes, increasing to a peak 'hour' for the local area models and a 24 hour period for the sketch planning models.

Information Flows in the Hierarchy

The linkages between models from each level of the hierarchy are of great importance. These provide the means for the information transfers that are the essential features that turn a collection of models into the traffic microscope. In TPM the outputs from models at one level become the inputs to the next level, and this process allows for the overall study of a given area or situation and the concentration on some particular aspects of it. Information flows occur in both directions, and in general terms these flows may be seen in terms of travel demand or system performance:

(a) from the higher levels down, outputs from one level of TPM represent inputs (or constraints) to the next level. This progression may be seen as the transfer of demand information (i.e. who will attempt to use some part of the transport system over a given time period), and

(b) reverse direction flows, where model outputs from a lower (more detailed) level may be used as measures of performance, that is as system response ('supply') information. These outputs indicate the ability of that component of the transport system to handle the demands that are placed on it. In turn this will affect the attractiveness of that component to the users.

The hierarchical approach to modelling offers a practical, integrated methodology for examining transport systems models. It provides a framework for judging the appropriate position and use of a particular model, and its relationship to other models. The framework allows the development of a comprehensive strategy for the use of models in transport analysis.

Extent of Intervention by the Analyst

There is one further dimension to the hierarchy. This is the nature of the linkages themselves, largely reflecting the level of intervention of the modeller in the process of information flow. Brownlee et al. (1988) offered the following definitions of the types of linkages that are available:

(a) automatic linkages, in which all information transfers take place independently of the model user. No human intervention is required;

(b) accuracy checking, in which the output from one model is inspected by the user for general validity and accuracy before becoming the input to the next model;

(c) comprehension checking, which requires the modeller to inspect the output for general validity and to gain a better understanding of the modelling process, by following the process at each intermediate step. The modeller must 'certify' the output as acceptable before the process can continue;

(d) knowledge intervention, where the output may be adjusted by the modeller before being used as input to the next level. Any modifications are made in the light of additional knowledge, exogenous to the model but available to the modeller;

(e) knowledge intervention with calibration feedback, which follows the same steps as in d) above to form the initial input to the next level, but then reverses the direction of information flow to take revised inputs into the previous modelling level. This process may be repeated in iterative fashion until a balance between the two models is achieved (e.g. in balancing observed and modelled trip tables and link flows), and

(f) knowledge generation, where the output from one model is only used to provide insights needed to form the input for the next level. This form of linkage is completely manual.

Example: A Regional Centre

The principles behind the hierarchical approach and its practical advantages may be clearly seen by considering an example. The example chosen is the development of a major retail centre and the transport infrastructure required by that centre. The users of the centre are the retailers and the shoppers, and each user group has slightly different transport needs. For the retailers, the need is for the efficient delivery of goods. For shoppers, it is the ease and cost of access to the centre. There may also be adverse impacts from the centre development, e.g.:

(a) retail trade in other centres may decline when the new centre is opened. An evaluation of the development might seek to establish which of the competing centres might be affected, and the degree to which these effects would be felt, and

(b) increased traffic in the vicinity of the centre might overload the existing traffic system, or may lead to undesirable environmental impacts, such as excessive parking demands in surrounding streets.

There may also be positive impacts, such as:

(a) new and enlarged shopping, recreational and community facilities for local users, providing better opportunities, increased quality and range of services, and lower costs, and

(b) the centre may provide a new focal point for public transport operations, leading to improved level of service of transit supply to travellers.

The traffic investigations associated with the appraisal of the proposed development would cover a wide range. Within the development site the concerns would centre on traffic circulation and the provision of parking places and transit terminals, and the movement of pedestrian traffic. At the interface between the centre and the surrounding transport network, the problems relate to access/egress and the capacity and detailed design of the junctions and road links within the immediate environs. The overall traffic and environmental capacities of the roads in the area surrounding the centre are also of interest, and finally the regional impacts on travel demand, employment and system performance would need consideration at a broader level.

Use of TPM begins at the sketch planning level, with an assessment of likely shifts in level and distribution of travel demand arising from the development, over a reasonably long planning horizon. Then follows consideration of the regional transport system, and the changes in travel demand and network performance likely to arise from the development. This permits estimatation of the likely travel demand in the environs of the centre and possible traffic, community and environmental impacts. Finally the detailed performance of transport elements (e.g. junctions, links and parking stations) could be considered.

The subsequent sections of this paper introduce modelling methods that are applicable for studying the behaviour of transport users at each of these levels.

SKETCH PLANNING

Taylor, Young and Newton (1988) provided an account of the use of sketch planning models in transport planning and analysis. This sphere of analysis is characterised by the need for quick, broad brush methods that use readily obtainable data and do not require extensive data inputs for their operation. Two particular means that transport engineers can use in sketch planning are:

(a) interactive display and analysis of spatial data, using a package such as DIAMONDS, and

(b) simplified systems dynamics modelling, for which the TIP program is a useful example.

Full descriptions of TIP and DIAMONDS are found in Taylor, Young and Newton (1988). DIAMONDS combines an interactive mapping program with procedures for the display and manipulation of data matrices (e.g. O-D matrices) taken from a database held in a GIS (MapInfo). For example Figure 2 is a DIAMONDS display of a metropolitan O-D matrix that provides a 'quilt' picture of the structure of the matrix as a preliminary to trip distribution modelling.

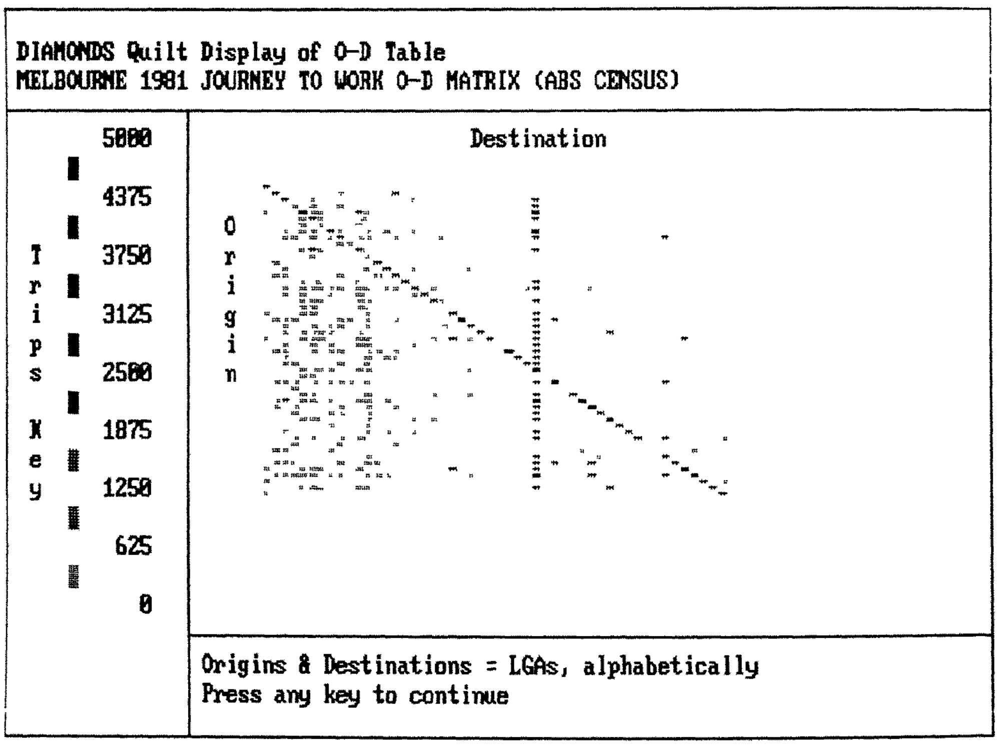

Figure 2: DIAMONDS display of a metropolitan O-D matrix, indicating relative importance of each cell in the matrix

The analysis module in DIAMONDS allows for conventional modelling of origin-destination flows, through the use of singly and doubly-constrained gravity models. More interestingly, it also allows for exploratory data analysis (EDA) of flows, using techniques such as Q-analysis (Atkin, 1974) and FOCUS (Shaw, 1980) that examine the strength and complexity of the interactions between the origins and destinations.

STRATEGIC NETWORK STUDIES

Transport modelling in strategic networks represents the classical form of travel demand modelling, typified by the 'four-step' process. There are a number of useful model developments on PCs, including EMME-2 (Florian 1977) and QRS-II (Horowitz 1987). The MONTRANP package is another such development, aimed at providing an educational system for travel demand modelling. A feature of MONTRANP is the strong use of interactive graphics for presentation. Figures 3 and 4 provide an example, indicating the use of the model hierarchy by TPM. Figure 3 shows a modelled set of link flows on a strategic network. An internal window has been drawn, corresponding to a local area within the strategic network. Figure 4 shows link flows on the main roads in that window.

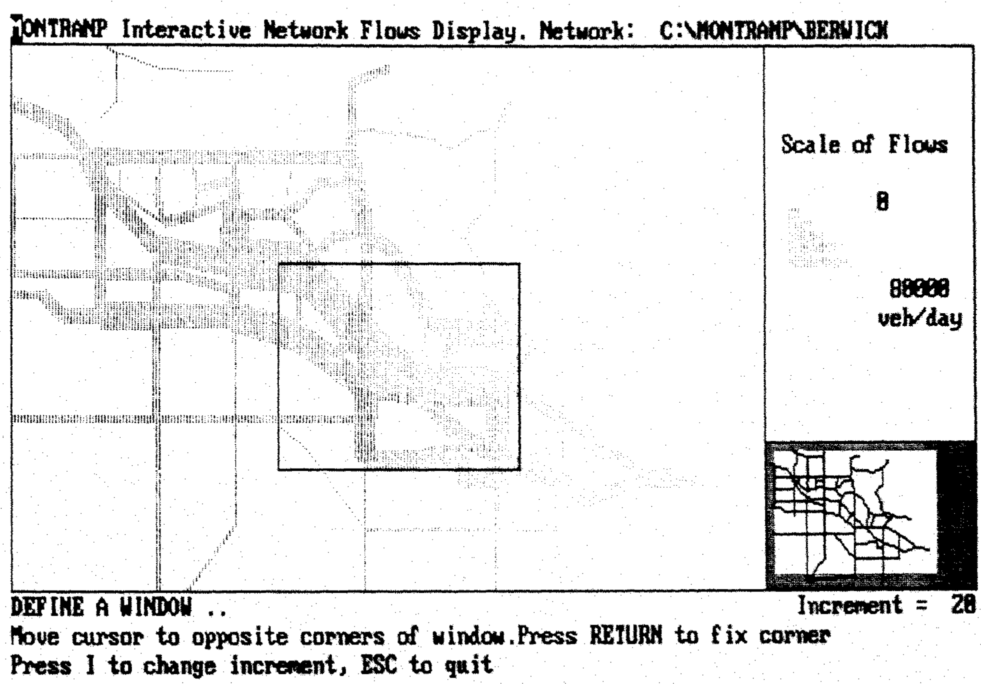

Figure 3: Interactive display of link flows on a strategic level network, showing a window defining a dense network inside it (MONTRANP display)

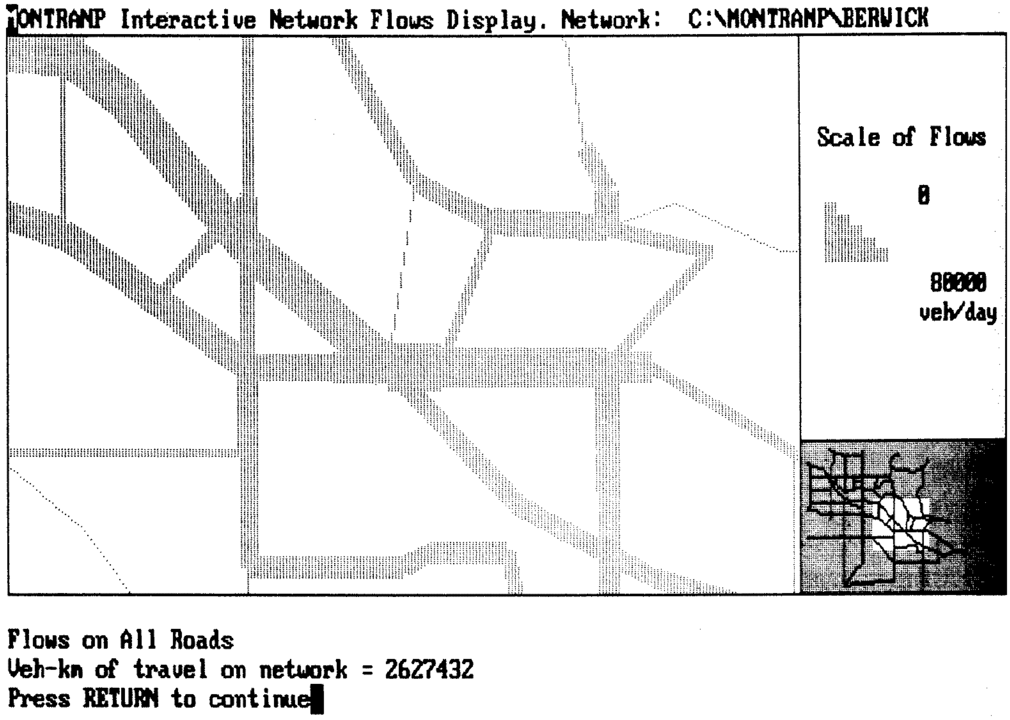

Figure 4: Link flows on main road links inside the window, from MONTRANP

DENSE NETWORKS

MULATM is one example of a dense network model. It is, however, a model that has developed its own 'shell', to the extent that the shell - a powerful interactive traffic database package - has subsumed the model (see Taylor (1987) for details). MULATM now has more than 75 users around the world. A feature of MULATM is its reliance on interactive graphic displays in all facets of its application. Graphic displays of the network, its components, traffic demands, volumes, and derived variables are always available.

One example is presented, in Figure 5. This is a desire line diagram for peak period traffic movements. Such displays are commonly used to display traffic data. The difference here is that this display is available as soon as the data are entered. Further, the display is interactive. Separate pieces of the travel demand pattern can be displayed on request - a boon for the analyst.

INDIVIDUAL JUNCTIONS

MULATM also offers the engineer some insights into performance of individual intersections. Interactive displays of intersection geometry and turning movement flows are available for any junction in the dense network. This information can be taken into the next level of interest, the design and analysis of individual junctions. A current research project at Monash University involves the development of communication links between MULATM and a Computer-Aided Design (CAD) package to permit even more detailed display of road network and traffic data.

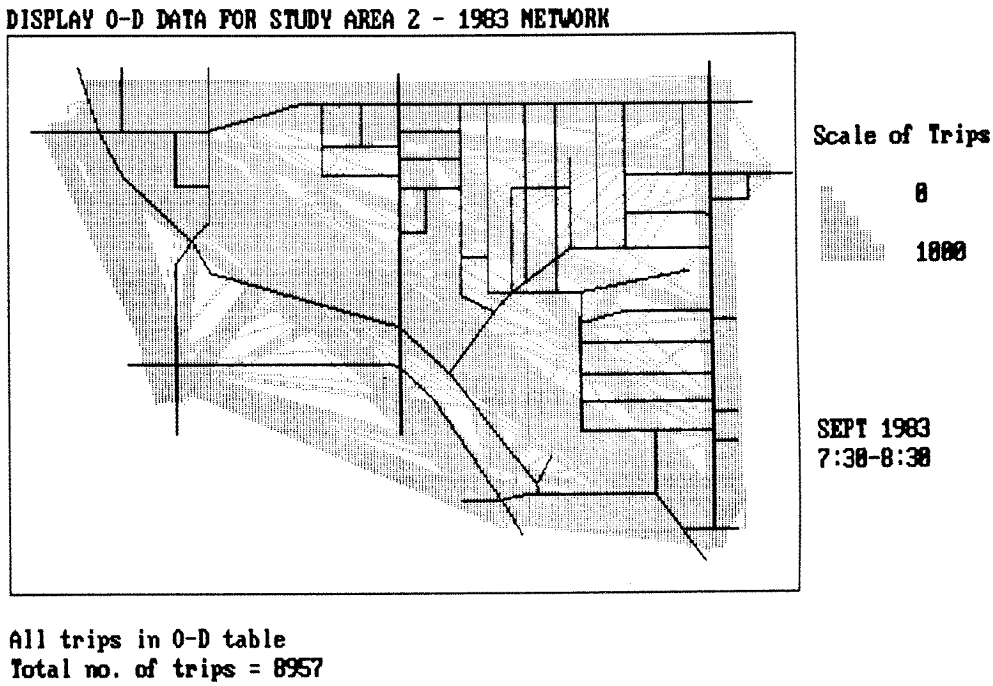

Figure 5: Interactive display of origin-destination flows as desire lines, from MULATM

Junction design, particularly signalisation, is perhaps the most important part of traffic design. The SIDRA package (Akcelik, 1984) is one of the powerful new procedures available for signal analysis. There are now over 90 SIDRA users, in many countries, most of these users run the package on a PC. One difficulty with SIDRA has been the complex input data set needed to use it. Here PC-based graphics provides a solution through the SIDGRA program (Chung, 1989), which provides an interface between the user and SIDRA. SIDRA version 4.0, due for release shortly, will include SIDGRA as the communication interface. SIDGRA shows a diagram of the junction, with windows to highlight one approach leg, or the signal phasings, as shown in Figure 6. A current collaborative project between ARRB and Monash University seeks to establish direct links between MULATM and SIDRA for these purposes.

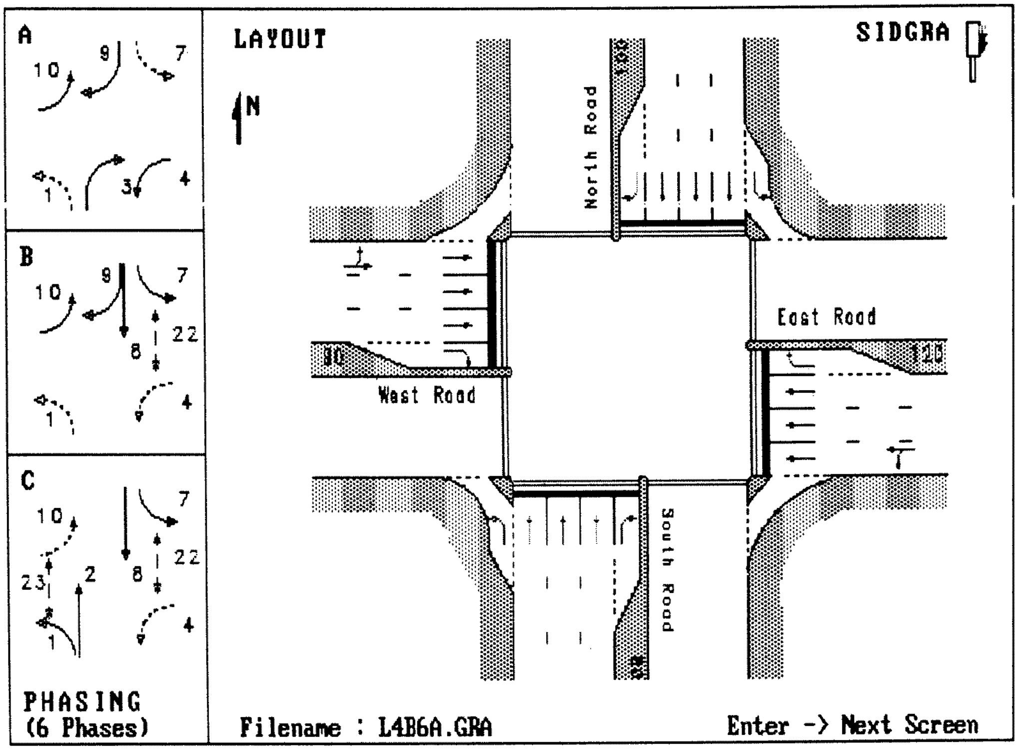

Figure 6: Interactive display of intersection geometry and traffic signal phasings, from SIDGRA

TRAFFIC AND ENVIRONMENTAL IMPACTS

Transport planners now have considerable scope for data analysis on their desk tops, due to the advent of the PC and its rapid dissemination into professional practice. Besides the enhanced opportunities for modelling, there are also new opportunities for the analysis of transport data - either observed data or that generated by models such as those introduced above. Analysis involves the 'straight' application of statistical methods, the interpretation of data through Exploratory Data Analysis (EDA) methods (Thompson, Taylor and Young, 1988), and the estimation of impacts of transport systems developments. Statistical analysis may be done using a general statistical package (such as STATGRAPHICS, which places a large emphasis on graphical presentation), special transport statistical analysis packages, such as TRANSTAT (Thompson, Taylor and Young, 1988), or within a modelling package, as a post-modelling process. Each of these alternatives has its own area of application. MULATM provides for several types of exploratory and statistical analysis of its data, and generates output files that may be taken for use as input to other analysis packages.

A further application of MULATM data is in environmental impact analysis, using the POLDIF model. This model and its linkages to MULATM are described by Taylor and Anderson (1988).

POLDIF takes network and traffic data from MULATM and produces area-wide air and noise pollution levels for the study area. It disperses the pollutants emitted on each link, and aggregates the pollution levels occurring at any point in the area. It presents its output in tables, as contour maps, perspective drawings, or as cross-sections on selected screen lines.

CONCLUSIONS

This paper has outlined the development of a connected hierarchy of traffic models, set under the umbrella of the 'Traffic Microscope', that provides transport engineers and planners with new and powerful means to investigate travel demand and transport systems performance. It provides an insight into the current developments in information technology that are reshaping the methodology of transport planning.

A common thread in all of these developments is the expansion of the computer package beyond the bounds of the model that provides the engine for the study. The model becomes the kernel of a larger database system that the engineer may use to achieve a better understanding of the system under investigation. The computer is the means by which the engineer gains greater insight into the features and problems of the study area. A Geographic Information System, for example, provides a powerful integrated database system that can merge separate databases (e.g. physical, land use, demographic and transport), whilst keeping the essential spatial dimensions of each data set in train. Land use and transport modelling packages can then operate from the integrated database, providing physical and traffic inventories, environmental impact analysis, and diagnostic appraisal of the existing state of the system. Full modelling and simulation capability is always available, but it is but one element in the tool kit available to the planner. Further, communications between the researcher and the practitioner are enhanced, as the practitioner may now take up the most recent developments in a short space of time, and can quickly inform the model developer of the needs for new or alternative output forms, or analysis capabilities. An emphasis on graphics capability provides the means for the rapid dissemination of findings, ideas and proposals to the engineer, other interested professional groups, and the community. These improvements are driven by the rapid advances in PC-hardware capability and the (more recent) rapid developments in PC-software environment and tools for modelling.

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EXPERT SYSTEMS FOR URBAN & BUILDING PLANNING & MANAGEMENT

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ABSTRACT

Expert systems enable knowledge and expertise to be captured and disseminated widely to increase the quality, safety and maintainability of cities and buildings. This is very important in the Asian region which needs to rapidly assemble and transfer expertise to alleviate pressing urban and infrastructure problems.

Applications to be discussed include expert systems to help planners and engineers to correctly interpret complex design and operation procedures to produce safer, more durable and more efficient buildings and infrastructure. Most of the systems run on PC compatible computers which will enable them to be delivered widely and cheaply.

INTRODUCTION

While there is always a need for new knowledge, most problems that exist in both developed and developing nations could be solved using existing expertise. A major difficulty arises from a lack of access to experts who can transfer and adapt the existing knowledge to new situations. For example, experts in our Division continually quote cases where knowledge that was reported and publicised many years ago goes unheeded as costly mistakes are repeated. Typical cases include the design of housing, towns and cities to reduce the impact of cyclones, fires and floods. For example, Darwin was badly devastated by a cyclone in 1975 with a substantial loss of life and 80% of the housing was destroyed. In contrast, larger structures such as a hotel and a drive-in theatre suffered only superficial damage since they were designed by expert engineers whereas houses were not. and subsequent research led to the redesign housing to resist cyclones. However, while this information has helped to reduce the impact of later cyclones, it has not gone far enough. The design procedures have become more complex as a result and more expert assistance is required to interpret the design codes.

As a result of difficulties in disseminating existing information and knowledge more effectively when and where it is required, buildings and urban services are often built with a life expectancy lower than what could be achieved and this places an unnecessary maintenance burden on future generations as well as failing to meet acceptable levels of performance. Likewise in the control and operation of infrastructure, errors or omissions can occur because expert advice is not at hand when needed.

While our technical publications (including those from this conference) and libraries are bulging with valuable information, much of it is either unknown or relatively inaccessible to practitioners because of cost, time or location constraints. Often language is also a constraint on knowledge transfer. As a result the practitioner often makes unsatisfactory planning, design or construction decisions. The use of expert systems offers a way of making critical expert knowledge more readily accessible to practitioners when needed.

EXPERT SYSTEMS

Over the past decade or so, the range of applications for computers has been extended from the processing and storage of numeric, text and graphical information, to the processing and storage of certain forms of knowledge and expertise. Expert Systems is the name given to the computer software which encapsulates the knowledge of an expert (or set of experts) in a given field, most commonly in the form of IF ... THEN ... rules. The user can conduct a dialogue with an expert system in a similar manner to talking to a real expert, with each asking and answering questions and providing details as they progress towards a problem solution.

While the knowledge in expert systems can never hope to be as good as the knowledge of the individual experts (or sets of experts) they emulate, they can be made to offer many advantages including:

Accessibility. While expert systems can be made available 24 hours per day, experts are generally only accessible during working hours, excluding periods of holidays, sickness, etc. Often they are too busy to be disturbed during working hours and when they leave or retire their expertise is lost. Usually only one person at a time can access a human expert while an expert system can provide multiple access, especially via low cost microcomputers.

Cost and Quality Improvements. Expert systems can often lead to significant benefits if designed carefully.

Release of Experts. Experts are freed from answering large numbers of routine queries and have more time to concentrate on new or more creative problem solving.

Knowledge Crystallisation. After many years of practice experts may forget the underlying reasons for much of their decision making. In many cases knowledge engineering can help reveal this lost reasoning and thus crystallise expert knowledge into a more explicit and usable form. Others can add to the knowledge base or modify it where appropriate for other applications.

Consistency. While experts and practitioners are not always consistent in their answers and sometimes overlook critical factors, well-developed expert systems avoid these shortcomings.

Knowledge retention and dissemination. Expertise can be retained within organisations and where appropriate passed on to others with an opportunity for cost recovery or profit from sales, including export to foreign markets.

Training. Expert systems are often used to raise the level of expertise of other staff and reduce the training burden on experts.

Multiple knowledge sourcing. While it is unlikely that an expert system built from the knowledge of a single expert could outperform that expert, expert systems have been built which have accumulated knowledge from many experts and can thus go beyond the knowledge of a single expert.

Overcoming Language Problems. Explanations can be provided using graphics to minimise the need for extensive use of language to explain difficult concepts. This can be particularly valuable for populations with limited vocabularies.

Limitations of Expert Systems

While many expert systems are now under development around the world, the technology is relatively new and the number of notable successes is limited. They can be expensive to develop and heavily demanding on skilled resources such as the experts, the knowledge engineers (who capture knowledge from the experts) and software engineers. However, the supporting environment is improving rapidly and is driven by the significant returns expected.

Expert systems are not creative in the human sense of being able to invent or create entirely new approaches to solving problems. They cannot reason by analogy or employ 'lateral thinking'. However, they have an ability to quickly explore a much larger number of rules and conditions than a human and sometimes can 'discover' logical solutions overlooked by humans.

APPLICATIONS OF EXPERT SYSTEMS

Expert systems offer great potential to improve:

design,
development and interpretation of standards,
approval processes,
training of staff,
funding processes,
tender specification and evaluation,
maintenance, and
control

for cities, buildings and infrastructure systems by making expertise more readily available when required (Wager, 1984; Kim et al, 1986; Sriram and Adey, 1986; Sharpe et al, 1986; Allwood, 1988).

The CSIRO Division of Building, Construction and Engineering has pioneered the development of several expert systems for the construction and infrastructure sector over the past five years. Some have been developed as demonstration prototypes, while others involve collaboration with industry groups. Several new initiatives have also been proposed and funding is being explored.

Water, Sewerage and Drainage Expert System

A prototype expert system has been developed in a one-year collaborative project with the Melbourne and Metropolitan Board of Works (MMBW) to advise operators of the Melbourne water and sewerage networks using data provided by the Integrated Telemetry Network (ITN). The ITN (Cosgriff et al, 1985) continuously checks for pump faults, pressure limit violations, flow rates, valve positions, water levels, etc., at over 400 automatic pumping stations in the metropolitan area, and reports any abnormal conditions on computer consoles to the system operators for action.

Codifying the response to alarms, especially when there are multiple alarms, is an ideal application for an Expert System. Such a system also acts as a repository for 'corporate knowledge' and provides diagnostic advice on faults, which the operators can draw upon. The overall objective in using the expert system is to 'send the right person at the right time' to attend each fault, taking into account the station configuration, time of day, weather, demand or loading and availability of personnel.

The prototype expert system contains knowledge covering most of the sewerage kerb side pumping stations (about 100 automatic pump stations) and a part of the water supply network (6 pump stations). The project is now in the evaluation phase and preliminary cost benefit studies carried out so far indicate that the productivity and service improvements gained through more effective utilisation of operations and maintenance staff time and more reliable fault diagnosis will produce a high return on investment (Thomson et al, 1987).

The prototype will be extended to cover the rest of the network and incorporated into the ITN to become a regular part of the MMBW's monitoring and control system.

National Standards

Every nation has a set of standards covering its private and public sector design, planning, manufacturing and construction activities. In Australia, the local standards authority (Standards Australia) is responsible for over 4000 standards, many of which relate to the design, control and maintenance of cities, buildings and infrastructure. Many of these standards are complex and difficult to interpret quickly and accurately, especially by inexperienced or infrequent users. Errors are often made leading to either costly over-design or inferior and sometimes unsafe structures (Melchers, 1984).

Standards Australia and CSIRO have collaborated in a two year project to convert the Wind Loading Code (AS 1170.2) into a microcomputer-based expert system (WINDLOADER) for estimating wind loads on structures. The expert system not only includes code clauses, but also help in interpreting the complex code. The expert system is expected to find wide use not only within Australia, but also New Zealand and other South Pacific countries. It is also applicable to other nations. The code affects all buildings and structures including public buildings.

WINDLOADER posed many difficulties as an expert system since the code on which it is based makes extensive use of complex equations and table interpolations. The code also uses graphics to convey complex concepts. In addition it was desired to deliver the system as a PC microcomputer software package which could run fast and not require more than 640 k RAM. An expert system shell called CRYSTAL met the necessary requirements and WINDLOADER is now complete and being distributed within Australia.

Planning and Building Regulations

Governmental agencies throughout the world have various regulations to control urban and building development. These often run to many volumes within any one city and frequently they involve several government departments with different responsibilities, for example, urban development, transport, water supply, energy and health. While regulations are intended to provide for orderly and efficient development, their complexity and subdivided responsibilities can impede achievement of those objectives. Furthermore, when regulations are drafted, contradictions, omissions and other inconsistencies may not become obvious until the regulations are adopted into practice. Expert systems offer a way to improve both the drafting and interpretation of such regulations.

As an example, an expert system for the Building Code of Australia (BCA) is being developed in collaboration with the Australian Uniform Building Regulations Coordinating Council (AUBRCC). The BCA will be simultaneously restructured to become a performance based code and the project is expected to take about three years. The project aims to help code developers, checking authorities, designers and the building industry through:

faster and easier checking of the logical consistency of the BCA and proposed amendments including incorporation of State and local government variations;

restructuring of the BCA into a more logical format by removing contradictions, obscurities and omissions and presentation of regulations to users in a more convenient form (including use of menus and colour graphics);

helping to overcome problems of shortages of skilled knowledgeable staff;

greater speed, accuracy and ease-of-use ensuring better compliance and savings in time and cost;

an ability for designers to explore a wider range of design options by quickly testing out variations (e.g. dimensions, exit locations, fire protection); and assisting in the education of building designers and checking officials.

The total value of residential and nonresidential building construction in Australia is over $20 000 million p.a. and the expert system could bring substantial benefits to the industry. An attempt will be made to include a standard construction terminology currently being developed (by a working group of the International Standards Organisation) in the expert assistant so that it might communicate with CAD and other software packages.

A demonstration prototype for a small part of the code has been developed using the Crystal PC expert system shell and this was instrumental in AUBRCC deciding to collaborate in further development.

Unlike WINDLOADER the BCA does not have any complex equations making development easier in one respect, but this is offset by the greater size of the BCA. The development of the prototype has indicated that while the BCA is rule based and thus could be directly coded into a rule based system with depth-first search, it is much more convenient for the user if a menu based format is adopted to allow much faster processing and removal of unnecessary questions.

For example, the building classification section (Figure 1) is more conveniently replaced by a series of menus to allow breadth-first search (Figure 2). Otherwise if the rules were entered in the order that they appear in the code, a depth-first search would be undertaken in which the designer of a residential or office building could be asked a series of irrelevant questions about other classes before getting to his area of interest. Instead he may quickly quickly select his area of interest in Figure 2(a), and then proceed to more detailed questions in the next menu (Figure 2(b)) and so on. In the actual program these figures are displayed on the screen in color and a cursor bar is used to highlight the options.

Diagrams have also been used as an aid to assist users to interpret complex rules. Figure 3 shows explanatory screens to help the user calculate the *rise of storeys*. The result is used in determining classification in section A3.2(c) of Figure 1 as well as being used in subsequent calculations to determine necessary levels of fire resistance in walls and ceilings.

Environmental Noise Expert System

A Very Fast Train (VFT) system is being planned to run between Melbourne and Sydney at speeds up to 350 kph allowing the trip to be made in three hours. An extensive feasibility study is being undertaken and part of this will include environmental noise impact. Very few trains in the world operate at speeds above 300 kph and hence considerable expertise is required to assemble and extrapolate relevant sources of information to estimate the likely impact. This is being done through the development of an expert system called NOISEXPT.

High-speed trains in Japan and France operate at speeds above 200 kph. Also it has been reported that the InterCity Experiment train in Germany and the TGV in France have approached 400 kph under test conditions. However noise experts, especially experts on railway noise, are scarce and hence it is very difficult for the railway designers to consult them frequently. Instead reliance must be placed, at least initially, on reports and publications using expert interpretation.

The goal for noise control engineering design is to limit the propagated noise levels within the requirements of the relevant regulations and standards. These vary from country to country. For example, Japan has established a national standard for its high speed train (Shinkansen), which limits the average peak noise level (L_{max}) during the passage of a set of trains. Other countries generally prefer to limit an equivalent noise level (L_{eq}) obtained by averaging the noise level over a set period, e.g. 24 hours. In the three Australian states through which the VFT will pass (New South Wales, Victoria and the Australian Capital

CLASSIFICATION OF BUILDINGS AND STRUCTURES

A3.1 Principles of classification

The classification of a building or part of a building is determined by the purpose for which it is designed constructed or adapted to be used

A3.2 Classifications

Buildings are classified as follows

Class 1 a residence which may comprise one or more buildings including any habitable outbuildings which in association constitute-

(a) a single dwelling-house terrace house townhouse, row house villa house or the like which may be detached or separated by a *common wall*,

(b) a dwelling house used as a boarding-house hostel, group house dual occupancy house or the like, in which not more than 12 persons would ordinarily be resident, or

(c) a residential building that does not exceed a *rise* of 3 *storeys* and contains only 2 *sole-occupancy units* located one above the other and each unit has direct egress to a road or *open space*

Class 2 a building containing 2 or more *sole-occupancy units* each being a separate dwelling other than a building of Class 1

Class 3 a residential building other than a building of Class 1 or 2 which is a common place of living for a number of unrelated persons, including-

(a) a boarding-house, guest house, hostel, or lodging-house

(b) a residential part of an hotel or motel,

(c) a residential part of a *school*,

(d) accommodation for the aged disabled or children, and

(e) a residential part of a *health-care building* which accommodates members of staff

Class 4 a dwelling in a building that is Class 5, 6, 7, 8 or 9 if it is the only dwelling in the building

Class 5 an office building used for professional or commercial purposes, excluding buildings of Class 6, 7 or 8

BUILDING CODE of AUSTRALIA 1988 Page **A-15**

(reproduced with permission)

Figure 1. Part of the Classification section extracted from the Building Code of Australia. Remainder of code then refers to a building by its class number.
Note references to key terms (in italics) which may require expert interpretation, eg *rise of storeys* in clause A3 2(c)

Project: Ape   Location: Melb   Building: Ape 1   Designer: rs

Classification Ref BCA A3.2

Is your building	LIKELY CLASSES
a residential building	1,2,3
an office building	5,6,7,8
a building of a public nature	9a,9b
an non-habitable outbuilding or structure	10a,10b

Specific Definitions	E it

F1-HELP

(a)

Project: Ape   Location: Melb   Building: Ape 1   Designer: rs

Classification Ref BCA A3.2

Is your building	LIKELY CLASSES
a single dwelling-house, terrace house,..	1
contains two or more sole occupancy units ...	1 or 2
a dwelling house used as a boarding-house ..	1
a common place of living for unrelated people ..	3

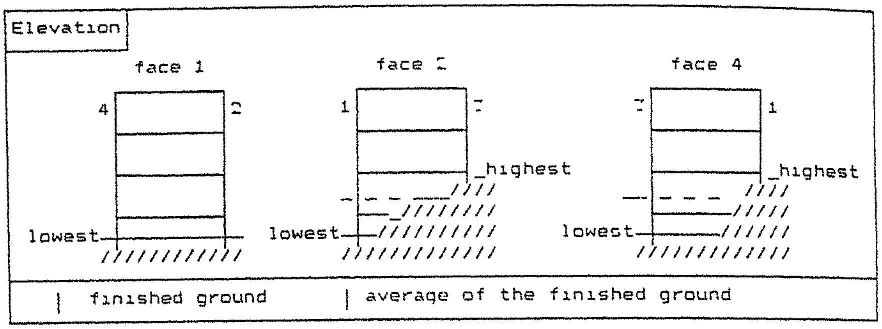
previous screen	Specific Definitions

F1-HELP

(b)

Figure 2 Menus to help user to select Classification subdivision at
(a) upper level, and
(b) at a lower level if first item selected in (a)
Note These diagrams are screen dumps of actual color displays to a printer and do not show the cursor bar highlight

The rise in storeys depends on face 1, 2 or 4, face 3 being a common wall.



Face 1 is the highest wall and certainly going to give the greatest rise in storeys.

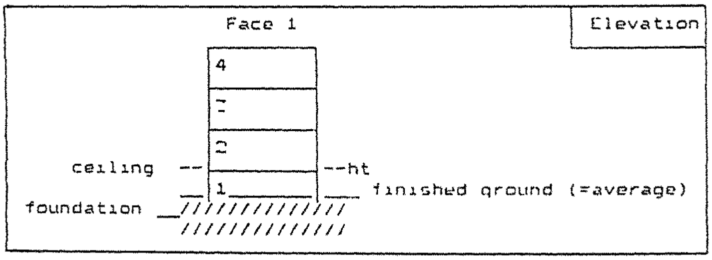
N/n-Next screen   P/p-Previous screen   E/e-Exit

Rule 1 - Storey partly below the finished ground - storey 1

If the height () between the average ground and the underside of the ceiling is less than 1 meter, the first storey is not counted.

Rule 2 - Storey at the top of the building - storey 4

It is not counted if it contains only service units or equipment.



N/n-Next screen   P/p-Previous screen   E/e-Exit

Figure 3. Character graphics displays to help user interpret the *rise of storeys* for deciding Class 1 or 2 and also for fire safety requirements in other parts of the code.

Territory), no standard has been developed for trains. Instead there are general noise standards. Noise is recognised as a critical problem by the community and although no standard has been set for trains, overseas experience suggests that an equivalent noise level over a 24 hour period in the following range could be acceptable:

$L_{eq,24h}$= 55 - 60 dB(A).

NOISEXPT estimates the components of railway noise, namely wheel/rail and aerodynamic noise, based on a method developed by Ringheim (1984) to calculate $L_{eq,24h}$ along track sections. It also allows for noises peculiar to the power system (diesel or electric). In the case of the VFT which is electric, this means including noise generation from the electric motors and the power collection via overhead wires Corrections for exposed track lengths, rail support system, ground effects (embankments, cuttings and tunnels), screen effects as well as other track conditions are made. In addition, the system enables users to take noise countermeasures into account and, if needed, to generate a set of points for mapping noise contours.

Information about noise sources, noise control design and relevant references are organised through an interface between CRYSTAL and dBASE III Plus. NOISEXPT suggests the most effective countermeasures for engineers to take to reduce noise impact. In addition, published references dealing with aspects of noise estimation and its control may be quickly searched on the basis of keywords, author, year of publication, country, title, and journal. There are about 400 references and searches may be conducted using full or partial strings of characters.

CONCLUSION

The above projects show that the development of practical expert systems for improving the quality of urban areas, buildings and infrastructure is possible. While most of the systems discussed have yet to undergo extensive field testing and operation, preliminary results are encouraging. The potential scope is very wide including all areas where human knowledge and expertise is used. It is expected that many expert systems will be developed in the next decade, especially in areas requiring more widespread use of scarce skills and greater consistency, quality and safety.

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AN EXPERT SYSTEM FOR FORECASTING ROADSIDE DEVELOPMENT

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ABSTRACT

An expert system for forecasting roadside development along projected roads and streets in urban and suburban area has been developed on a personal computer. Answering to the inquiries from the computer step by step, one can easily obtain the conclusion which indicates the possibility of settlement of miscellaneous kinds of buildings.

The items to be input are traffic volume, number of lanes, type of streets, population, existence of public establishments, building regulation and other miscellaneous informations. The knowledge base is constructed by synthesizing such informations as books, miscellaneous maps and inquiries to urban planners and to experts on small buisiness management.

1. Introduction

The purpose of this paper is to develope an expert system to forecast location of miscelaneous buildings along a newly constructed road in urban or suburban area.

It has been great concern of planners to forecast such economic effect due to construction of new roads and streets. The specific features of forecasting roadside development are: [1] subjected areas are small and local, [2] characteristic of each area where road or street is constructed must be taken into consideration, [3] it is not sufficient with such rough classifications as residential, commercial or industry.

We have felt that, because of these features, the usual quantitative urban land use models are not appropriate for given purpose, and decided to apply an expert system.

The peculiarity in building our expert system is: [1] as there is no experts in roadside development itself, we gathered knowledges from miscellaneous sources, [2] we applyed K J method developed by Jiro Kawakita in synthesizing process of gathered informations. The expert system is constructed by production rules and Japanese expert shell " Sogen " is used.

2. The knowledge sources on urban roadside development and collection of the knowledges

In order to forecast roadside development we must analyze and specify complex mechanism of the phenomena.
The knowledges are gathered not only from experts but also from papers, statistics and maps in the process of building the expert system. As there is no experts in roadside development itself, we interviewed and gathered

knowledges from such miscellaneous experts as urban planners of Kobe city government, consultants for small business management in Hyogo prefectural government and real estate experts.

The existing states of roadside development are observed as other important knowledge sources with urban land use maps, road and street maps, traffic flow maps, retail business maps, roadside service business maps and others. The survey on covenient store and mini-super store business by bureau of economy of Kobe city and statistics are reviewed. General rules on roadside development are also gathered from papers by several authours and books for retail business and other fields.

3. Production of production rules

The knowledges gathered as above are generally piecemeal, some of them are inconsistent with each other and sometimes they are duplicate. The knowledges must be arranged and systematized to build a knowledge base for the expert system from those widely gathered knowledges. The production rules as written in if ~ then ~ form must be produced after arranging and systematizing knowledges.

We applied K J method developed by Jiro Kawakita to process of elicitation of knowledges and to produce production rules. The advantages of applying this methods are: [1] a great number of piecemeal knowledges gathered from complex knowledge sources can be classified, arranged and systematized without duplication and inconsistency, [2] the confliction of rules due to increase of rules can be resolved and the completeness of rules can be kept, [3] the builder of the expert system can learn many domain expert knowledges in systematic way in the process of elicitation of knowledges and production of rules.

The process of producing production rules by K J method consists of six steps as shown in Fig.1.

In the first step, a great number of knowledges are widely gathered from miscellaneous sources. In the second step, each piecemeal knowledge thus gathered is written as a simple and plain statement on a label. We will have a number of labels in this way. This process is called the labeling process In the third step, the labels which have resembled contents are gathered into a group. The group formed in this way is given a title, which is also written on a label. The title thus given must be such that it represents the content of the set of the labels exactly. Such grouping processes are repeated until the number of groups converges less than ten. In the fourth step, the sets of labels are distributed and placed to neighbour each other according to their similarity on a large size paper. After placing at proper positions the labels are encircled, tied to each other or indexed with other representations to understand the total image. This step is called A type illustration in K J method. In the fifth step, the contents of illustrated labels are composed into an article. This step is called B type composition in K J method. In the final step or sixth step the article is transformed into a number of production rules in if ~ then ~ form.

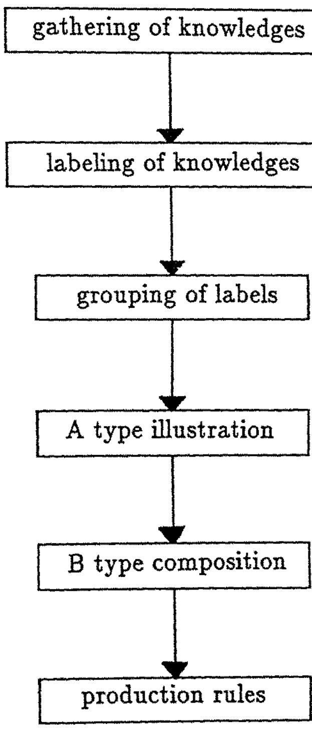

Fig.1 Production of production rules by K J method

Application to commercial buildings can be shown as one example of these processes. Many information gathered are all written on cards. This is because we can refer to necessary information any time. Then we copy the contents of the cards into many labels. The total number of labels become 178. Then these labels are grouped. We have 51 groups in the first try and 23 groups in the second try, we have 10 in the third try and 8 finally. In the fourth step the labels are placed on a large paper considering their similarity. After this step the placed labels are illustrated. As there are too many labels, we draw one main drawing which shows the main issue of things and three detail drawings. The main drawing is shown in Fig.2 and the part of a detail drawing is shown in Fig.3.

Fig.3 is the part which shows "it is better to have many passers-by". The drawing as Fig.3 can be transformed into a sentence as: a commercial area is better to have many passers-by than to have many inhabitants. The neighbours of a railway station usually has many passers-by. Commercial area may be formed in the neighbour of a station. However, it should have many passengers. About 60 percent of big stores are located within 300m from station and other small shops are often located within 500m ········. From these sentences production rules are produced. Some examples of production rules are shown in Fig.5.

4. Outline of the system

(1) The expert shell used.

We applied Japanese expert shell "Sogen". The reason why we applied Sogen is that it has following features as: [1] the system run on a personal computer, so it is very handy, [2] the representation of knowledge is easy by IF $\sim$ THEN $\sim$ type production rules, [3] Japanese language is used as representation of knowledge, [4] development of prototype is easy because modification of rules are very easy in this system, [5] hierarchical knowledge base can be constructed as grouping of production rules is possible using meta-rules, [6] certainty factor can be used for representation of vagueness.

(2) The purpose of the system and subjected area

The subjected area of the system is the urban area of Kobe city. We aim to construct such a system that planners or engineers can consult with the system on roadside development after a new road is constructed.

(3) Composition of the knowledge base

The total knowledge base is constituted from three subsystems in hierarchical structure as shown in Fig.4. Each subsystem is composed with production rules. The production rules are given certainty factors. The certainty factors represent reliability of each production rule with numeric values which rank from -1.0 to +1.0. -1.0 means a complete denial and 1.0 means a complete affirmation. The certainty factors are set consulting with experts modified and renewed until the conclusions coinside existing land use along roads and streets. Number of rules in each subsystem is 157 in subsystem one, 92 in subsystem two and 235 in subsystem three. Total number of rules are

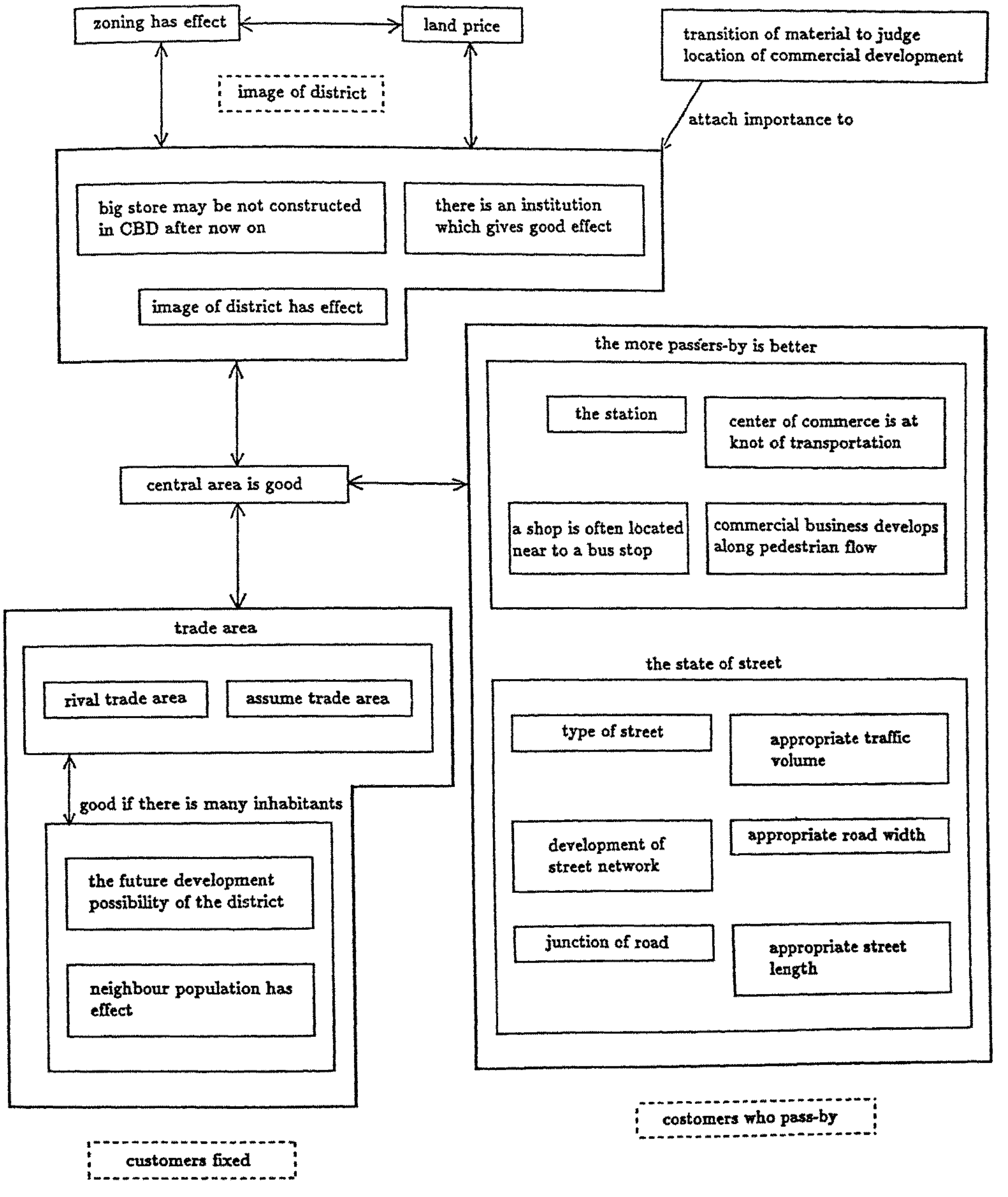

Fig.2 An example of illustration which is applied to commercial development

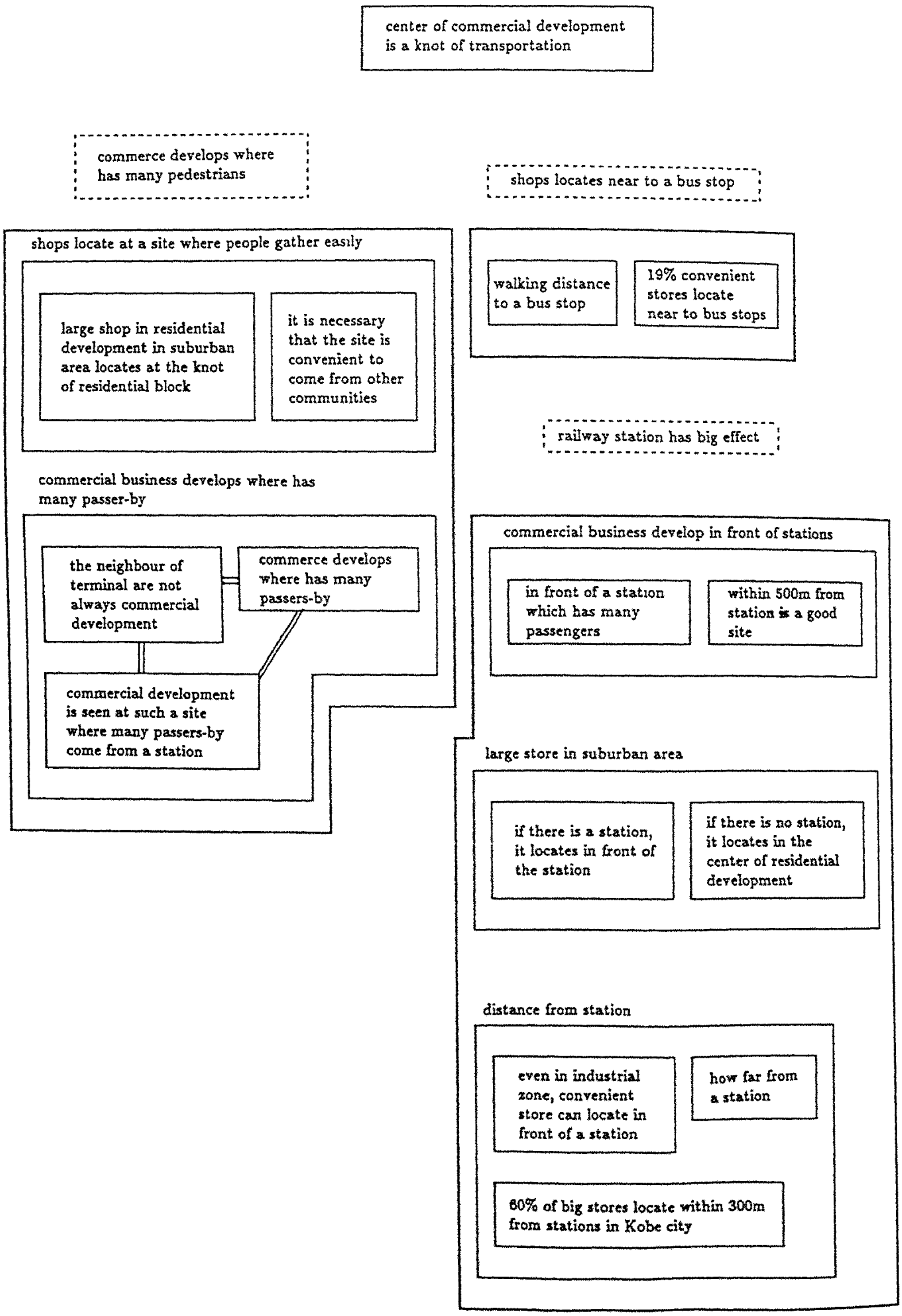

Fig.3 Detail illustration of 「It is better to have many passers-by」

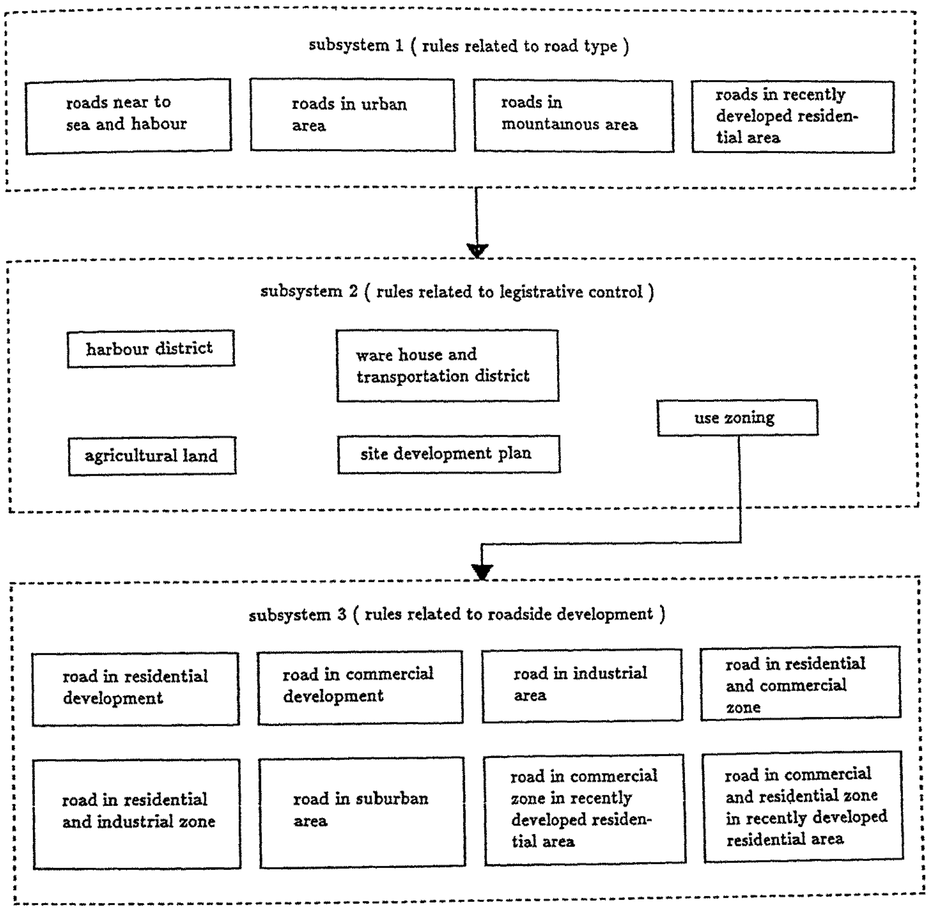

Fig.4 Total composition of knowledge base

if

middle scale commercial development is expected judging from **residen-tial population**

and **there is a station**

and **the site is in front** of a station

then

there is possibility that a large super store is located.

(C F. = +0.20)

if

middle scale commercial development is expected judging from **residen-tial population**

and **there is a station**

and **the site is not** in **front** of a station

then

there is possibility that a large super store is located

(C.F = -0.80)

Fig.5 Example of production rules

510 in the knowledge base. The 26 meta rules are also installed to control the subsystems. In the subsystem one, the projected roads are classified into eight types in order to present effective questionaire to users and the classification is done according to value of certainty factor.

Namely, classification is done refering to the rules which have such traffic volumes, number of lanes and other factors that represent tendency of land use in conditional part, and have large certainty factors in the conclusion stage. The eight classification categories are: [1] roads and streets with high potentiality of residential development, [2] roads and streets with high potentiality of commercial development, [3] roads and streets with high potentiality of industrial development, [4] roads and streets with high potentiality of residential or commercial development, [5] roads and streets with high potentiality of residential or industrial development, [6] roads and streets with high potentiality of agricultural land use, [7] roads and streets with high potentiality of location of commercial building in recently developed residential area, [8] roads and streets with high potentiality of residential development and location of commercial buildings in recently developed residential area.

In the second subsystem, the possibility of location of buildings is checked according to the urban planning law and the building codes. In the third subsystem, the final judgement for the most possible buildings are drawn considering with hunch and experiences of the experts and the socio-economic characteristics of the area.

(4) Input informations

According to the inquiries from the computer a user must input such informations as: [1] expected traffic volume, road type, number of lanes of the road, [2] classification of roads as arterial, subsidiary arterial or minor etc. according to the function of road network, [3] items on existing land use of subjected area as population, public institution and commercial buildings, [4] classification as city center area, subcenter area or center of residential area and so on, [5] regulations such as zoning and building codes, [6] future land use plan such as expectation of location of certain kind of public institution.
The inquiries from the systems are multiple choice and the user keyes in one which he selects.

Some of the inquiries are given commentaries by which users can answer easily. One example of the inquireries from the system is shown in Fig.6.

(5) Output from the system

The land along a road is used in miscellaneous ways. Comercial buildings, for example, cover such variety of buildings as from large department stores to small candy stores. As it is impossible to provide all kinds of buildings, location of buildings which characterizes the land use of the subjected area is selected as the output.

The land use of road side area is roughly classified into residential, commercial, industrial, urban unused land and agriculture.
These rough classifications are further devided into following buildings or land use and these are output for the final conclusion.

name of the file TURU8.EXP input roadside development forecasting system

===

the site is located in
(1) near to harbour or sea
(2) urban area
(3) mountainous area
(4) recently developed residential area

----------------------------------- ---------------------------------

[explanation]
the section of Kobe city

```
                                       Mt.Rokko
                                        /^:  recently developed /^
                                             residential
                                      /      ‡                 /
                                    /         ‡ ----------/
                     ----------/               |          |
sea      ---- | ,,,---   |     |               |          |
 == / ============================================================
              urban    residential         agricultural  mountainous area
```

----------------------------------- - ---------------------------------

select one appropriate item

Fig.6 An example of inquirery from the system

[1]residential··· single family residential,
multi family residential

[2]commercial··· large super store, convenient store, hotel,
family restaurant, pachinko store,
gas-station, retail, other commercial

[3]industrial······ factory, warehouse

[4]unused········ parking lot, vacant

[5]agriculture··· agriculture, forest

One example of conclusion is shown in Fig.7.

5. Conclusion

In this research, a prototype of an expert system to forecast the roadside development of newly constructed road and streets in Kobe city was developed.

The knowledges are gathered from three different sources. K J method was successfully used to synthesize the total process and to produce production rules.

References

(1) Jiro, Kawakita, " Zoku Hasso-hou " (method for creative idea), [1970] [in Japanese]

(2) Haruki Ueno, " Introduction to expert system ", Joho-Syori, Vol.28 (No.2), pp.147-157, [in Japanese]

name of the file	TURU8.EXP	output	roadside development forecasting system

The inference is terminated. The conclusion is presented.
The potentiality of location

(1.01)	convenient store	(C.F. = +0.83)
(1.02)	usual retail shop	(C.F. = +0.83)
(1.03)	gas station	(C.F. = +0.53)
(1.04)	multifamily residential house	(C.F. = +0.50)
(1.05)	restaurant	(C.F. = +0.43)
(1.06)	pachinko store	(C.F. = +0.36)
(1.07)	hotel	(C.F. = +0.36)
(1.08)	parking lot	(C.F. = +0.20)

Fig.7 An example of conclusion

INTEGRATION OF PROGRAMMING MODELS AND EXPERT SYSTEMS: AN APPLICATION TO FACILITY MANAGEMENT AND PLANNING

by

SANG-YUN HAN, T. JOHN KIM, and ILKER ADIGUZEL

ABSTRACTS

The purpose of this paper is to examine possible benefits of combining mathematical programming models and expert systems. This paper discusses the relationship between operations research, decision support systems, and expert systems. To demonstrate the feasibility of coupling expert systems with other existing computer techniques, this paper also discusses the design and development of an automated computer system, XPlanner. XPlanner is a knowledge-based decision support system which integrates an expert system with an integer optimization model and a database management system. XPlanner is developed to aid decision making in the area of facility management and planning.

1 Introduction

Decision makers in both the public and private sectors often face the difficult problem of effectively managing facilities that range from utility plants to small offices. The task of facility management not only requires quantitative reasoning but also a great deal of qualitative reasoning. In developing the best possible facility management plan, one should have easy access to a great amount of facility inventory data, knowledge of experts on various domains including diagnosis of facility structure, and analytical mathematical models to ensure efficient uses of resources.

Despite the fact that separate approaches can provide only partial solutions to the problem, there have been no attempts to devise an *integrated* computer tool in the area of facility management and planning. Fortunately, the recent advances in artificial intelligence (AI), particularly expert systems (ES), can provide a means of narrowing the gap between what traditional problem-solving methods can do and what decision makers want (Han and Kim 1989)[2].

To shed light on how to combine traditional programming models and expert systems, this paper has the following objectives: (1) to briefly review how an operations research (OR) approach to problem solving is different from an AI approach, (2) to discuss how to develop an integrated computer tool which effectively aids decision-making in facility management and planning. For the second objective, this paper presents the design and implementation plan of a knowledge-based decision support system XPlanner. XPlanner combines ES with a zero-one integer optimization model and a database system to create a comprehensive decision aid for the management and planning of military facilities.

2 Operations Research and Artificial Intelligence

The field of OR is large and includes many subareas. The problems that have been solved by OR include queueing, inventory, allocation, routing, scheduling, search, replacement, and competition (Wilson 1985)[14]. AI, on the other hand, has focused on such areas as representation and use of human knowledge through logic, learning, and understanding of natural language and perception (vision and touch). Simon (1987)[11] compares OR with AI by defining OR as "the application of optimization techniques to the solution of complex problems that can be expressed in real numbers"

	LP models	Expert systems
Knowledge	Constraint equations	Knowledge base: rules and frames
Solution method	Simplex algorithm	Inference engine: backward and forward chaining

Table 1: Different Approaches of Linear Programming Models and Expert Systems

while defining AI as "the application of methods of heuristic search to the solution of complex problems that defy the mathematics of optimization, contain nonquantifiable components, and involve a large knowledge base."

Both expert systems (ES) and OR models are designed to help decision makers. But ES normally incorporates qualitative knowledge while OR primarily uses quantitative knowledge. Table 1 briefly compares the different solution approaches of linear programming (LP) models and ES. The linear programming model, for instance, involves arithmetic computations to solve a goal:

$$\begin{aligned} \text{Minimize} \quad & \textstyle\sum_i \alpha_i X_i \\ \text{subject to} \quad & \textstyle\sum_i \beta_i X_i \quad \leq A. \end{aligned}$$

It solves the problem using a simplex algorithm resulting in the optimum values for the objective function (goal).

On the other hand, ES involve symbolic processing in representing knowledge and finding a value of goal parameter. For a simple example, consider the following knowledge base written in Prolog syntax:

Goal *acceptability (X, development-proposal)*

Rule 1 *zoning-change (needed, X) :- landuse (incompatible, X)*

Rule 2 *acceptability (reject, X) :- zoning-change (needed, X)*

Fact *landuse (incompatible, development-proposal)*

In finding the value of the goal (e.g., acceptability of the land development proposal), ES may use backward chaining (deduction) to find out if the proposal requires a zoning change.[1] This is a simple example of the knowledge base and inference engine. Actual problems normally consist of hundreds of rules and a long inference process.

As shortly reviewed here, OR and AI (including ES) have developed different solution techniques, according to the type of knowledge they possess. The important question here is how and when OR and AI could be combined to take advantage of both their strengths. The rationale of the integration of these two fields is that most decision-making problems, particularly in urban planning, require both quantitative and qualitative knowledge and reasoning. The facility management problem, for instance, may be quickly and optimally solved by OR techniques once the nature of the problem is mathematically formulated. But the process of formally defining the problem requires significant expertise in many subject areas of facility management. In addition, implementing the solution provided by the OR models may be better handled by ES through its qualitative reasoning process. The benefits of coupling ES and OR in this regard will be evident as the design concepts of XPlanner are discussed later.

[1]In this example, the backward chaining process first fires Rule 2 because this rule contains the goal parameter *acceptability*. Then it checks if the condition part of Rule 2 is true, i.e., whether a zoning change is needed. This fires Rule 1 because this rule contains the parameter *zoning- change* and checks if the condition part of Rule 1 is true, i e., if the land use is incompatible. Upon finding that the land use proposed by the development proposal is incompatible, it sets the value of the parameter *zoning-change* to *needed* and then sets the value of the goal parameter *acceptability* to *reject*.

Type of knowledge needed for problem solving	Nature of problems	
	Structured or routine	Unstructured or semistructured
Quantitative reasoning: numeric computation	Data processing systems	Decision support systems
Qualitative reasoning: intuition and rules of thumb	Expert systems	Human experts

Table 2: Taxonomy of Decision Problems

3 Expert Systems and Decision Support Systems

Although some authors see expert systems as special instances of decision support systems (DSS), many authors distinguish ES from DSS because of the former's unique structure, technology, and ability to solve different types of problems (see, for instance, Kroeber and Watson 1987[4]; Liang 1988[7]). Table 2 summarizes major differences between ES and DSS in terms of types of computer processing involved and types of decision problems solved. In DSS, the computer is used to store data and various decision models and the user interacts with the computer through the user-interface, providing the computer with judgments. In ES, the computer stores all expert knowledge, including judgments, into a program and recommends a solution by using appropriate analyses and its own programmed logic.

In discussing the possible relationship between OR, DSS, and ES, Wynne (1984)[15] describes these techniques as a sequence of means for providing assistance to decision makers (Figure 1). OR models are developed into DSS to incorporate human judgments into the decision-making process through an effectively developed man-machine interface. DSS, in turn, can be further developed into ES, in which human judgment is coded into a knowledge base.

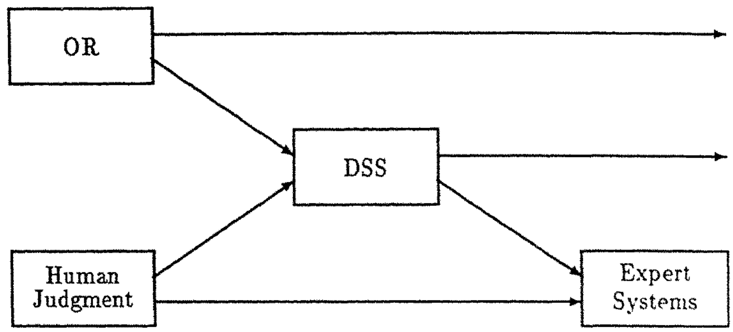

Figure 1: Progression of Operations Research to Decision Support Systems and Expert Systems (Tingley 1987)

The feasibility and desirability of these progressions from OR to DSS and from DSS to ES are, of course, dependent on the nature of decision problems.

The idea of integrating ES into DSS to create more powerful and useful computer-based systems has recently garnered much attention, creating a new terminology, "expert decision support system" (EDSS), "knowledge-based decision support system," or "intelligent decision support system." The possible contributions of ES to EDSS include: (1) helping users in selecting models, (2) providing judgmental elements in models, (3) simplifying building simulation models, (4) enabling friendlier interface, and (5) providing explanation capability (Turban and Watkins 1986)[13].

Of these, the most important role of ES in EDSS is in model selection and building. As Strauch (1974)[12] points out, the process of problem analysis (or modeling) usually involves three interrelated components: formulation of the formal problem, mathematical analysis, and interpretation of the results. While the mathematical analysis is handled effectively with DSS through its embedded OR models, the formulation requires the subjective knowledge of the user. Further, the interpretation requires the personal judgments of decision makers. The coupling of ES and DSS in this case is based on the assumption that subjective knowledge and personal judgment can be better made by experts than by decision-makers and users of the system.

The sections that follow discuss the design concepts and implementation plan of XPlanner. XPlanner is an example of adding a rule-based system to the optimization model for facility management for the purpose of aiding users with the various tasks involved, such as formulating facility optimization models and diagnosing structural conditions of facilities. It is developed to stimulate planners to employ mathematical models more frequently and easily in their problem-solving processes.

4 Decision Problems Supported by XPlanner

Most decision problems may be broadly categorized into (1) structured and (2) unstructured, or semistructured. XPlanner is developed based on the notion that there are different types of computer- based information systems, each with its own unique ability to solve decision problems. Data processing systems are suited for structured problems that have standard operational procedure, decision rules, and clear output formats, such as identifying low income districts or determining the median income of a city. Decision support systems (DSS), on the other hand, are intended for unstructured or semistructured problems, such as evaluating land development proposals, for which DSS can be used to perform "What-If" type analyses estimating fiscal and other impacts of proposals based on different sets of variables, providing quantitative support to the decision maker.

Kroeber and Watson (1987)[4] define DSS as "an interactive system that provides the user with easy access to decision models and data in order to support semistructured and unstructured decision-making tasks." As the definition implies, the interaction between the decision maker and the system is very important in DSS. The interaction is usually achieved in the form of "What-If" dialogue.

While expert systems (ES) are very good at solving problems which require qualitative reasoning, they have the strict requirement that the decision problem be structured so that experts' knowledge on solving the problem can be captured in a computer program. As the characteristics of each computer system imply, only the integration of different types of computer-based systems can produce effective decision-making aids, because most decision making in urban planning deal with a mixture of structured and unstructured problems.

The task of facility management and planning has both the structured and unstructured decision-making components. Cities in urban areas and military installations maintain a variety of facilities from utility plants to housing units, and the decision tasks involved in facility management range from the task of determining the current physical and functional conditions of facilities to the task of deciding which facilities to close or build. While the former example is a somewhat structured decision problem, the latter example can be regarded as an unstructured or semistructured problem.

XPlanner is targeted for both areas of decision making. In military installations, for which XPlanner is developed, the decision problems in facility management and planning can be categorized as follow:

1. Project possible changes in planning constraints such as mission types and budget levels.

2. Estimate facility requirements based on the missions of installation.

3. Determine the current physical and functional conditions of facilities.

4. Estimate facility deficiencies based on 2 and 3 above.

5. To handle the facility deficiency or surplus, create a facility management plan for an effective and efficient utilization of existing and future resources.

Only the effectively integrated computer system can support all the decision-making tasks listed above. The task of projecting mission and budget changes can be handled by an effective man-machine interface of DSS, which incorporates the judgments of the decision maker. The interface enables a series of "What-If" dialogue. This What-If interaction is critical in developing XPlanner, because decision-makers want to incorporate their judgment on the future of the Army (e.g., mission and budget changes) into the problem solution process of XPlanner. For example, when the user inputs different types of missions, the system produces new facility management plans.

The task of determining current *physical* conditions of facilities can be handled by a database management system that maintains comprehensive facility inventory data, whereas the task of determining *functional* conditions of facilities may better be handled by an expert system. Examining the functional conditions of facilities involves such heuristic tasks as determining if a particular facility is suitable for accommodating certain types of activity and assigning each activity (e.g., training or recreation) to a facility. Further, the task of developing a facility management plan can be supported by an optimization model in order to achieve efficient allocation of resources.

In short, the major decision problem involved in military facility management and planning is developing an effective facility management plan that supports constantly changing missions. The facility management plan prepared by the Army planners should effectively utilize the current and future resources of the military installation and should also comply with the safety and welfare standards prescribed by the Army authorities. XPlanner is designed to support these tasks.

5 Structure and Components of XPlanner

To effectively support all the tasks involved in facility management and planning, XPlanner consists of several components (Figure 2): (1) knowledge base, (2) model base, (3) database, (4) user interface, and (5) inference engine. The inference engine and knowledge base control the whole system.

5.1 The Role of The Knowledge Base

The knowledge base of XPlanner contains two types of knowledge: (1) knowledge about the classification of functional areas of facilities and about the diagnosis of the physical conditions of facilities and (2) knowledge of the formulation and interpretation of a zero-one integer optimization model for facility management and planning.

For the examples of the first type of knowledge, consider the following rules used in XPlanner for diagnosing physical problems of structure:

1. IF structure = wood-frame AND humidity-level >= 70, THEN termite-infestation may be high,
2. IF termite-infestation = high, THEN building-decay = serious AND wood-treatment by chemical A = required,

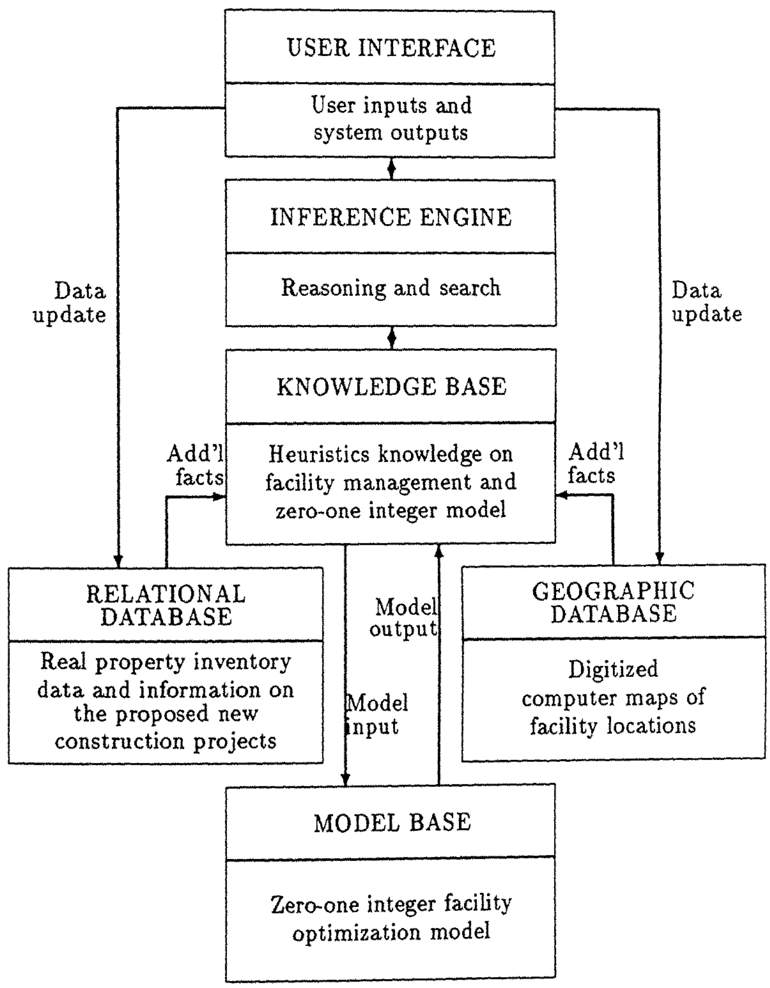

Figure 2: Schematic Structure and Components of XPlanner

3. IF sagging-roof OR non-vertical-walls OR tilted-floors OR misalignment-of-doors, THEN excessive-settling,

4. IF excessive-settling, THEN foundation-wall = to-be-replaced.

These rules can be used to effectively estimate the cost and feasibility of each type of project (e.g., demolition, conversion, or renovation) related to each facility. Based on this type of knowledge, the major function of the knowledge base is to estimate parameter values necessary to formulate the zero-one integer optimization model. The list of parameters to be estimated by ES (the knowledge base component) is described later under the model base.

In addition to estimating parameter values for the facility optimization model, ES screens existing facilities in order to eliminate the facilities that are irrelevant for consideration by the optimization model. For this purpose, ES maintains the knowledge base that classifies existing facilities into several condition categories ranging from Class 1, **usable** (meeting all criteria), to Class 6, **disposable** (no longer tenable for any purpose). Machine learning programs with effective induction algorithms can be used to develop the knowledge base in this area. Many induction algorithms have been successfully applied to the knowledge acquisition problems, particularly to classification problems (Michalski (1985)[8]; Forsyth and Rada (1986)[1]; Shaw (1988)[10]; Liang (1989)[6]). Because ES classifies and eliminates the irrelevant facilities, the facility optimization problem may be reduced to a size manageable by the zero-one integer optimization model (described later).

Another important role of the knowledge base is to interpret the results of the optimization model using its knowledge of a zero-one integer model. In this system, ES serves as an extra layer between the model and the user, translating qualitative criteria into the numeric input and also translating the model's numeric output to qualitative concepts that are more intuitive and informative to the user.

In addition, the knowledge base has the important function of controlling the whole system, accessing the database and the model base of XPlanner as necessary. In addition to the domain knowledge specific to the facility management, the knowledge base maintains control knowledge (meta-knowledge) to control the steps involved in reasoning. For instance, it initiates the forward chaining mode in the middle of backward chaining[2] or it forces some rules to be fired before other rules by using meta-rules. This type of control knowledge is necessary to control the flow among the knowledge base, the model base, and the database.

5.2 The Role of The Model Base

The model base of Xplanner contains a zero-one integer optimization model that is designed to devise a facility management plan with efficient allocation of resources. Integer programming (IP) is a special case of linear programming with the characteristic that the values for all the variables in the solution must be integers. A further sub-class of IP is zero-one programming, in which all variables in the solution have a value of zero or one. Such a formulation is needed when the decision variables represent a binary decision. An example of the set of binary decisions involved in XPlanner are *renovate* or *don't renovate*. IP problems are computationally much more difficult to solve than linear programming problems (Greenberg 1971)[3].

All the parameter values contained in this model are supplied by the knowledge base. In return, the model base supplies model output to the

[2]In the ES shell Personal Consultant Plus, this can be accomplished by assigning ANTECEDENT property to necessary rules

knowledge base for the interpretation (see Figure 2). The structure of the model is described here without further discussion on zero-one integer programming.

Objective Function

The objective function is to determine which facilities to be closed, renovated, converted, and stay as they are, based on the cost minimization objective. The objective function is formulated as below:

$$\text{Minimize} \sum_i \Big(\alpha_i C_i + \beta_i R_i + \gamma_i D_i \Big) + \sum_i \sum_j \delta_{ij} V_{ij} \qquad (1)$$

where:

$$C_i = \begin{cases} 1 & \text{if facility } i \text{ is to be closed} \\ 0 & \text{otherwise} \end{cases}$$

$$R_i = \begin{cases} 1 & \text{if facility } i \text{ is to be renovated} \\ 0 & \text{otherwise} \end{cases}$$

$$V_{ij} = \begin{cases} 1 & \text{if facility } i \text{ is to be converted to } j \\ 0 & \text{otherwise} \end{cases}$$

$$D_i = \begin{cases} 1 & \text{if facility } i \text{ is to stay as it is} \\ 0 & \text{otherwise} \end{cases}$$

α_i = closing (demolition) costs of facility i,

β_i = renovation costs of facility i,

γ_i = maintenance costs of facility i,

δ_{ij} = costs of converting facility i to facility j.

As shown above, the option of constructing new facilities is not included in the objective function, because the objective of the optimization model is to optimize the utilization of *existing* facilities. As discussed in the later section, the new construction option is considered by ES in two ways:

1. Before XPlanner gets into the model, ES evaluates new construction projects that have already been proposed for the installation. ES estimates facility requirements that can be satisfied by the scheduled construction projects, and then the optimization model solves the problem for the remaining facility requirements.

2. When there are still facility deficiencies in the optimization model results, ES considers new construction (not already proposed) by checking the condition and availability of empty spaces.

The whole working process of XPlanner is explained in later section.

Choice Constraints

The constraint below is to ensure that only one option (e.g., renovation or closure) is selected for each facility:

$$C_i + R_i + V_{ij} + D_i = 1 \quad \forall i, j \tag{2}$$

Budget Constraints

The facility optimization model has the following budget constraints to ensure that the facility management plan is devised within given budgets:

$$\sum_i \beta_i R_i \leq A \tag{3}$$

$$\sum_i \gamma_i D_i \leq B \tag{4}$$

$$\sum_i \sum_j \delta_{ij} V_{ij} \leq C \tag{5}$$

where:

A = budget available for renovation projects,

B = budget available for minimal maintenance of facilities,

C = budget available for conversion projects.

Mission Constraints

The mission constraints are to ensure that the solution by the model satisfies the facility requirements generated by the mission. Through the user-interface, XPlanner aids users in developing scenarios regarding possible mission changes. The knowledge base maintains the rules that interpret the scenarios developed by the user into the mission constraints. All the parameters in the mission constraints are also estimated by the knowledge base. An example of the parameter supplied by the knowledge base is the capacity of facility i (i = 1, ... ,n) to accommodate troop type k (k = 1, ..., enlisted woman, ... ,m) for activity p (p = 1, ..., recreational use, ... ,l) after the facility is renovated. The mission constraints are formulated as below:

$$\sum_i \epsilon_{ikp} R_i + \sum_i \sum_j \eta_{ijkp} V_{ij} + \sum_i \theta_{ikp} D_i \geq T_{kp} \quad \forall k, p \tag{6}$$

where:

ϵ_{ikp} = facility i's capacity of accommodating troop type k in activity p after renovation,

η_{ijkp} = facility i's capacity of accommodating troop type k in activity p after conversion to j,

θ_{ikp} = facility i's capacity of accommodating troop type k in activity p without any change,

T_{kp} = total number of troops of type k in activity p as given by new mission.

All the parameters in this model (e.g., α_i through θ_{ikp}) are estimated by the knowledge base. In addition, the values of the right-hand side constants (A, B, C, and T_{kp}) are also supplied by the knowledge base.

The task of the ES component of XPlanner to configure the zero-one integer optimization model requires much computer power and speed. Even with eight facilities, the number of decision variables in the objective function is forty, which is the maximum that can be solved by the integer program package called Lindo. The number of parameters to be estimated by the knowledge base is 472, with eight facilities, three conversion types, three activity areas (training, recreation, and housing), and four troop types (enlisted man, enlisted woman, noncommissioned officers, and officers).

Because of this large number of parameters, the knowledge base of XPlanner is so big that Xplanner will not run with 640K memory. At least 1 or 2 megabyte of memory are required to run XPlanner. Considering the actual size of the real problem, which normally involves hundreds of buildings, scores of facility types, and several troop types in a typical military installation, the task of solving a real problem may not be feasible on personal computers. In Xplanner, ES is effectively used to reduce the size of the optimization problem.

5.3 The Role of The Database

As an additional component, XPlanner maintains a relational database to store and access information on the current physical conditions of facilities. The database basically maintains two types of data:

1. Real property inventory data which describe existing conditions of facilities, such as area, current use, age, type of building materials used, and structural conditions of each facility.

2. Detailed information on the new construction projects which have been proposed for the installation. It includes completion year, location, type, and expected capacity of facilities.

In addition, XPlanner maintains a geographic database in which digitized computer maps are stored to provide spatial data such as location of roads and utilities (Figure 2). This information is used by the ES module of XPlanner in recommending candidate sites for new construction.

The knowledge base accesses the database to obtain additional facts. In XPlanner, the data flows from the database to the knowledge base and finally to the model base. The software dBase III Plus or the spreadsheet of Lotus 1-2-3 may be used as a database manager of XPlanner. The geographic database is developed by using AutoCad and is utilized through a graphic utility program of the ES shell, Personal Consultant Plus.

6 Workings of XPlanner

The workings of XPlanner involves frequent interactions among the user, the knowledge base, the model base, and the database. The user provides XPlanner with additional judgmental factors not encoded in the knowledge base, and the database supplies additional facts to the knowledge base. The knowledge base generates inputs for the model base and the model base, in return, supplies model outputs to the knowledge base (see Figure 2). As depicted in the flowchart of XPlanner in Figures 3 and 4, the steps involved in the consultation of XPlanner can be summarized as follows:

1. As the consultation with XPlanner begins, XPlanner first help users develop their own scenarios regarding the future of the Army. They can play with their judgments in deciding possible mission changes, budget level, and some demographic changes (e.g., participation rate of woman labor force in the military).

2. ES of XPlanner estimates facility requirements generated by the new mission, using it knowledge about the space allocation standards set by Army regulations.

3. XPlanner asks the users if they want XPlanner to consider new construction projects that have been already proposed for the installation. If no, go to Step 6, otherwise go to Step 4.

4. The database management system (DBMS) of XPlanner supplies information on the proposed construction projects and the users further describe and modify the nature of projects if they want.

5. ES of XPlanner estimates facility requirements that can be satisfied by the proposed construction projects.

6. XPlanner accesses the database (real property inventory data) to check current physical conditions of facilities.

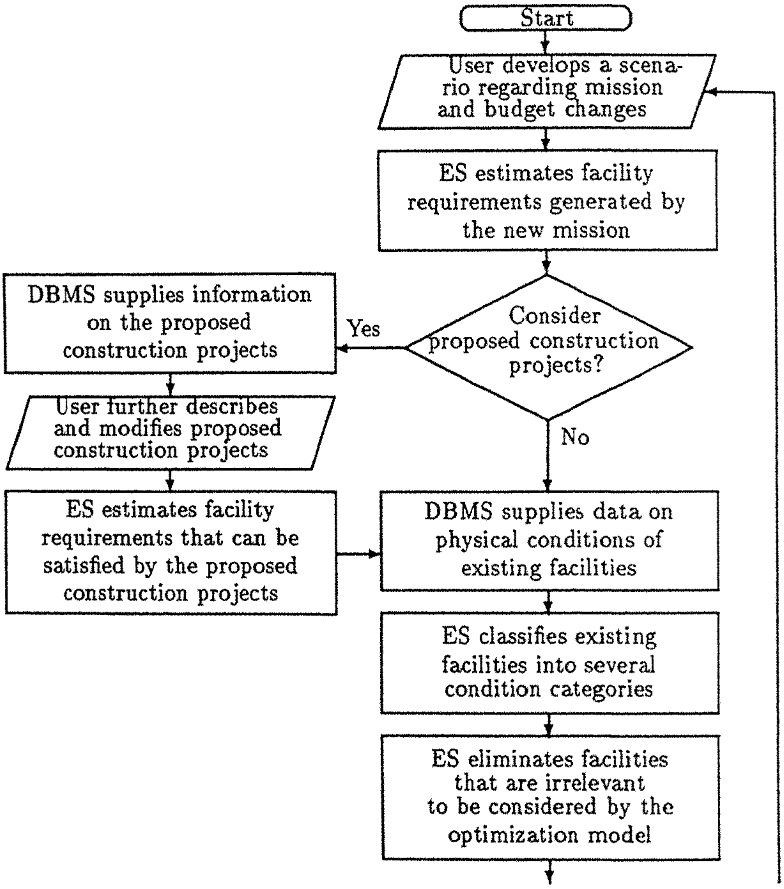

Figure 3: Flowchart of XPlanner (Part 1)

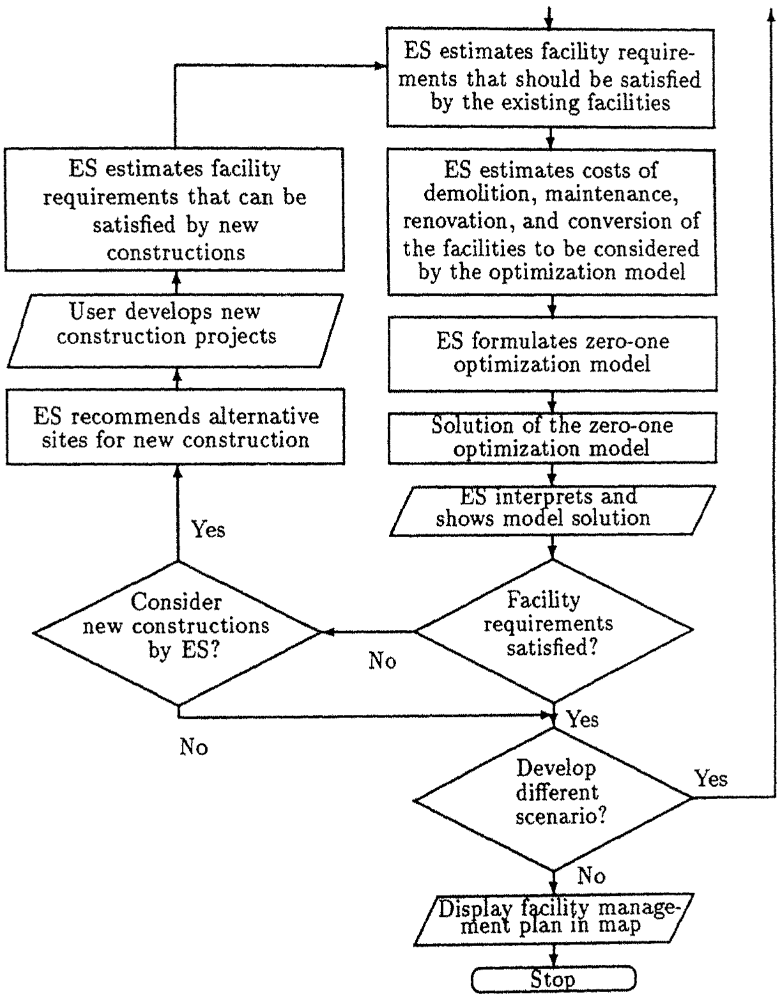

Figure 4: Flowchart of XPlanner (Part 2)

7. Based on the physical conditions, the ES module classifies existing facilities into several condition categories ranging from Class 1, **usable** (meeting all criteria) to Class 6, **disposable** (no longer tenable for any purpose).

8. ES eliminates the facilities that are irrelevant for consideration by the facility optimization model.

9. ES estimates facility requirements that should be satisfied by utilizing existing facilities.

10. ES estimates costs of closure, renovation, maintenance, and conversion of the facilities to be considered by the optimization model, using its heuristic knowledge in the knowledge base.

11. After obtaining all the necessary parameter values, ES formulates the zero-one integer facility optimization model. As described earlier, the decision variables included in the model are whether to (1) close facility i, (2) renovate facility i, (3) convert facility i to j, and (4) use facility i as it is.

12. The facility optimization problem formulated in an integer programming model is solved.

13. The ES components of XPlanner interpret the results of the optimization model and explain the results to the user.

14. XPlanner asks the user if the results given by the model are acceptable in terms of facility requirements. If yes, go to Step 15; otherwise go to Step 17.

15. XPlanner asks to the users whether to develop another scenario. If yes, go to Step 1 and repeats the whole process; otherwise go to Step 16.

16. XPlanner displays the results (facility management plan) in computer graphic (map) format.

17. If the results given by the optimization model are not acceptable to the users in terms of facility requirements, XPlanner asks the users if they want XPlanner to consider the other option, new construction. If yes, go to Step 18; otherwise go to Step 15. Here XPlanner considers the option of constructing new facilities after the optimization model solves the problem with existing facilities, in order to conform to the Army policy that "no new facilities will be established or acquired unless the needs cannot be effectively served by existing facilities."[3]

18. Utilizing its knowledge, ES recommend candidate sites for new construction projects, and the users finalize the type of new construction projects.

19. XPlanner estimates the facility requirements that can be satisfied by constructing new facilities and returns to Step 9.

As explained above, the problem-solving process of XPlanner involves an *iterative* process between the optimization model, the expert system, and the user. The user may continue the consultation until an acceptable answer (facility management plan) which satisfies facility requirements generated by new missions is found.

[3] Army Regulation 210-15: Activation, Inactivation or change in status of Installations Page 2.

7 Summary and Conclusions

As pointed out by O'Keefe (1985)[9], as operations research has shifted away from pure optimization models, it is likely that expert systems will shift away from pure symbolic processing systems and will increasingly employ optimization techniques. The coupling of ES and DSS basically takes two different forms: (1) integration of ES into the conventional DSS to provide qualitative reasoning capability and intelligent user interface, and (2) integration of DSS into the conventional ES to provide modeling capability. In the first type of coupling, ES may help the users select proper models, input necessary parameters, and interpret outputs of DSS. In the second type of coupling, DSS provides modeling capability to ES, recognizing that human experts often use quantitative models to support their experience, intuition, or rules-of-thumb.

From the experience of designing XPlanner, it is believed that the intelligent interface provided by expert systems for the modeling tasks in DSS may stimulate planners to employ mathematical models more frequently and more easily in their problem-solving processes. As often pointed out by planners, modeling components tend to be treated as black boxes, inadequately recognizing the need for judgments by the users and concealing implicit judgments and assumptions from the users (Langendorf 1985)[5]. The integrated approach of XPlanner certainly provides a great improvement over the unaided use of modeling algorithms, encouraging easier use of quantitative modeling to support many planning decisions.

To develop Xplanner for field-level application, the hardware limitations should be resolved. XPlanner involves the complex numeric computations of integer programming in addition to the memory-consuming symbolic processing of the inference engine. The tasks involved in XPlanner require much more computer power than other types of traditional algorithmic processing tasks. XPlanner solves the hardware limitation to some degree by having the ES component reduce the size of the optimization problem.

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A PLANNER-MODIFIED EXPERT SYSTEM FOR STRATEGIC PLANNING

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ABSTRACT

This paper describes a strategic planner's expert system, as modified by reactions to it from environmental planners, computer scientists and strategic managers. Attitudes ranged from apathy and scepticism to lukewarm support and fascination. This was hardly surprising, because the system tries to combine the precision of computer science with the imprecision of strategic planning.

The result has been an expert system which will, on demand, recommend a strategic plan - one which is based upon the system's latest simulation of what the user's prioritorized goal hierarchy seems to be. But the system also realizes that users can be impulsive, undisciplined, incomplete and irritable. It therefore tries to upgrade its recommended plan by continually prompting the user for further information about their goals' true intents, effectiveness levels, overlaps, conflicts, pre-requisites, success chances, attainment scores and effort : satisfaction functions.

As this questioning proceeds, tension builds up within the expert system for it to ask about those goals for which its information is almost complete. Hence the probability that it will produce a fully-informed plan, at least in terms of upper-level goals, continually grows. The system also tries to learn when and why it irritates a user. Hence the more it is used, the more "tactful" it becomes. The possibilities are exciting.

TEXT ANIMATION OR KNOWLEDGE ENGINEERING?: TWO APPROACHES TO THE DESIGN OF URBAN PLANNING EXPERT SYSTEMS

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ABSTRACT

Applications of expert system technology in the urban planning domain range in complexity from the relatively simple task of representing existing manually-held knowledge bases within a single shell, to complex exercises in knowledge elicitation and modelling within a multi-system environment. It is suggested that the complexity of expert system construction relates to the nature of the knowledge to be contained within the system. In particular, it depends on the degree to which knowledge is pre-processed and on the mix of knowledge types. After reviewing the concepts of knowledge, knowledge bases and knowledge capture with respect to urban planning subject matter, two contrasting systems are examined which illustrate this range of approach. Both systems are models of human judgement and experience. The first, however, can be thought of as a text animation system since its expertise lies essentially in the ability to navigate a complex document in a way that the professional planner might. The second represents a more protracted exercise in knowledge engineering involving the formalistion of concepts and decision logic and the interfacing of GIS and expert system technologies.

APPLYING AN INTEGRATED EXPERT SYSTEM TO URBAN MANAGEMENT AND PLANNING

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ABSTRACT

The purpose of this paper is to present a tool for urban management and planning which integrates a sophisticated expert system, a very large distributed date base, a simulation facility and a dialog layer.

It is applied to the urban texture including blocks, ways and various pipe networks (water, gas, sewer) and cable networks (electricity, telecommunications).

HBDS (Hypergraph-Based Data Structure) is a knowledge structure model with a clear graphical representation which can be used to modelize any phenomenon. It is based on six data types: sets named classes, their properties (named attributes of classes), their elements (objects), the properties and relationships of these ones (attributes of objects and links between objects). Types can be recursively embedded. There is no limitation on the number of these components. They can be interactively created, destroyed, hibernated or awaked.

Behind the scenes, hidden to the users, a very large and distributed database, automatically ensures the storage of any component handled. The user has the impress that all his knowledge resides in core memory, but it is of course an abstraction.

Around this kernel and using the preceding concepts, SES, a structured expert system, with several inference engines, has been developed; working forward and backward, but with no backtracking, either for deduction or for hypothesis demonstration, they include vectorized and parallel processing capabilities. This expert system is connected to a discrete simulation engine dealing with an illimited set of non-resident processes, working in quasi-parralelism.

The outer abstraction is a dialog layer based on a Q-graph; it allows an easy, interactive and graphical processing in clear language for people who are not familiar with computers and programming. It includes a boot-strap which is a dialog owing to which we can build new dialogs or update some other ones.

Using HBDS, the urban texture has been modeled, with classes of ways, segments, blocks, block-faces, crossings,

with their attributes and links; on this basical structure, we superimpose the network structures; any network may be represented by three elementary classes: vertices (nodes), arcs and domains (areas); according to the network considered, they carry more specific attributes and links; these networks deal with electricity (3 networks), water (3 networks), gas, heating, telecommunications (4 networks), traffic light control, sewers, and other minor ones.

To each vertex class we connect various classes of urban furniture, and to each arc class, various classes of components (for instance, pipes and cables).

A second category of networks has been developed, which are unmaterial: garbage collection, mail collection and mail distribution, urban furniture maintenance, etc.... This second category is directly concerned by dynamical simulation requiring quasi-parallel processing.

We have recognized families of rules managing each network, in connection to its furniture and its maintenance procedure. Others rules concern the extension of each network, taking into account the fact that a network is not isolated but intersects many others networks with several contraints and/or uncompatibilities. This aspect requires problem-solving methods and strategies development.

In the full paper, we present some examples such as a rule testing whether the total of water is sufficient, due to the different fire hydraut surrounding a given block in connection to its height and surface; it takes into account the surpressors, pipes, central water-tank and its pumps.

We thus have a catalog of urban sub-structures, the urban rules, allowing to manage the urban texture components and to plan new developments. It is thus a multithematic interactive tool for managers, planners and decision makers.

"SILP": A MICROCOMPUTER TOOL FOR ACCESSIBILITY-CENTRALITY ANALYSIS AND PLANNING IN DEVELOPING COUNTRIES

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ABSTRACT

"Facility location in a network" is a well known theoretical concept with far-reaching implications for urban and rural-regional development planning and management. The conceptual framework for "location" (of facilities) and "allocation" (of resources) has been firmly established in the literature, but when it comes to applications in practice, most planning agencies are limited to relatively simplistic approaches. It remains difficult to translate the complex web of the many parameters involved into a planning procedure which would equally meet the criteria of theoretical soundness and practical application. This is particularly true for developing countries where severely limited resources must cope with the fluid and rapidly changing conditions of reality.

In this context, the availability of comparatively inexpensive microcomputers holds considerable promise, although appropriate software is often difficult to find. Aiming at this gap, a new microcomputer package was developed at the Asian Institute of Technology for the use of agencies involved in urban and regional development planning. "SILP" (Services Identification and Location Package) has been tested and practically applied for some four years.

Written in a user-friendly, "menu-driven" way, the package deals with the main components of the facility system, i.e., the existing and possible future facility locations, the users within the respective time zones, the underlying planning standards, and the access network including its specific conditions such as transport modes and speeds. After analysing each type of facility individually or in combination with others, the package allows the analyst to gradually approach sensible planning recommendations in an interactive manner, including the display of thematic maps. Alternative strategies can be simulated and assessed by means of a cost-effectiveness analysis, which is going to be part of the package.

Version 1, which is largely in compiled BASIC, will soon be replaced by a much more versatile Version 2, written in "C" and Pascal.

USE OF COMPUTERS IN URBAN PLANNING AND MANAGEMENT IN BANGLADESH

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ABSTRACT

Planners in developing countries like Bangladesh have to perform without adequate access to information and research facilities. This is due to the unavailability of a computerised planning information systems. As a result decisions are being made without proper analyses of relevant data thus causing further undesirable development of the urban landscape already in an unmanageable situation. A computerised LIS based on detailed parcel-based information may be too costly and therefore use of coarser information, considered adequate for planning applications in Bangladesh, is suggested to improve the overall decision making capability of the local government. ULIS, a model urban land information systems for developing countries is presented.

INTRODUCTION

Urban centers in the developing countries are usually characterized by rapid growth caused mainly by a continuous migration flow from rural to urban areas. With high population density, poverty, squatters, slums, crowded roads, inadequate community facilities and an over-burdened public infrastructure, these urban centers have posed unmanageable problems for the decision makers. Governments in developing countries have been trying to cope with these situations with limited resources. Planners and decision makers responsible for the enormous task of converting existing urban landscape to a more organised one often find themselves without adequate research facilities necessary to support the planning and management activities of the urban Government. This specifically refers to the problem of storing, retrieving and analysing information relevant to such key urban problems such as land development, housing, transport, and public utility services, etc. At present, such information is mainly collected and stored in traditional hand-written documents, making subsequent retrieval very difficult. Any inquiry into the urban information-base therefore takes weeks or months rather than minutes or hours, making the day-to-day activities of the urban Government difficult. As a result most planning and management decisions are made without up to date analyses of the most relevant information, thus causing further undesirable developments characterised by incompatible urban land development, poor housing environments, traffic mismanagement, unbalanced and inefficient distribution of services, etc.

Computerised Planning Information Systems

A computer system can facilitate the creation of an urban information system that will allow easy storage, updating, retrieval, and the mapping of a wide range of information related to planning and management. With the help of computer and relevant data management and analytical software, a planner/researcher can easily carry out relevant analysis and present findings on land development, population, housing and shelter, transport, the local economy, environment, and other relevant aspects to support better planning and management of the urban landscape. Land is the most important of all resources and is of fundamental concern to planners. In effect, most planning issues can be addressed through land planning and management. It has also been argued that many of the problems in developing countries are related to land (Williamson,1987). Accordingly, computerised Geographic or Land Information Systems (GIS or LIS) has become the information-base for planners in recent times.

The need for appropriate and easily accessible information for research cannot be overemphasized. The need for such systems is clearly no less for developing countries like Bangladesh where resources are scarce.

LAND INFORMATION SYSTEMS

GIS/LIS may be defined simply as database systems (figure 1) in which data are spatially indexed, and upon which a set of procedures operates in order to answer queries about spatial entities in the data base (Smith, Menon, Star and Estes,1987).

Of course, planners and decision makers have been making use of computerised land information systems for a quite some time now. However, most of these previous systems deal only the numeric (and often textual) information of geographic phenomena. A modern GIS/LIS utilises all such data but it also has the significant additional capability of providing a spatial view of all this information. In other words it can store, create and display maps.

A useful distinction between GIS and LIS can be made based on the existing literature on current practice. Traditionally, GIS has been used to deal with land information at a regional scale, while LIS has been applied mainly at the urban or local scale where there is often a need for detailed property-related information about land parcels.

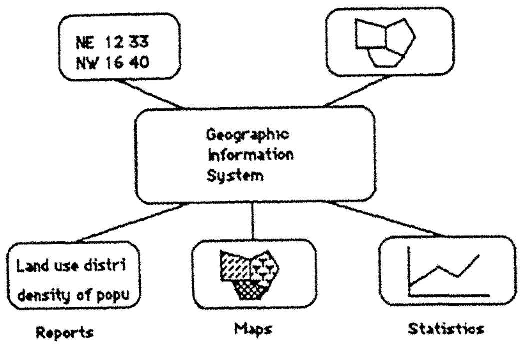
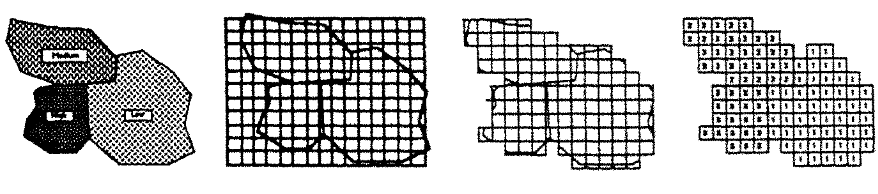


Figure 1. A generalised Geographic Information System (adapted from Dale and McLaughlin,1988)

Data Types used in LIS

Data for input to GIS/LIS are typically acquired in a variety of formats, including graphic and non-graphic information (i.e. nominal data, descriptive or attributive data, and textual data). In a GIS/LIS each spatial data type or theme is referred as a *spatial data layer* or *data plane* which is capable of holding four possible types of geographic entities: points, lines, surfaces and areas-enclosing lines or polygons. For each spatial data layer, spatial objects may be encoded employing two basic techniques: Raster mode or Vector mode.



(Population Density)
Figure 2. Process of digitizing a map

Entities can be encoded in raster mode (using grid cells) or they can be encoded in vector mode (using lines defined by exact co-ordinate points rather than grid cells). The raster mode is often preferred since it is simpler to analyse grid cells than vector lines. Usually boundaries and maps are first digitised in vector mode (it is easier to digitise vectors using a digitising tablet) and then converted to grid cells. There is of course a loss of information involved in the conversion process since the grid cell is the base unit of analysis and therefore within-cell variation of data is lost (Figure 2). The larger the size of the cell the less is the accuracy of data. Cell sizes of under 10 acres are generally considered adequate for local area applications, whereas a cell size of 40 acres or more is preferred at the regional level (Lindgren,1985).

The three principal classes of Land Information commonly required by planners are: (a)Natural resources; (b) Socio-Economic; and (c) Property (land-parcel) level information. A suitable means of integrating all this information is then necessary to achieve successful analysis of planning-related information.

Data Analysis

Three main categories of data analyses are usually available to be derived from a GIS/LIS system using graphic (mapping) and/or non-graphic (numeric and textual) processing of the information.

a. Spatial analysis, including procedures such as polygon overlays; cell overlay; connecting and neighborhood statistics;
b. Measurement of line and area lengths; point-to-point distances; areas and volumes;
c. Statistical analysis, forecasting and modelling.

A GIS/LIS should also be able to display and produce maps, graphs and tabular information in a variety of output media.

Applications in Planning and management

Most GIS/LIS applications utilise some form of geographic or spatial analysis. Traditional applications of LIS by planners have been in the area of land capability - or suitability - analysis for an envisaged particular use of the land. Recent applications, however, have been extended to include the more detailed and routine management aspects of land, *i.e.* tax and rates collection, valuation, administration of utilities, change of title, building permit/contracts, *etc*.

Land Suitability Analysis

Land suitability (or capability) analysis helps a planner to identify those areas which are most suitable for particular uses under consideration. A series of maps are first generated to show the distribution of those factors that would influence the suitability of the land use in question.These factors or variables are then assigned values based on their relative importance. Resultant maps indicate the location and relative importance of each variable according to its value.

Individual factor maps are overlaid physically by placing them on transparencies which then forms a composite map showing the spatial spread of the *combined* effect of those variables. It is then a relatively straightforward task to locate areas exhibiting a particular combination of factors which indicates the suitability of the land for a particular use (Figure 3).

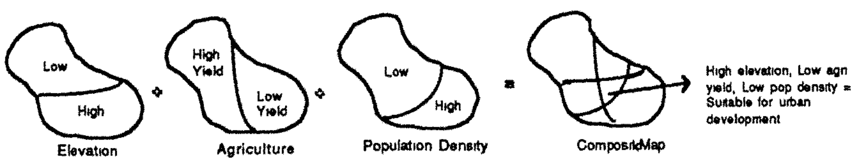


Figure 3. Land Suitability Analysis

With the advent of the computerized LIS all required map overlay and land capability analysis may now be done using the computer. Instead of being transformed into maps by hand, the geographic data are now converted to computer readable format, digitised, and the resulting information may be processed using software routines that allow changes of scale, overlays, and the eventual production of a land capability map.

Hardware and software requirements for a LIS

A standard hardware configuration for a LIS typically calls for a Computer (Mainframe/Mini/Micro) with a high capacity hard disk, a high resolution monitor with requisite graphics hardware, a digitiser, a plotter, and a printer. Prices may range from US$10,000 for a small micro-computer based system to US$500,000 for a large mainframe-based system. Many suitable software packages are available now and their prices may range from a few hundred dollars to 10,000 dollars (or more).

COMPUTERS IN BANGLADESH

History of development

The first computer in Bangladesh came into operation in the year 1964 when an IBM 1620 computer was installed at the Atomic Energy Commission in Dhaka (Patwari, Alam and Rahman,1984). In the same year the Institute of Statistical Research, Dhaka University acquired an IBM 101 statistical machine. The first private sector computer was installed by the Janata Bank in 1967 with an IBM 1401. The Adamjee Jute Mills Ltd was the first industry to install a computer (in 1970). In 1973 the Bureau of Statistics, Government of Bangladesh installed an IBM 360/30 to computerise data processing of the National Census. Bangladesh Engineering University became the first university to own a modern computer when it installed an IBM 370/115 in 1979. Following this, several 370/115s have been installed by other organisations within a short period. IBM in the meantime have also installed a good number (around 10) of their S/34s within various organisations. In the latter half of the 1980s, several IBM 4300 series computers were installed, mostly to upgrade existing installations. The clear domination of the field by IBM was due to the availability of their after-sales servicing facilities within the country. Other companies that have marketed their machines in Bangladesh include NCR, PRIME, DEC, and HP. Almost all computer installations are located in the capital city of Dhaka.

The most significant development in terms of computerisation, however, happened with availability of micro-computers which started arriving in Bangladesh in early 1980s. Tandy Corporation of USA, through its dealer began selling their TRS 80 III and II in the early 1980s. Later APPLE, IBM and many of their compatibles and clones started pouring into Bangladesh. Currently, there are hundreds (if not thousands) of micro-computers in Bangladesh. There are around twenty local companies who are marketing micro-computers. Many, of course import their own from overseas. The success of the micro-computer in developing countries like Bangladsesh is due to : (1) It's low-cost; (2) low operating and maintenance cost; (3) easy serviceability; and (4) user-friendly operation requiring less user-expertise. Its low cost has made it affordable to many small organisations. One could, in fact, buy a complete micro-computer system with the monthly maintenance cost of a main-frame computer in Bangladesh.

Problems

Computerisation is mainly seen as a man-power replacing machine. Computerisation in developing countries should be planned to increase efficiency in an organisation without replacing man-power. Also, there is resistance from senior officials who feel uncomfortable about change to some new system.

One of the major problems of computerisation is the re-organisation that is necessary before it is possible to successfully computerise the operation of an organisation. This is probably more so in developing countries where information collection and storage usually does not follow a systematic format.

The lack of trained man-power is a serious problem. There are only a few formal educational institutions providing training in computer programming and systems analysis. Bangladesh University of Engineering and Technology has recently started the only undergraduate degree program in Computer Engineering in Bangladesh. There are many private organisations (even motor driving schools) providing short courses in computer programming. However, the quality of most of these courses is generally unsatisfactory. Various agencies of the United Nations have also been training personnel from developing countries in micro-computer applications. However, to make the knowledge acquired in this way useful and effective, such training programs should ensure availability of necessary computing facilities at the trainee's home organisation.

A lack of proper servicing facilities is another serious barrier to computerisation in Bangladesh. Only IBM has its own servicing facility within the country. For micro-computers there are a few local servicing organisations, but having no properly trained technicians these resources are far from satisfactory. Because of this problem, many people are hesitant to take the steps to computerise their business operations.

Prospects

Computers (and specifically micro-computers) represent one of the few high-level technologies that is affordable and can benefit developing countries in many ways if it is wisely implemented. Micro-computers have also been recognised and accepted as an appropriate high-technology suitable for developing countries by the United Nations Organisation (UNO). Bangladesh has a large pool of educated-unemployed young population. These young people may be trained for the overseas computer market where there is also a serious shortage of computer personnel. This may help lessen the unemployment problem in Bangladesh. Recognising the importance of computers the Government of Bangladesh has recently decided to include computer programming as a subject of study at various levels of education including secondary schools. When this policy is implemented in nearly 10,000 schools and colleges there will be phenomenal growth in the computer industry in Bangladesh, with adequate number of trained personnel to service both local and overseas demands.

URBAN PLANNING AND MANAGEMENT AUTHORITIES

Urban planning activities in Bangladesh can be identified at four levels of administrative organisation : (1) National and regional urbanisation planning; (2) Major urban centres; (3) Zilla Shahars (District towns) and (4) Upazilla Shahars (Sub-district towns). The Urban Development Directorate (UDD) is the central authority under the Ministry of Works which carries out research and advises on national urbanisation policies. It also helps prepare and coordinate regional plans and development plans for all urban centres except the four largest urban centres for which there are four specific development authorities. These four urban development authorities are : (1) Capital Development Authority (RAJUK), which prepares and implements development plans for the Capital Metropolis, Dhaka; (2) Chittagong Development Authority (CDA) undertakes development for Chittagong city, which is the second largest urban centre in the country. Similarly (3) Khulna Development Authority (KDA), and (4) Rajshahi Town Development Authority (RTDA) are responsible for the cities of Khulna and Rajshahi respectively. All theses organisations carry out research relevant to planning and management of the areas under their jurisdiction. Municipal authorities are mainly responsible for the management activities of the urban government. However, in smaller urban centres they also prepare, with help from UDD, development plans.

There are many other Government Sectoral agencies which participate in urban development. Lack of coordination among these agencies is a serious management problem.

USE OF COMPUTERS IN URBAN PLANNING AND MANAGEMENT

Present scenario

Unfortunately none of the five development authorities above, except UDD has its own computing facility. Only UDD has an APPLE II with a hard disk which is used to maintain a data bank and occasional limited data processing. The system was procured under the National Physical Planning project funded by U.N.D.P. Obviously the APPLE II system is now extremely inadequate compared to the scope of potential applications. The system is not adequate for mapping operation. Most of the applications handled are confined to numeric information processing.

However, all these planning organisations on most occasions employ consultants to do the research required by the organisation. These consultants use available computing facilities to process the data. Sometimes in the past, due to the unavailability of SPSS on local Computer installations, consultants used to travel overseas to access the necessary computing facilities outside the country.

Areas of application

The unavailability of a computer system with graphic software suitable for mapping and overlay has restricted the application of computers to non-graphic information processing. In general computers have been used to create data banks, produce tabular information, and to carry out statistical analysis, forecasting and modelling of information on population, housing and shelter, socio-economic factors, industry, landuse, land value, traffic and transport, physical infrastructure, utility services, education, health, community facilities, and other phenomena related to urban planning and management. Most of these studies have been funded by the Government of Bangladesh and/or International organisations. The UDD and the four urban development authorities through their consultants carry out background studies necessary to prepare development plans for the urban centres under their jurisdiction. UDD for example, recently appointed a large number of consultants to carry out a range of planning-related studies for many medium and small towns.

The Centre for Urban Studies at Dhaka University is one of the major research organisations devoted to the study of the urban sector. The Centre frequently carries out urban studies funded by both Government and International organisations. It presently uses its own IBM PC/XT to process research data. Major Software used include WordStar to prepare reports, dBaseIII to manage urban data bases, LOTUS for forecasting, and SPSS for statistical analysis and modelling. Previously the Centre has used Mainframe and Mini computers at other organisations. Some of its projects involving computer applications include studies into Socio-economic aspects, Squatters and slums, Rural-urban migration, Urban Housing, urban land use and mapping, etc. The Department of Urban and Regional Planning at the Engineering University is another strong participant in urban planning and related research. In addition to its own academic research the department also acts as consultant to the Government and International organisations. The department makes use of its own microcomputer and University's Mainframe Computer.

In addition there are many academic institutions and private planning and research firms in Bangladesh that carry out urban research as consultants. They either use their own microcomputer (mostly an IBM compatible) or access one of the available Mainframe computers which supports SPSS or another relevant software package.

Scope of Future Applications : Problems and Prospects of Computerised LIS

Land is probably the most limited commodity in supply in Bangladesh. The ratio of land to population has already gone far beyond acceptable levels. Land in Bangladesh, specifically in the crowded urban areas, therefore deserves most attention in regard to its utilization.

In 1914, the then British Government produced cadastral survey (CS) maps for all parts of India, including the areas now forming Bangladesh, to assist their revenue collection. Although most of these cadastral maps have not been updated, they still provide a very useful base map leading towards establishment of a computerised Land Information Systems. By comparison, many other countries do not have available such a complete mapping coverage of their land.

Establishment of a large, comprehensive, and multifunctional LIS for the entire country is a very costly exercise which many developing countries could not afford (Moreno,1984). For example, even the digitizing of base maps at the land parcel level at a desired scale may take many years to complete and represent a huge cost to the government. Even many developed countries are presently finding it difficult to establish a comprehensive LIS.

While achievement of a comprehensive multi-purpose LIS is highly desirable, many developing countries may simply not be able to afford it. A more feasible approach for developing countries would be to establish a progressive LIS that offers basic applications and which can be upgraded when required.

Some of the key issues which need to be resolved before it is possible to consider developing a full scale LIS for Bangladesh are considered below:

1. Reorganisation of existing land recording systems to suit a LIS;

2. An updating and digitising of cadastral maps at considerable cost :Who should pay ?

3. Sub-division of the basic land parcels would complicate the operation of a LIS. Existing land parcels can be sub-divided and sold individually thereby fragmenting the original land parcel. This happens mostly as a result of inheritance practices and inadequate legal protection against unlimited land fragmentation. In many other countries subdivision of the basic land parcel is restricted.

4. The education and training necessary for staff ;

5. A financial commitment to this huge task required at the National Government level.

6. Last-but not least - is the need for political will on the part of the Government (and ultimately the elite of the society) to achieve such a system. The question is whether the elite of society are ready to place their property-related information in such a system which can be easily accessed and analysed ?

A National LIS

It may not be financially feasible at present to establish a national LIS which would include all land parcels in Bangladesh. However, in terms of national land resources management, a large expenditure would be considered justifiable in view of the serious management problems and associated losses faced by this relatively poor country each year due to flood and other natural calamities. It is suggested in this paper that what is currently needed is an international effort to help establish a system that would both monitor land management and generate appropriate guidelines to combat these perennial problems which have forced the country's already critical land to population ratio to near impossible levels.

However, it is further suggested that creation of a scaled-down LIS mainly for planning purposes, and which would *not* require the digitizing of land parcels may represent a suitable and effective alternative. Maps made and digitized at suitable regional levels to display and analyse aggregated information may be adequate for national and regional planning. The smallest census units which have a census Geocode are the "Mouza" in rural areas and the "Mahalla" in urban areas. There are 60315 Mouzas/Mahallas in Bangladesh with an average population of 1400, with an average area of around 0.9 sq.mile or 2.4 sq.km. The next unit is the "Union" having an average population of around 20,000. The "Upazilla", with around 176,000 people, is a more recognised unit for regional and national planning. There are 495 Upazillas in Bangladesh.

The Urban LIS

Land Information Systems could also be developed to cater for the urban areas. There are around 500 urban localities in Bangladesh of varying size ranges accommodating 13 million of the country's 90 million people (1981 census). The capital city, Dhaka has a population of 3.4 million whereas the urban centre at the lower end of the hierarchy has a population of less than 5000.

The scope of the proposed LIS may be allowed to vary depending on the size of the urban centre. A micro computer based LIS may serve very well a medium/small urban centre whereas a mainframe/mini computer would be necessary to manage a LIS for some of the urban centers at the upper end of the hierarchy.

There are two main options to be considered in establishing an LIS to serve the planning and management needs of an urban centre: (1) A comprehensive LIS that would contain digitized maps for all the land parcels in the urban area; or (2) A scaled-down LIS that would hold digitised maps of aggregated information at a suitable level (considered adequate for planning purposes) higher than that of the land parcel. Non-graphic data can be easily managed at the land parcel level and the necessary upward aggregation can be achieved so as to integrate with a graphic data base. It is possible, however, to start with option 2, so that when available financial and technical capacity permits, the graphic data base could be enhanced by the gradual inclusion of digitised maps at the land parcel level and at a suitable large scale.

Need for Training

In order to effectively utilise a Planning Information Systems, planners and researchers should have training in the following areas : (a) Statistical techniques, forecasting & budgeting and modelling; (b) Database Management (dBase, etc.), Spread Sheet (LOTUS,etc); (c) GIS/LIS (digitising, map analysis, etc.); (d) Computer programming with emphasis on graphics (at least one in the organisation).

Urban Land Information Systems (ULIS) :
A model LIS for urban planning and management in developing countries

The ULIS model presented below (Figure 4) provides a low-cost micro-computer based land information system that can serve the planning and management requirement of a medium or small urban centre in a developing country such as Bangladesh.

Information types in the proposed ULIS

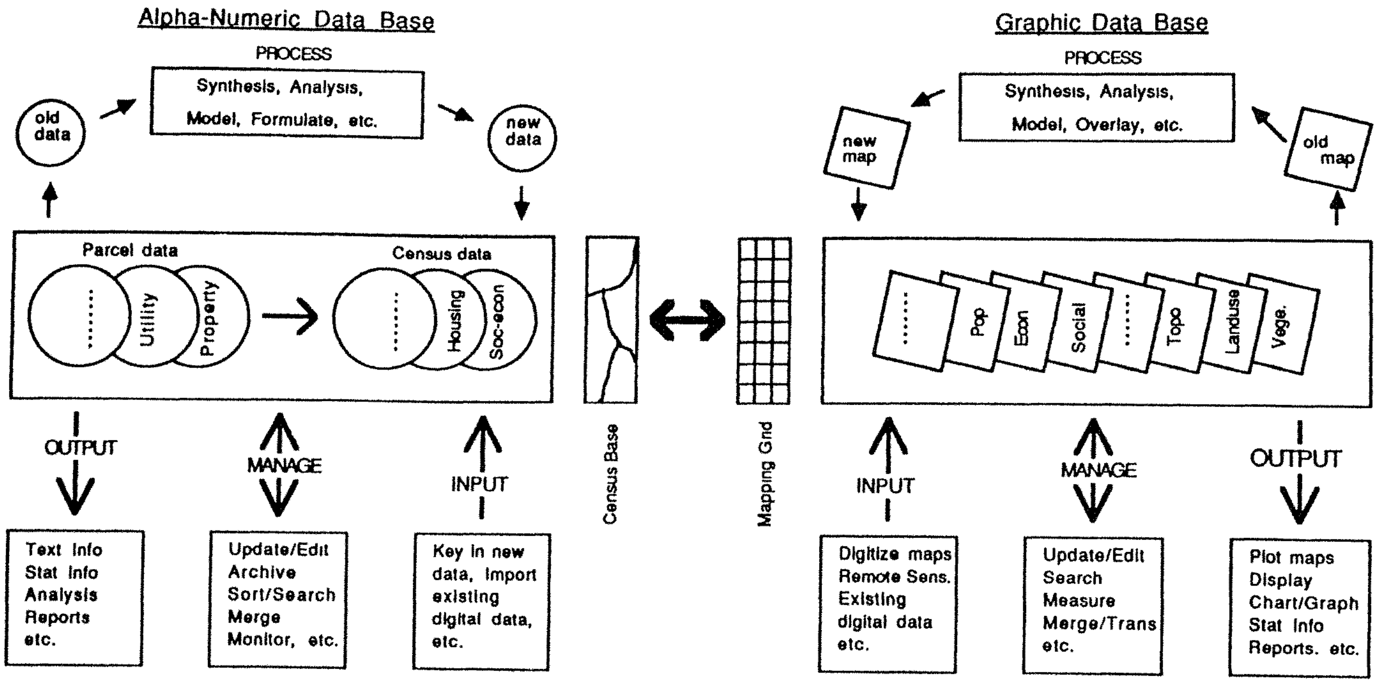
Information management in the proposed ULIS can be divided in two broad categories: - relating to an alpha-numeric (or non-graphic) or a graphic data base. A suitable interface between this dual-class data management should therefore be provided to make the system comprehensive and well-integrated. The LIS should also include analytical tools for statistical analysis, forecasting and modelling.

The Non-graphic data base

A suitable data base management system will contain information on the following items:

- Land and property related information (numeric and textual) at the land parcel level; and
- Census information at the smallest census unit level

The proposed data base will provide for ready interactive updating and retrieval of information that may be necessary to the local government unit for planning and management. Much non-graphic numeric and textual information is required by the local government authority for day-to-day management of the urban activities.This information could all be accessed readily and interactively from the non-graphic data base. It would also have the required data analysis capabilities at any selected unit of analysis. It should be



An Integrated Urban Land Information Systems (ULIS)
for Developing Countries

(Figure 4)

able to aggregate parcel level data to any higher level census unit for necessary interfacing with the graphic data base. This can be readily achieved if land parcels are identified by reference to the census unit within which they are located. Information on parcels (land and property, etc.) can then be aggregated into higher census units and may also be digitized for inclusion in the graphic data base. Other census information (socio-economic data, etc.) can similarly be digitized and included in the graphic data base.

The Graphic Data Base

This will comprise:

- Digitised maps of relevant information (such as land, property, socio-economic data, etc.) from the non-graphic data base aggregated to a suitable census spatial unit higher than the land parcel (for example, the "mahalla" which is the smallest census unit with a geocode number);

- Digitised maps of other relevant information on natural and man-made features which can be generalized at a suitable spatial level. It should be noted that considerable savings can be made in terms of time and money if these maps are generalized and digitised at a suitable spatial level higher than the land parcel. Although this means some loss of detail, the available information should be quite adequate for planning purposes; and

- The data base may also include large-scale digitised maps at parcel level of selected priority areas to display those features that cannot be aggregated and or require precise location. This kind of data should be at a scale adequate enough to represent each separate parcel as a recognizable unit. This will of course vary depending on the size of the parcels, but a scale of 1:1000 (1"=100') may be adequate in most cases (Dale and McLaughlin,1988)

The graphic data base will then contain integrated information on land & property, the census (socio-economic information), and natural phenomena. The graphic data base will also have various map analysis capabilities, including map display, overlays, and land suitability analysis, etc.

Rangpur : An application of ULIS

The following case study for the town of Rangpur represents an exercise to demonstrate the application of a low-cost micro-computer based LIS to a medium sized town in Bangladesh. This is a partial application which only shows the capability of the graphic data management system to do a land suitability analysis. Other software packages could be interfaced to include non-graphic data management and analytical capabilities. Such packages may include DBMS, Spread Sheet and Statistical software (see list below).

Rangpur is the principal town of Rangpur district located in the northern part of Bangladesh. It is a medium sized town having a population of 131,000 (1981 census) in an area of 15.5 (43 sq. km) sq. miles.

Land Suitability Analysis for Residential Development

The POLIGRID package was used to create the graphic data base for Rangpur town. A series of maps, as mentioned in the Structure Plan above, were digitised using the on-screen digitising facility of the Poligrid package. The same data base was also created using the IDRISI package and a digitiser on the IBM PC. However, the Macintosh based POLIGRID was preferred for analysis because of its ability to print the output maps on a laserwriter.

Once the maps are entered into the data base, they can be easily retrieved for various sorts of analysis necessary in the planning process. For example, a suitability analysis was carried out for residential development. Suitability analysis as explained above is carried out chiefly by overlaying maps. Maps showing the spatial spread of existing landuse, population density and elevation were used to find suitable land for residential development.

The process involves: (1) choosing the maps to be considered; (2) weighting various categories in each of those maps in terms of suitability; (3) assigning to the maps comparative weights; and (4) deciding on the number of required classes in the final suitability map. The Poligrid program then produces the final composite map which identifies areas suitable for residential development (see maps in Figure 5 below).

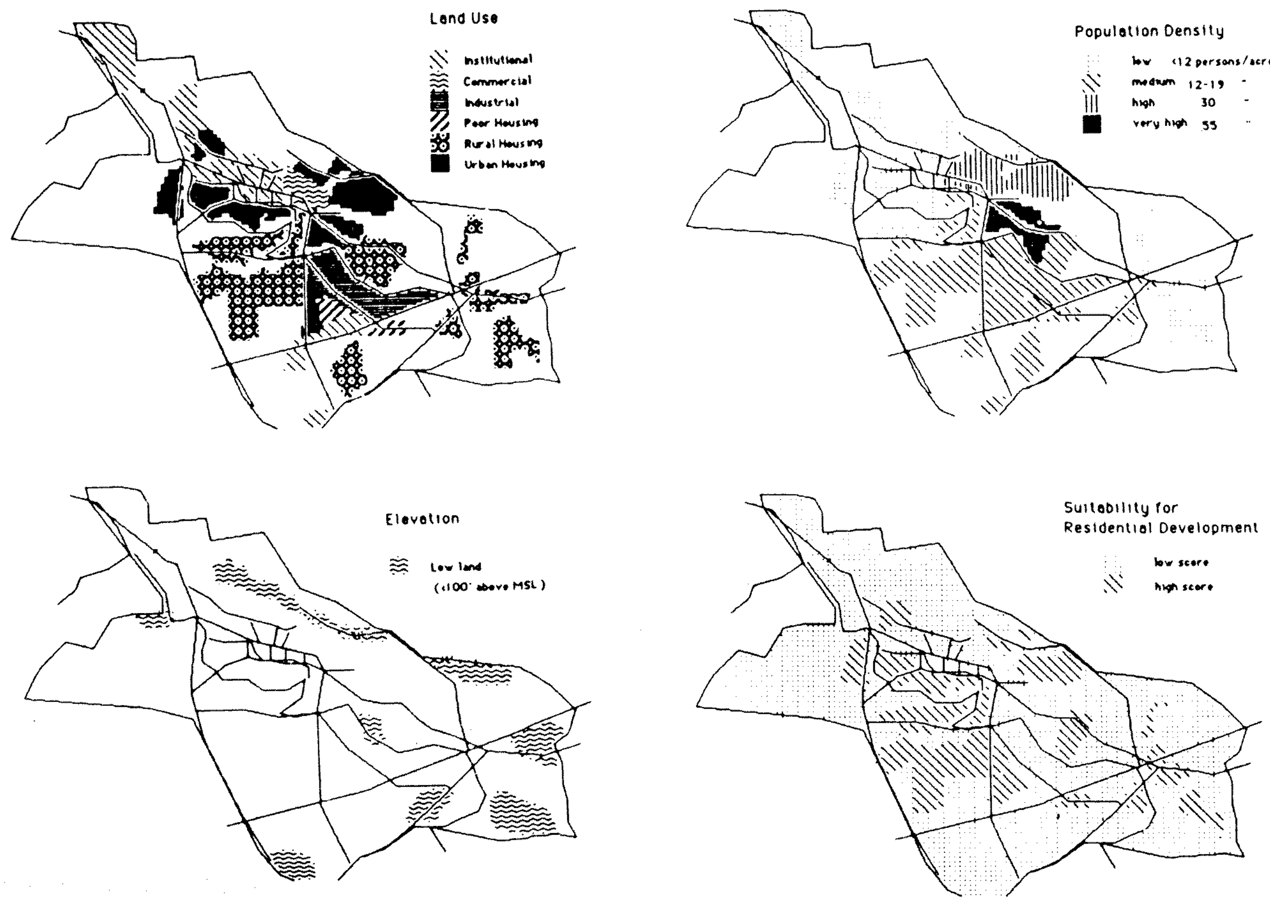


Figure 5 . Land Suitability Analysis for Residential Development

Available Software to establish a ULIS

Following are brief outlines of several low-cost software packages that may be utilised to establish the proposed ULIS on a micro-computer system. None of these individually, however, constitutes a complete package offering a LIS with integrated graphic and non-graphic data management and analytical capabilities. One needs to combine: (1) a mapping package; (2) a data base management package; and (3) a statistical analysis package to achieve the desired integrated ULIS. It is also possible to make the whole operation menu-driven and user friendly.

1. Map Analysis Package (MAP) - This package is a set of computer programs which provides for the encoding, storage, analysis, and display of geographic information. It allows generation of new maps by combining and/or transforming values from maps already on file. It is possible to use its map overlaying facility to perform land suitability analysis. Remember that it does not include a digitizing routine. An IBM PC/XT version of this package is available from the Laboratory for Computer Graphics and Spatial Analysis, Harvard University, USA.

2. Urban Data Management Software (UDMS) - UDMS is a polygon-based geographic information system. It is a useful urban planning and facilities location tool for urban and regional planners. It performs mapping, statistical analyses and location/allocation modelling. It provides a menu of choices, allowing the user to plan the most efficient location of public facilities such as hospitals, schools and transport lines. It prints maps and summary reports. It does not include a proper digitising routine. An IBM PC version of the package is available from UNCHS (Habitat), Nairobi, Kenya.

3. Micro Grid - This is a grid-based geographic analysis system and can be utilised for overlays and land suitability analysis. It does not include a proper digitising routine.The IBM PC version of the package is available from UNCHS (Habitat), Nairoby, Kenya.

4. IDRISI - This is a grid-based geographic analysis system that is designed to provide inexpensive access to computer assisted geographic analysis technology. Modules in the package include data entry and storage, management, retrieval and display, general analysis (overlay, scalar, reclass, filter), some statistical analysis, and GIS. It includes a digitising routine. An MS/DOS version of the package is available from School of Geography, Clark University, USA

5. POLIGRID - This is an Apple Macintosh computer based GIS for local application. Features include map digitisation (using the mouse or digitizer), map overlay, land suitability analysis, etc. The package is available from the School of Environmental Planning, University of Melbourne, Australia.

6. AUTOCAD and AUTOSKETCH - Autocad is a comprehensive drawing and drafting package which can be used to digitize maps and can be transferred to other programs through it's DXF files. It can also be used to overlay maps. AUTOSKETCH is a low-cost version of AUTOCAD providing limited facilities. These could be useful since many low-cost GIS/LIS do not come with a digitizing routine. These packages are commercially available for both IBM and Macintosh (AUTOCAD only) computers.

7. dBaseIII+ and dBase Mac : dBaseIII is one of the most user-friendly data base management systems widely available on micro-computers. A data base management system can be developed with this package to manage parcel based information (non-graphic) for local area planning and management. Most of the low-cost GIS/LIS only handle graphic data analysis, so that the user needs a data base management package like dBaseIII+ to manage the non-graphic data in the LIS. dBase Mac is for Macintosh computer.These packages are available commercially.

8. LOTUS and EXCEL : LOTUS is a spread sheet package for IBM PC which can be used for data entry to non-graphic data base, some basic data base management, forecasting, modelling and some statistical analysis. In addition it provides simple graphical display of your data suitable for presentation. EXCEL does the same for the Macintosh computer. Both packages are available commercially.

9. SPSS/PC and STATVIEW+ : SPSS/PC is the IBM/PC version of the popular statistical

package for the mainframe computer. It provides routines for general statistical analysis, forecasting and modelling. STATVIEW+ does the same for the Macintosh computer. Both packages are available commercially.

Suggested Configuration

The list above is not exhaustive and therefore you may find other packages (some even free or at a nominal cost) that are quite suitable for your purpose.

1. IBM PC/XT: Integrate IDRISI, dBaseII+, LOTUS and SPSS/PC. Develop interface routines to make the operation user-friendly.

2. Macintosh+: or SE Integrate POLIGRID (also look for other packages in the offing), dBase Mac, EXCEL and STATVIEW+. Develop interface routines to make the operation menu-driven and user-friendly.

CONCLUSION

It may not be feasible to establish a comprehensive national LIS system for managing land resources in Bangladesh in the near future unless international assistance is available. In the meantime, however, low-cost small scale urban land information systems could be developed to stimulate and improve the overall decision-making capability of a local government. These systems would assist planners and other decision makers to address specific current problems in housing, transport, and utility services, and in the overall planning and management of the urban landscape.

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2. Mr. Alauddin, U.D.D., Dhaka, Bangladesh provided much needed information.

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CONDITIONS FOR THE EFFECTIVE UTILISATION OF COMPUTERS IN URBAN PLANNING IN DEVELOPING COUNTRIES

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ABSTRACT

As a result of the advent of micro computers cost factors and technical considerations no longer seriously inhibit the utilisation of computers in urban planning in developing countries. Such developments highlight the critical role of organisational factors in restricting or facilitating the use of computer based technology. With this in mind the paper reviews the findings of studies from both western countries and the developing world and sets out three conditions for the effective utilisation of computers in urban planning. These are the need for a clearly defined information management strategy, the personal commitment of individuals at all levels in the organisation and organisational and environmental stability.

1. INTRODUCTION

The starting point for this paper is a discussion published ten years ago by Paul Sabatier and Daniel Mazmanian (1979) entitled "The Conditions of Effective Implementation: A Guide to Accomplishing Policy Objectives." In this paper the authors sought "to identify and explain a set of five (sufficient and generally necessary) conditions under which a policy decision that seeks a substantial (non-trivial) departure from the status quo can achieve its policy objectives." (p.483)

In writing their paper Sabatier and Mazmanian reflected a general concern among both scholars and decision-makers about why so many policies apparently failed to achieve their objectives. Such concerns are vividly captured by the sub-title of Pressman and Wildavsky's (1973) classic case study of "How great expectations in Washington are dashed in Oakland; or, why it's amazing that federal programmes work at all. This being the saga of the Economic Development Administration as told by two sympathetic observers who seek to build morals on a foundation of ruined hopes."

There are obvious parallels between these themes and the growing recognition amongst scholars and urban planners alike that a fundamental distinction must be made between the acquisition of computer based technology and its effective utilisation. Unless such a distinction is made it is impossible to explain how a system which has proved successful in one planning agency can turn out to be a disaster in another. It is interesting to note that even the terminology used by the evaluators of the impact of computer systems is the same as that used by some implementation researchers. For example, the Chorley report of the British Government on Handling Geographic Information (Department of the Environment 1987) also argues that, although the continued development of the technology is guaranteed, "we believe this to be a necessary though not a sufficient, condition for the take up of geographic information systems to increase rapidly." (para. 1.22) To ensure their rapid take up and effective utilisation it is also necessary to reduce a number of human and institutional barriers to change, some of which are administrative and personal while others are financial and technical in nature.

The extent to which effective utilisation is influenced by the personal and organisational setting in which computers are introduced is one of the most important findings of a series of studies on the utilisation of computers in local government carried out by the Public Policy Research Organisation at the University of California at Irvine (see, for example, Danziger et al 1982, King and Kraemer 1985, Danziger and Kraemer 1986). The Irvine group emphasise the dynamic, political and context specific nature of the environment in which local government computer usage takes place.

With these considerations in mind the present paper examines some of the broader issues involved in the utilisation of computers by urban planning agencies with particular reference to the experience of developing countries. Like Sabatier and Mazmanian's paper it attempts to introduce a more prescriptive dimension into a discussion which has been largely dominated by the findings of descriptive analysis. By trying to identify necessary and possibly generally sufficient conditions for effective utilisation it seeks to sharpen the focus of the current debate and also to provide some guidelines for practitioners. Because of this it follows Sabatier and Mazmanian in addressing two different audiences: scholars interested in developing a conceptual framework for the analysis of computer utilisation in urban planning agencies, and practitioners seeking to maximise the chances of effective utilisation.

The paper is specifically directed towards the needs of developing countries for two main reasons. Firstly, because this is where the needs of urban planners are probably greatest given the extent of rapid urbanisation and economic transformation that is taking place whereas the resources at their disposal are probably least. Developing countries are also the areas where the impact of what Mannheim (1987) has called the Third Computer Revolution brought about by the advent of micro-computer based technology is likely to be greatest because of the general lack of operational experience based upon involvement in the first two computer revolutions. Secondly, and more pragmatically, a great deal of information has recently become available about the utilisation of computers in urban planning in developing countries as a result of the efforts of international agencies such as the United Nations Centre for Human Settlements (HABITAT) and the United Nations Centre for Regional Development which have promoted cross-national comparative evaluation of experiences. In contrast, the role of similar agencies in more developed countries is generally more restricted although there are some notable exceptions (see, for example, OECD 1978).

The organisation of the paper is as follows. The first major section reviews the findings of the studies carried out by the Irvine group. It draws attention to the importance this group attach to three main factors: the organisational context, the role of individuals, and the impact of change and instability. The work of the Irvine group deals with local government in general whereas the next section evaluates the experiences of British local planning authorities in terms of these three factors. This section draws heavily on the findings of the junior author's own research on the use of computers for processing planning applications (Campbell 1987). This section is followed by a review of the findings of a number of studies examining the experiences of developing countries which deal specifically with factors of this kind. With all these considerations in mind the last major section sets out three conditions for the effective utilisation of computers in urban planning. Like the conditions set out in Sabatier and Mazmanian's paper these are presented as "necessary and generally sufficient conditions" for the effective utilisation of computers in urban planning. The final section of the paper outlines various strategies for increasing the chances of effective utilisation in situations where these conditions are not met.

2. CONCEPTUAL FRAMEWORK FOR ANALYSIS

2.1 Introduction

The work of the group based at the Public Policy Organisation at the University of California at Irvine provides a systematic account of the impact of computerisation on local government activities in the United States (see, for example, Danziger et al 1982 and King and Kraemer 1985). This involved a census survey of all local authorities in the United States and a more narrowly focussed analysis of 42 city governments. The project has subsequently been extended to include comparative data from a number of European countries.

The findings of these studies suggest that the adoption and effective utilisation of information technology is largely dependent on organisational rather than technical considerations. As a result the Irvine group have argued that computer technology should be regarded as a package including not only hardware and software but also personal skills, operational practices and corporate expectations. The package concept is valuable as it indicates the need for substantial supporting resources for the operation of automated systems. The computer package is not, however, an independent entity. The studies undertaken by the Irvine group highlight the contribution of three sets of organisational factors to an understanding of the use of the computer package within a particular organisation. These are the organisational context, people and the impact of change and instability. The manner in which these organisational factors interact with the computer package determines the processes which influence the development and use of automated systems. These factors will be examined in turn.

2.2 Organisational Context

Studies focussing on computer equipment have tended to view the outcome of automation to be universal. The first element of the conceptual framework questions this assumption emphasising the contribution of the organisational context to the initial adoption and subsequent use of computer based systems. Contextual factors are sub-divided into two levels, the internal organisation and the external environment which together provide the background against which computer usage takes place.

The internal organisational context relates to the attributes of the organisation in which the information system is located. These include features such as the organisational structure, administrative arrangements and procedures for decision making in general and specifically with regard to computing resources. In many instances there are two sets of internal organisational factors which must be examined, those that relate to the planning agency itself and also to characteristics of the wider organisation in which it is set such as a local or regional authority or national government. However consideration of contextual factors must not be limited to the organisation in which planning activities are located, features of the external environment also influence the development and utilisation of automated systems. There has been a tendency for evaluations of external factors to be limited to the actions of computer suppliers and manufacturers. The Irvine group questioned this perspective, stressing in addition the importance of examining the political and administrative influence of other local authorities as well as central government. Socio-economic characteristics, professional opinion and the views and technical awareness within the society served are also included under this heading.

It will be clear from these comments that by emphasising the need to consider the organisational context it is not assumed that the conditions into which a computer package is located are universal. The important implication is that studies must start by examining how organisations are not as many prescriptive studies, how they should be. It is inevitable that the pertinent details will vary between and also within an individual organisation over time. The stress placed on the constraining as well as facilitating role of the internal and external organisational contexts should not be assumed to suggest rigid determinism. These contextual factors are regarded as the background against which the activities of the second element of the conceptual framework should be set.

2.3 People

The Irvine group, in contrast to traditional technically oriented studies do not presume that the interests of individual members of staff coincide with the goals of the organisation in which they work or that the benefits of computerisation are shared evenly. It is emphasised that individuals have differing values and motivations and that computerisation tends to challenge traditional interests, threatening some and offering opportunities to others. As a result it is argued that the adoption and development of computer based systems must be viewed in relation to the underlying political processes of an organisation. The political allocation mechanism is perceived to act as the means through which negotiation takes place between interested parties. In most planning contexts bargaining over the allocation of benefits emanating from computer based systems takes place both within the agency itself and with other units in the same organisation. Individuals can perform an important role in this process with the acquisition of resources frequently associated with a single member of staff who possesses the necessary ability, willingness and probably experience to fight the inevitable political battles.

In the face of these activities the rest of the staff are not passive. There appears to be no necessary link between the existence of an information system and its use. A great deal would appear to depend upon user characteristics and the relationship between personalities. Individuals within organisations possess very different skills, views of the type of activities for which information systems are useful as well as varying in their willingness and inclination to use technology. Danziger and Kraemer's (1986) work indicates that staff confidence in their own computing capacities and the interpersonal relationship between users and technocrats have a marked impact on the utilisation of information systems.

The activities of individuals can substantially effect the development and utilisation of computer based systems. The outcome of automation is thus influenced by the interaction of a complex set of human and contextual factors but conditions are not static as the third element of the conceptual framework emphasises.

2.4 Change and Instability

The Irvine group point to instability as a key factor in understanding the difficulties organisations encounter and the tendency for unexpected outcomes. Computer based systems tend not to be designed once and for all, circumstances change requiring alterations to be made. Development thus appears to be ad hoc and incremental with amendments to existing systems favoured over the potentially greater disruption of an entirely new system. No organisation is static. Staff in particular change but as far as is practical it appears that stable internal settings enhance computer usage. A highly volatile technical, social and political external environment is liable to impede the effective development and utilisation of automated systems.

2.5 Summary

The conceptual framework developed from the work of the Irvine group attempts to take account of the social and political processes which underly the utilisation of computer based systems. Three sets of factors are highlighted which will either facilitate or constrain the activities of the computer package. The detailed factors which need to be considered in relation to each element of the conceptual framework will vary between organisations and in time. However, having distinguished the pertinent factors and the manner in which they interact understanding of the varied outcomes of the introduction of information systems is possible.

3. ORGANISATIONAL FACTORS AND THE USE OF COMPUTERS IN BRITISH LOCAL AUTHORITY PLANNING DEPARTMENTS

3.1 Introduction

The study reviewed in this section (Campbell 1987) was designed to supplement existing research based in British local authority planning departments (see, for example, Bardon 1985, Bardon, Elliott and Stothers 1984, Farthing 1986a, 1986b, Grimshaw 1988). The work focused on computer applications designed to process planning applications. The results of the study indicated a substantial discrepancy between the theoretical merits of a computer based system and the problems associated with the operation of a system in practice. The research also showed that the benefits of computerisation vary widely between authorities even where similar configurations of hardware and software are being used. These results raised questions as to the appropriateness of approaches which focus on equipment. A much broader theoretical perspective was required to provide the necessary explanatory power. The conceptual framework outlined above was adopted as a means of evaluating the findings.

3.2 The Organisational Context

The context in which a computer based system is developed may facilitate but more likely constrain its operation. In many instances planning departments can exert very little control over their organisational setting. For example many authorities have adopted policies restricting equipment purchases to a single British or local manufacturer. In other cases difficulties arise as a result of reliance on the central computing section which is often located in the Finance Department for which Planning is not a particularly high priority. With respect to development control systems in many cases expected benefits such as time savings have been very limited due to institutional factors including committee cycles and delays resulting from the consultation process (Farthing 1986b).

External factors also have a significant impact on the operation of computer based systems. Outside organisations such as central government, computer manufacturers and joint working arrangements with other local authorities may restrict the options available to an authority or disrupt existing practices. For instance central government's requirement that the calculation of development control returns should be modified undermines existing systems causing extra work, while restrictions on local government funding constrains the type of system that can be developed. Socio-economic changes in the wider community may also inhibit system development demonstrated by the current staff recruitment difficulties facing authorities in south east England.

Most of these factors are an intrinsic part of the operational environment in which the activities of planning departments are located emphasising the need to study computer based systems in real world settings. However, the operation of such systems is not entirely determined by the context as the actions of enthusiastic and skilled staff can overcome such barriers.

3.3 People

The motivations of individual officers can have an important bearing on the development of computer based systems. The individual with responsibility for the implementation and subsequent maintenance of the system has a key role. This member of staff can either reduce staff anxieties about computerisation or exacerbate deeply embedded scepticism. Many issues are resolved by informal contact between officers with such chance meetings also acting as a means of communicating the potential of computer based system. Senior staff can also make a significant contribution by creating a favourable culture and a stable environment. Senior officers often make little direct use of computers but can play a vital role in securing resources and encouraging staff to gain sufficient knowledge to make use of the available technology. In terms of development control applications user involvement in the design of the system is essential. Development control officers frequently resent the discipline imposed by computerisation as well as the extra work associated with filling in coding sheets. Staff may also question the personal benefits to be derived from this task and the situation is managed carefully inaccurate data may be input. Personalities thus play a vital role in the operation of automated systems.

3.4 Change and Instability

Instability and an ever changing environment has a significant impact on the operation of computer based systems. It may be vital for instance to take account of modifications to the organisation's internal structure or changes in key personnel in order to gain insight into the impact of a particular computer based system. As a result of constantly changing circumstances computerisation tends to be more of an ad hoc process than the once and for all implementation of systems. Frequently at the point when problems appear to be diminishing conditions change, modifications to the system become necessary and the process of learning must be repeated.

3.5 Summary

These findings stress the importance of organisational factors in understanding the utilisation of a computer based application in British planning authorities. A similar structure would seem to be appropriate to other planning contexts as emphasis is placed on examining how organisations are not assuming how they should be. Description of the underlying social and political processes would seem to be an essential prerequisite for prescription.

4. THE UTILISATION OF COMPUTERS IN URBAN PLANNING IN DEVELOPING COUNTRIES

4.1 Introduction

A great deal of useful evidence regarding the utilisation of computers in urban planning in developing countries can be found in the proceedings of the international workshop and expert group meetings that have been convened by agencies such as the United Nations Centre for Human Settlements (UNCHS) and the United Nations Centre for Regional Development (UNCRD). The latter has played a particularly important role by commissioning detailed case studies of computerisation experience in developing countries which have been presented in a series of meetings since 1984 (see, for example, UNCRD 1986 and 1988). Some of the main findings of UNCRD and UNCHS experience are reviewed in this section together with those from a broadly representative sample of case studies. These include the findings of two studies dealing with technology transfer which give some additional insights into factors governing the take-up of new technology.

4.2 Some Lessons from UNCRD Experience

A major theme in the most recent of the expert group meetings organised by UNCRD in Singapore was critical success factors in the development and implementation of information systems/information technology in local and regional planning. A key section of the report of this meeting reviews these issues (Edralin, 1989). This section recognises the critical distinction made at the outset of the paper between the availability and the utilisation of computer based technology.

> "The main message of the expert meeting . . . was that the central focus of IS/IT should be on their implementation. After a decision is made to establish an IS/IT project, what is done by those who implement the project will determine its success or failure." (Edralin 1989, p.37)

The findings of a number of case studies that were presented at the meeting are reviewed in these terms with reference to three groups of factors: human, organisational and technical factors. These broadly correspond to the three sets of factors defined by the Irvine group.

The discussion of human factors emphasises the critical role that is played by leadership in many projects.

> "A primary function of leadership is to set clear goals and objectives, to win acceptance among IS/IT users for such goals and objectives, and to provide commitment to achieve project goals and tasks." (Edralin 1989, p.38)

Another critical function of leadership is coordination, particularly where data collection and administrative responsibilities are fragmented.

The discussion of organisational factors deals largely with the context of computer based operations. It stresses the need for appropriate policy support for such developments from central government. This is particularly important in the case of projects initiated by donor agencies from the standpoint of securing their long-term financial viability. The development of organisational capabilities is regarded as the most important task for implementers. The most successful cases are those where projects are able to build upon existing organisational capabilities and personnel. Wherever possible top down, centralised, non-participatory approaches to implementation should be avoided (Edralin 1989, p.42).

Under the heading of technical factors a number of issues relating to the dynamics of computer utilisation are discussed. Particularly important in this respect is the need to develop systems that evolve in response to changing circumstances.

> "The successful projects will continue to evolve and adapt to new applications . . . A major goal for these projects is to become 'learning systems' - systems that continually update their activities, refresh their training facilities, and review their goals and objectives." (Edralin 1989, p.43)

4.3 Some Lessons from UNCHS Experience

UNCHS has played an active role since the early 80s in promoting the use of microcomputers for planning in developing countries through the development and dissemination of its Urban Data Management Software (UDMS) package (Robinson and Coiner 1986) and its participation in specific planning projects in many different countries. Some lessons from the latter experience are reviewed by Cartwright (1987) with particular reference to work carried out in India, Mexico and Sri Lanka.

The case of the information system for human settlements that was initiated by the Town and Country Planning Organisation of the Indian Ministry of Works and Housing highlights the importance of taking an incremental approach to design which reflects the dynamics of the organisation concerned.

> "Even the best designed systems are going to change over time, as the role and priorities of the planners themselves change - and as planners gain experience with the information system. So the prudent thing to do is to make and implement a design that is based on a) an identification of the needs of a real group of users; and b) the knowledge that the system has to change and probably expand over time." (Cartwright 1987, p.192).

The case of the information system developed by the Secretaria de Desarrollo Urbano y Ecologia in Mexico draws attention to the difference between collecting data and creating an information system. In the latter case, the crucial question is as much what can be done with the data as what data is available in the system.

> "Information systems serve a purpose, and how good they are depends upon how well they serve that purpose. This means that their design should be based on a clear understanding of who is going to use the system, what it will be used for and how it will be used." (Cartwright 1987, p.200)

The case of the management information system developed for local authorities in Sri Lanka raises important questions about the organisational setting of such applications. In this case the government failed to recognise the extent to which information systems could have helped to shape urban administration by altering individual roles and changing institutional responsibilities.

> "Instead of merely an administrative convenience for the central government, the information system would become a key component of efforts to strengthen the managerial capacity of local government. Instead of being merely a record of urban performance, the information system would become an active component of urban development." (Cartwright 1987, p.203)

4.4 Some Lessons from Metropolitan Planning

Because of their political and economic importance metropolitan regions throughout the world have a leading edge function that makes their experiences especially interesting for the analyst. Panganiban's (1986) case study of the Metropolitan Manila Commission in the Philippines illustrates graphically the kinds of problems that inhibit the effective implementation of information systems for a rapidly changing metropolitan region where administrative responsibilities are highly fragmented.

The Metropolitan Manila Commission prepares and administers programmes for the 4 chartered cities and the 13 municipalities that come within its boundaries. Its planning duties include the preparation of comprehensive plans such as the 1982 Regional Development Framework Plan, the maintenance of a Capital Investment Folio for monitoring progress on major projects in the region that are funded largely by central government or international agencies, programme planning for 11 basic needs sectors, and the preparation of physical development plans for localities within the region.

The development of effective information systems for the Metropolitan Manila Commission has been seriously inhibited by the number of agencies involved, conflicts of priorities between these interests, and a lack of organisational stability. Although some progress has been made in developing collaborative efforts there have been major difficulties in coordinating data collection among the various agencies involved and the commission has largely failed in its attempts to utilise operational data for planning purposes. As a result it has had to rely on secondary sources of data with known deficiencies. In practice this has led to the emergence of two contrasting types of information systems within the same organisation: small scale ad hoc manual systems developed for particular project management purposes which are in sharp contrast to the more comprehensive multi-purpose information systems that are required for strategic planning. The difficulties for those involved have been exacerbated by a general lack of organisational stability. At the time of the study, according to Panganiban,

> "The fluidity of the organisation is not confined to the information system alone. The whole of Metropolitan Manila commissioned is still experiencing a large degree of uncertainty." (Panganiban 1986, p.241)

4.5 Some Lessons from Technology Transfer

The importance of exploring the wider context of computer based applications is demonstrated by Drummond and Stefanovic's (1988) discussion of factors affecting the transfer of geographic information systems (GIS) technology to developing countries. They point out that while there is evidence of large investments having been made to acquire GIS technology, there is much less evidence that the systems are functioning satisfactorily and contributing to national development efforts. This is due partly to the degree to which technology transfers of this kind are usually initiated by suppliers rather than receivers, and partly to the failure to fully take account of the organisational setting and personal motivations of those involved. Under these circumstances bureaucratic inertia, political instability and personal cynicism are critical constraints on the effective utilisation of new technology.

Calhoun et al's (1987) evaluation of lessons from the design and implementation of a micro-computer based system for the Sudanese Planning Ministry gives a number of specific examples of the problems encountered in technology transfer to a relatively inhospitable environment "where computerisation efforts could not built on strong foundations from prior computer use, on strong support systems, physical infrastructure, technological familiarity or even a common linguistic base." (p.363) In situations of this kind serious difficulties are encountered as a result of the mismatch between the organisational culture that is implicit in information management ideology of the suppliers and that of the receiving organisation.

Calhoun et al also make a number of suggestions as to how to increase the chances of successful technology transfer to inhospitable environments. They stress the importance of increasing overall computer awareness at all levels in organisations of this kind while recognising that "the success of any computer application will be determined largely by its effect on the career paths (and remuneration) of individuals." (p.372) They also point out that technical efficiency is seldom in itself sufficient reason for adopting computer based technologies, particularly if they threaten the existing balance of power within the organisation. Like the Irvine group they conclude that the effective utilisation of computers in planning agencies generally does "notsomuch modify or redistribute power within an organisation as reinforce the existing power structure." (p.370)

4.6 Evaluation

The findings of the experiences of developing countries generally support those of the American and British studies discussed earlier. In developing countries, as the experience of international agencies such as UNCRD and UNCHS demonstrates, the importance of appropriate policy support for computer developments cannot be underestimated while the Sudanese example demonstrates the kind of problems that have to be solved when technology is transferred into a relatively inhospitable environment. The technology transfer issue adds a new dimension to the discussion of organisational and environmental factors by contrasting the organisational cultures of the suppliers and the receivers of technology.

All the case studies bring out the importance that is attached to clear leadership and personal motivation. The Sudanese example, in particular, emphasises the need to develop computer awareness at all levels in the organisation if the chances of success are to be maximised. The kind of problems that can arise where there is a fragmentation of tasks and a diffusion of responsibilities are clearly illustrated by the Manila case study.

The UNCRD and UNCHS experience also places great stress on the need to develop adaptive learning systems which can evolve in response to changing circumstances. The experience of Manila draws attention to the lead time that is involved in such efforts and the extent to which developments of this kind may be inhibited by organisational and political instability.

5. CONDITIONS FOR THE EFFECTIVE UTILISATION OF COMPUTERS IN URBAN PLANNING IN DEVELOPING COUNTRIES

5.1 Introduction

With all the above considerations in mind an attempt is made in this section to define conditions for the effective utilisation of computers in urban planning in developing countries. The following discussion builds upon the work of the Irvine group, and draws upon experience from British local authority planning practice and that of planning agencies in developing countries.

The contention of this paper is that three necessary and generally sufficient conditions have to be met for the effective utilisation of computers in urban planning agencies in developing countries. These are:

1. The existence of an overall information management strategy based on the needs of users in the planning agency and the resources that are at its disposal.

2. The personal commitment of individuals at all levels in the organisation with respect to overall leadership, general awareness and technical capabilities.

3. Organisational stability with respect to personnel, administrative structures and environmental considerations.

5.2 The Existence of an Overall Information Management Strategy Based on the User Needs of the Agency and the Resources at its Disposal

In effect this condition involves three sub-conditions relating to the development of information management strategies in general, the expression of management needs and the availability of resources respectively. The importance of developing an information management strategy is central to the distinction made by Cartwright (1987) between collecting data and creating an information system. Without an overall information management strategy which takes account of data availability, computing capacities and management requirements it is likely that major problems will arise in relation to computing utilisation. This is particularly the case with respect to strategic monitoring activities where a high degree of selectivity is required to ensure that the right information gets to the right people at the right time (Masser 1986). Without a well developed information management strategy it is likely that there will also be mismatches between information needs and data availability as well as between data collection and information processing.

The chances of failure are likely to be increased where there is no clear expression of management needs. All too often information system designers are faced with circumstances that reflect the findings of a study of monitoring practices in US Government agencies. This concluded that many system developers had "to design and supply information to a management structure which may not know what information it wants or how it would act if it received particular types of information." (Waller et al 1976, p.19)

Operational difficulties will be further aggravated where unrealistic assumptions have been made about the resources at the disposal of the planning agency to promote effective utilisation. There is often a tendency to assume that the bulk of the costs are incurred in the process of setting up the computer system. In the process the recurrent costs of data collection associated with maintaining and updating the systems are seriously underestimated and little if any provision is made for adapting the system to meet changing circumstances. In order to develop an incremental learning approach to computer utilisation it is essential that adequate resources are set aside for these purposes from the outset.

The situation in developing countries is often further complicated by two other factors: the likelihood that the agency itself has relatively little experience on which to base its formulation of managerial needs, and the possibility that the initial installation of the system was undertaken with the help of international aid on the assumption that the recurrent costs would be picked up from local sources.

The chances of effective utilisation are likely to be seriously inhibited where a number of agencies are involved, even where there is substantial agreement about the desirability of the overall objectives and even where resources have been made available for this purpose. The extent to which apparently minor differences in interpretation and relatively small differences in the emphasis given to operational priorities can affect the chances of successful implementation have already been demonstrated by Pressman and Wildavsky's case study of the operations of the Economic Development Administration (1973) in Oakland.

The experience of the urban planning field indicates that problems of this kind are particularly likely to arise where computing tasks are carried out by other agencies as a service function. It has been argued, for example, that this was a major factor in inhibiting the effective utilisation of computers in British planning agencies until the advent of microcomputers during the late 1970s (see, for example, Masser 1988). As a result of this separation of tasks many planning agencies found themselves faced with not only problems of access to computer technology but also with the possibility of having to implement planning applications on hardware and software systems designed for very different types of operation.

5.3 The personal commitment of individuals at all levels of the organisation with respect to overall leadership, general awareness and technical capabilities

This condition also involves three sub-conditions relating to leadership, awareness and technical capabilities respectively. The most successful cases of computer utilisation are those where there is clear leadership and a commitment from senior staff who are aware of the potential opened up by computers for urban planning. However, success also depends upon the commitment and enthusiasm of agency staff at all levels. Effective utilisation is unlikely unless, as Calhoun et al (1987), have pointed out, computer applications are seen to have a tangible effect on personal career development paths and remuneration within planning agencies. The prospects for effective utilisation are likely to be further inhibited where the need for technical capabilities has been underestimated, particularly in relation to operations management experience. Specific skills training shortages can be remedied relatively quickly by special programmes if the resources are made available, but extensive on-the-job experience is necessary for operations line management.

It should also be recognised that most users in urban planning agencies are essentially passive users whose primary responsibilities lie outside the field of information management (Danziger and Kraemer 1986). Effective utilisation is therefore likely to depend on the extent to which these users see the execution of their primary responsibilities as being facilitated passive computer based information.

5.4 Organisational and Environmental Stability in Terms of Personnel, Administrative Structures and Environmental Considerations

Given the lead time that is required to absorb computer-based innovations a relatively stable organisational environment must be regarded as a critical factor in promoting effective utilisation. Failure to recognise the vital importance of key individuals, particularly those working in rapidly changing technological fields, and the need for continuity in order to build up operational experience can seriously undermine the chances of effective utilisation even in organisations with clearly defined information management strategies and a high level of staff commitment. These difficulties are likely to be further aggravated by uncertainties created by the periodic internal reshuffling of tasks and personnel between sections and threats of transfers of responsibilities and staff to different agencies within local government as a whole.

The overall stability of organisations is also likely to be affected by a variety of broader environmental considerations. Political and economic instability must be regarded as an important factor in the external environment of urban planning agencies in many developing countries and it should also be noted that in all countries planning responsibilities are constantly evolving as the issues agenda itself changes. Under these circumstances the chances are high that systems designed to meet one set of requirements may find themselves having to adapt to meet completely new configurations of policies and programmes.

Matters relating to stability, overall leadership, general awareness and the technical capabilities of urban planning agencies are likely to reflect prevailing attitudes in each country, particularly those of the central government agencies responsible for gathering data and promoting information technology. As a result, there are likely to be important differences between the experiences of planning agencies in countries which have given a high priority to the collection and dissemination of information and the development of information technology skills and those countries which have not (Masser, 1989).

6. SOME ADVICE FOR PRACTITIONERS

Three conditions were set out in the last section as being necessary and generally sufficient conditions which must be met for the effective utilisation of computers in urban planning agencies in developing countries. It must be accepted that only a small minority of agencies in these countries are likely to be able to satisfy these conditions in full and that the vast majority will fall short in one or more respects. This raises the question about what these agencies might do to reduce the risks of ineffective computer utilisation. With this in mind the concluding section of this paper outlines some strategies which may be of value to planning agencies who wish to promote more effective computerisation while failing to meet all three conditions.

Two general strategies underlie the whole discussion about conditions for effective utilisation. These can best be summarised by the slogans "small is beautiful" and "one step at a time". The former strategy is a general response to the need to avoid over-ambitious plans which carry with them high risks of failure. Where there is no clear information management strategy a small is beautiful strategy should concentrate on limited applications which directly meet perceived needs. Such an approach should also impose less demands on leadership, staff commitment and technical resources. It is less vulnerable to organisational and environmental changes because the lead time that is required for implementing projects of this kind is likely to be relatively limited.

The small is beautiful approach to effective computer utilisation in urban planning agencies in developing countries have been given fresh impetus over the last few years by the advent of powerful micro-computers with a wide range of user-friendly software packages. The cost of the hardware has fallen dramatically while computer capacities have increased in an equally spectacular fashion to the extent that a typical desk top configuration today is likely to have similar capabilities to those of the typical mainframe computer a decade ago (Yeh, 1988). From the standpoint of the non-technical user the availability of powerful word processing, spreadsheet and data base management packages is particularly important as it enables them to develop operational applications for specific planning activities such as forecasting, budgeting, and maintaining files of data on key land uses with a minimum of operational expertise.

The obvious limitations of a small is beautiful strategy in terms of its overall impact on the work of the agency as a whole can be overcome to some extent by following the one step at a time strategy. Such a strategy emphasises the vital importance of learning by practical experience in a field which tends to be dominated by technological innovations. It is impossible to underestimate the impact that a modest demonstration project can have on raising overall levels of awareness in an agency and its value in highlighting the potential costs and benefits of further developments. By building up experience in this way many of the problems associated with a lack of an overall information strategy can be minimised and overall awareness within the organisation of the potentials and the limitations of computer technology is increased. Such an approach is also likely to help in exploiting the opportunities and countering the threat imposed by organisational and environmental change.

User participation in the design and ongoing development of computer based systems would appear to underlie these strategies and should be seen as the key to ensuring effective utilisation. Users are most aware of the organisational limitations that exist and the strengths and weaknesses of their environment in terms of resources and personnel. As organisational factors rather than technological issues are increasingly recognised as the critical constraint on computer usage it is vital that those with the fullest appreciation of their context and needs are involved. However, participation represents very much more than the consultation of users by technical staff through formal working parties. In calling for greater user involvement reference is not being made to this type of symbolic participation rather than to a situation which places potential users at the centre of the process and not the periphery. This type of approach obviously requires significant commitment as well as a willingness to take responsibility on the part of management and users. Management must encourage staff and be prepared to allocate time for their involvement in the development of automated systems. It will also be necessary for flexibility to be built into the work programmes of staff to enable the valuable process of informal learning in the workplace to occur which in many instances is more useful than attendance at official courses. A minimal strategy would appear to be the designation of an individual as intermediary, someone with experience of user needs as well as basic technical knowledge. If handled well user participation will help to diffuse the anxieties which lead to a lack of staff cooperation and in some circumstances to an active effort to impede system development. By involving staff at all levels a supportive environment should be created in much technical staff act as facilitators serving the needs of users. Time spent at the early stages of development should save resources later as well as ensuring the utilisation of systems by the individuals actually required to operate and use the technology.

There can be no guarantee that there will be effective utilisation of computers in urban planning agencies in developing countries unless the four conditions set out above are fully satisfied. However, given the suggestions that have been made in this section, it can be seen that a great deal can be done to increase the chances of effective utilisation even in agencies which cannot meet all these conditions.

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What is the next step? - training in information systems design.

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Abstract

For six years now I have run a course at University College London in computers for development planning, for five I've been involved in an M.Sc in information systems design and management and for the same period a undergraduate degree in computerised information systems at Kingston Polytechnic.

The rationale for the UCL course I've discussed recently in some detail[1] elsewhere but to summarise - it was that senior urban planners in developing countries should neither study a programming language nor advanced utilities in detail, but should gain a broad grasp of current information processing capacities - which has meant something like dBase and Lotus - and more importantly understand the processing of the information within their system as a social and management decision taking issue.

This argument was elaborated in my discussion of the Kingston Courses[2]
and how the question of the environment of information systems should be taught.

The broader issues of training I elaborated further in papers for the UNCRD[3] and the issues of training for urban settlement planners have been elaborated in a number of works by colleagues at the DPU[4]

In the meantime there has been considerable progress in geographic information systems[5] and in methods for information systems design[6]. What I want to dwell on here is what seems to me a problem in how these two worlds interface and the training implications. It appears that the mistakes of the past, of islands of automation in factories, are being repeated because people responsible for buying hardware and software for the setting up of geographic information systems are not paying sufficient attention to the information systems design aspects. In turn the developing countries angle needs to be restated as the level of computing competence increases and the availability of hardware and software increases, the capacity for design mistakes too increases.

Let me summarise the information systems design issues:

1) Do you automate what you are doing or what you ought to be doing?
2) What is the relationship between the strategy of the organisation and its information system strategy?
3) Which organisation or department is responsible for the information system strategy?
4) What is the relationship between the strategy, the architecture proposed for its achievement and the design process?
5) What is the relationship between the design and implementation of the system, over space and time, and related to the budget?
6) What are the factors of the environment which will affect the design?
7) What will be the effect of the implemented system on the environment and to what extent can this be modeled?
8) How do you design the interface between the analysis, design and implementation phases?
9) How do you design the interface between subsystems within a larger system?
10) How do you design the interface between the humans and the automated procedures?
11) How do you integrate the entity- relationship, data modelling, state transition modelling, object oriented and rule based approaches?

Now what are the implications of this for the design of a GIS? Let us start at the very beginning, with a point, "which has position and no magnitude". This point is the position of a cursor on a digitising tablet, of a cursor on a screen or of a dot on a dot matrix or ink jet printer for example. The position is defined by the co-ordinates and the resolution of the device. According to a second level of meaning, that defined by the system, the co- ordinates in turn relate to a real world entity instantiation for example on the digitising tablet the co- ordinates of the copper membrane map onto an overlay which define the co -ordinates as the centroid of an enumeration district for example. This point could in turn have an address - a post code or a building, or a city. The point, according to the scale within which the real world entity type and the system entity type map onto one another, could vary from the atomic to the astronomic. Within the sphere of GIS, we are probably concerned from the millimetre to the kilometre - from an electric cable to the significant land mass. (Though other systems based on GIS technology might be concerned at the biological, cellular or molecular, down to 10^{-10} then from the spatial up to the astronomical, say 10^{10}.)

A second point produces a line, a third a polygon, and a fourth a more complex polygon, including a third dimension. The line can be a street centre, a property boundary, the polygon an externality - three streets, or an internality, a property. That polygon may have a centroid, calculated by an algorithm, an area, calculated by another algorithm. The centroid, a point not created by digitisation but by calculation, could in turn be the statement of an address. The line could contain flow or capacity, for example in a pipe, calculated by another algorithm from an address contained elsewhere. Two points might define the ends of a set of points, but according to another address the contained points,. which might represent far from a straight line, will be represented by a straight line, because that is the content of that address at that level of aggregation.[7]

The polygon might at one moment be a property, but at another an enumeration district, the point at one corner might be at one moment the boundary of a property, the next of an enumeration district, the next of a city. The externality of two polygons might be the area of an enumeration district which is not in a post code district. This would have been calculated from a combination of an algorithm and a library of addresses, which we might call a procedure.

Some of these polygons could be stored as special procedures in libraries, from which they could be called up, as "houses" or "doorframes" or "dwelling for low income family" or "plotsize". These procedures in turn could be linked together according to the level of aggregation or disaggregation that a particular operation concerned itself with.

A special form of "point" would be the set which produces the alphanumeric character set. These would be "understood" by the computer on the basis firstly of a set of codes, ASCII for example, which govern their representation, then by a set of protocols which govern their handling (say for example a word processor which allow point size, bold, indexed, find, replace, spell check). or a set of protocols called algorithms or functions which handle their processing (say add, divide, square root, area, flow, greater than).

A more complex set of protocols would possibly define them as legitimate "words" from a dictionary, or capable of being parsed, as a result of which an approximation to natural language could be attempted. Some of these "sentences" could in turn be grouped into messages which could be called up as procedures, or "forms", for example planning application pro formas, which would link to committee agendas, to minutes and to site visits. Parts of these forms would produce fields of entity occurrences which would provide dates or times or places, which would take us back to the addresses of the earlier points. An address is at another level simply a set of fields within a database, but one of those fields could be a unique land identification number, which could link to the set of co- ordinates which defined that property, which linked to another database which defined the unique property indentification number, which in turn located the taxable value or the owner, which in turn could link to family data and so forth.

I'm presuming that the concept of normalisation and of tables are now common knowledge. Relational databases were in their time a step forward on hierarchical files. But the consequence of separating the data from the operations to be performed on it led to the possibility of nonsense occurring. The advantage of linking data sets and the operations to be performed on that data, as objects and object types with addresses is that not only can nonsense not be operated on data, but groups of sets of objects can be composed and decomposed at meta levels of the system.

In turn there is no reason why an object cannot contain a set of rules - conditions under which a set of procedures apply:

> **If** the PROPERTY is in ENUMERATION DISTRICT N **then** check whether it is a *LISTED BUILDING*. So we have entities called PROPERTIES and ENUMERATION DISTRICTS.

These have co- ordinates and relationships to addresses and owners. We have conditions, such as *LISTED BUILDING* which in turn have other rules such as the conditions which define a listed building, or rules on what an OWNER might not do to a listed building. Or these rules can trigger state transitions such as:

> **If** the APPLICATION has not been returned within n days **then** initiate COURT PROCEEDINGS.

A COURT PROCEEDING could in turn check whether that OWNER (for an APPLICATION can be returned only by an OWNER who must have a PROPERTY and all this is implied from the rules that link the objects at the meta object level) had other proceedings out against him. APPLICATIONS and COURT PROCEEDINGS are in turn objects which contain text which produce forms, fields, which draw data from data sets and initiate procedures.

There are now software packages which are capable of integrating these entity- relationship, object oriented and rule based approaches. They are still however quite expensive and tend to need to run on fairly expensive equipment. There are however packages which can achieve parts of this general picture, which can be integrated at the design level if the designer has a grasp of the general approach. Experience indicates that the drop in price of software and hardware is such that packages capable of producing usable results will be soon available. One must not wait for the desirable kit to being the planning process.

What lies behind all this rather long winded detail, is that the core digitised map data set, the set of co- ordinates by which features are recorded has the potential of more views on the data than possibly any other form of data with which we have had to deal before. The sheer quantity of data generated means that it is more likely that data will be bought and sold in a market, but that the originator of the data might not have recognised the value of the market, or the range of possible uses. The greater the extent his data is tied to particular machines or processes, the less the likelyhood that the market will be realised. In developing countries where the expertise is more rare and the capital equipment costs higher, the argument for avoiding waste by putting in place information plans which deal with the definition of these protocols and primitives and the functioning of this market is stronger.

We would want to touch on several other points on the particularlity of developing countries at this stage. The rate of change of information is very high. In Britain the number of people who change address, rates of birth and death, and so forth is all fairly predictable with the consequence that volumetrics for system design are not too complex. In many urban areas in developing countries it would be completely unrealistic to attempt data capture with the same level of granularity. But it is precisely in the developing countries that there is a tendency to increase the centralisation of the data processing procedures. The contrary ought to be clear: distribution of processing to a disaggregated level at which the decision has to be taken and aggregation only of results which are required for higher levels of decisions.

The costs of data collection and organization are higher as a result of a shortage of skilled persons, larger distances and lower transport infrastructure facilities. We are short of comparative analyses of project costs so hard evidence for these propositions cannot be provided. But again the decisions appear clear: we are accustomed to working with dirty or unreliable data, and under these circumstances heuristics are more reliable than algorithms.

But most difficult of all is the organisational complexity consequent on sharing data sets. In Britain the combination of British Telecom, the Water Authorities, Electricity supply, Post Office, public health, census, birth and deaths registration, motor vehicle licence, drainage, to mention but a few, show both how interdependent organisations might be on one another, and how waste through bureaucracy is a matter of little concern to their planners and managers. Yet the very argument about information *systems* makes possible the argument that a market in information will come into being

This organisational complexity is mirrored in the complexity of the decision taking process. Information systems either engage in transaction processing, where systematisation in intended to reduce costs, or in decision support, where the consequences of systematisation is intended to improve effectiveness. If the transaction processing systems are not capable of producing information which is both reliable and capable of being aggregated to the right levels of granularity there is no possibility if decisions based on that data being useful. Yet the introduction of such systems requires precisely the attention to detail which senior planners are unprepared to make. The idea that clerical work is below them is only partially counteracted by the supposed sexiness of the computer.

A less important factor but often commented on is the absence of an adequate telecommunications infrastructure allowing for effective networking. A distinction needs to be made between local area networking within one building which requires no communication across space not under the control of that organisation, and wide area networks which require interfacing more than one organisation. It needs to be born in ind that other than when issues are time critical, on- line interaction or file transfer is not essential. Data may be communicated via disks in the post or by systematic delivery.

So we return once more to the issue of training in information systems design, which increasingly seems to me to be a different issue from either "computers" or the "use of computers in"[8]. It in turn must cut with the specific domain, which raises the issue of the background discipline of the practitioners. The experience of the DPU course is that regional or cultural difference, differences in seniority and experience of information processing technology, difference in background - engineer, architect, economist for example, are enough for it to become difficult for a course to gel. The divisions of urban planning, housing policy, transport planning, and so forth are so great that to get people to grasp the level of integration or interfacing which becomes necessary is hard. In turn it is necessary to confront the organisational weakness or political weakness which prevents any single body having the influence to undertake the co- ordination necessary. Finally there is the issue of the personal and political freedoms of the dwellers of the area being planned, for whom co- ordination of information at this level well might prove a threat.

There is still, I think, a role for a one month course for senior planners, three month courses of the sort funded by the British Council and one year M.Sc. level courses. Each of these courses needs to include hands on experience of the basic applications still if not known, (such as Lotus and dBase) though increasingly I think this should be done in country and not part of a course such as that I'm considering. This will probably come to include the study of GIS software packages such as Arc Info Secondly a consideration of the information necessary for decision taking, its sources, organisation and presentation. Thirdly a study of systems, best done by looking at working ones and working on a project involving change in their own environment. Fourthly a study of the relationship between the design of the information architecture (as I've discussed above) and the technology architecture (which I've not dealt with in this paper at all, but which includes the capture, storage, processing, retrieval and communication of informaiton), which must be linked to budgeting and project management. Fifthly the study of a structured systemic approach to analysis and design, along with an introduction to one of the tools. CASE tools linked to project management tools are likely to form the basis on which the GIS sits. The ESPRIT RUBRIC project results might be an indicator of what these will look like.

Which parts of this are best studied in country, which in a regional centre of excellence and which best studied in an aid donor country must be dependant on factors outside this paper: levels of infrastructural development, levels of training capacity, project definition, aid- funding policy, manpower planning policy.

What I'm suggesting here on the integration of geographic information systems and information systems design is not yet achievable, partly because the technology is not yet up to it, but much more because the organisational issues impede. The training of a layer of professionals who are capable of integrating the policy decisions with the information on which that policy is formulated and evaluated is immediately necessary and to that question training and aid bodies should address their attention.

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[2] Teaching the environment: problems of addressing management issues in information systems design. Kingston Polytechnic. School of Information Systems. Research Report 88-1.
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[4] Wakely, Pat. International strategy for human settlements training in developing countries. Nairobi: UNCHS, 1987 and Mumtaz, Babar. Housing finance policy training manual. London: DPU, 1989.

[5] In Britain the key point is probably the Chorley report: Handling geographic information. London: HMSO, 1987. Various journals such as Mapping Awareness, Computers, environment and urban systems, Geographic information systems, BURISA newsletter comment on developments.

[6] see for example Olle, T.W. et al. Information systems methodoligies. Wokingham: Addison- Wesley, 1988.and the Proceedings of IFIP WG 8.1. Sesimbra, 1989.

[7] I don't want to touch here on whether the data sets are acquired by digitisation, remotely sensed data, ariel photography, survey or whatever - these techical questions are dealt with at length elsewhere. I'm using the term digitisation in the sense of turning into 0 and 1 finally.

[8] I've been forced to this conclusion while writing the opening paper for the British Computer Society colloquium on training in July 1989 in London. Proceedings forthcoming.

COMPUTER GRAPHICS PRIMER
THE INTRODUCTION OF COMPUTER TECHNIQUES IN TEACHING PLANNING GRAPHICS

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ABSTRACT

This paper reports on the planning aspects of recent applied research into the teaching of graphics in architecture, building and quantity surveying, and planning courses. The focus of the research was to identify the aspects of introductory graphics units which could be undertaken using computers and user friendly software.

A fundamental categorisation of knowledge, skills and standards was developed for the analysis of traditional and computer aided, graphics. Knowledge includes the subject matter of formal and informal graphic production. Skills include sketching techniques for informal graphics, and line drawing techniques for formal graphics. Standards include Australian Standards and locally accepted means of graphic representation.

Common aspects of graphics for architecture, building and quantity surveying and planning, were identified and particular needs of each discipline. Traditional graphic methods were compared with computer aided methods to assess the relative suitability and ease of introduction of computers.

A questionnaire was distributed to the graphics unit instructors and professional offices. The offices were a sample of large, medium and small firms, as well as those known to be using computers. The questionnaire responses suggested: useful expansion of the scope of the graphics syllabi; desirable common and particular areas of knowledge, skills and standards; and, areas where computers could replace, or supplement, traditional graphic methods.

New syllabi, a common syllabus and a particular syllabus for each discipline, were classified in terms of two dimensional and three dimensional knowledge, skills and standards. Computer graphic exercises and commons were consolidated incorporating the necessary graphic techniques for each discipline. The relevant hardware and software were identified, giving particular attention to the degree of difficulty for an inexperienced user.

A SYSTEM DYNAMICS MODEL OF URBAN LAND USE "TUDY": A COMPUTER AIDED EDUCATION PROGRAMME FOR URBAN PLANNING, AT UNIVERSITY OF TSUKUBA

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INTRODUCTION

This paper will discuss the computer aided education programme for urban planning, which is currently operated in a workshop course at the Department of Socioeconomic Planning, University of Tsukuba. The System Dynamics Model, named "TUDY" (Tsukuba Land Use Dynamics), for forecasting the future land use pattern in an urban area was first developed in 1982 as a computer package programme for a workshop exercise. This programme has been revised every year through the practical course operation and become sophisticated as a comprehensive training tool.

FUNCTION OF THE MODEL

On the basis of initial condition of a city which is divided into twenty zones, the model estimates the future state of the city in each zone, and outputs the followings:

- The proportion of residential area;
- The proportion of commercial area;
- The proportion of industrial area;
- The proportion of land for public use;
- The proportion of agricultural land;
- Land price; and
- Environmental indicators such as overcrowdedness, pollution, and urban service.

For its operation, exogenous variables such as the population and the number of employees in the secondary and tertiary sectors in the city are provided as a control total. With regard to policy alternatives to be experimented, the following development plans and projects can be inputted in the model as zone-wise data:

- Demarcation between the developable and undevelopable area;
- Land use zone;
- Residential area development project;
- Land readjustment project;
- Transportation network improvement; and
- Construction of urban facilities.

The input data of these project options should be prepared on the digital basis including total area, the number of facilities, and the size of projects.

TRAINING CURRICULUM

As mentioned above, the "TUDY" is practically used in urban planning courses, at the University of Tsukuba. Three-hour classes for the workshop on computer aided planning meet twice a week for ten weeks. Six to eight students per group work cooperatively in the workshop to train themselves in making a master plan proposal.

Working schedule consists of three stages as indicated in Table 1. In the first stage, after initial arrangement and orientation on the course outline, students start to collect data and identify problems to be solved examining the present condition of a study area. These works are summarized into a proposal of their final goals.

In the second stage, practical exercise with computer operation is scheduled so that students can master the use of "TUDY". Students try a basic run without using a project, but are encouraged to input a couple of arbitrary projects in the model so that they can grasp a clear idea of the characteristics of the model behaviour.

In the third stage, students start preparing a master plan. The future demands for public services and facilities such as schools, parks, and utilities are estimated based on the basic run in the second stage. All project components are then integrated into a plan and simultaneously inputted to the model to forecast the future land use pattern. Results will be evaluated on whether or not the original goals are achieved. If the result is not acceptable, the plan will be revised. Through such iterative works, a final plan will be proposed. This planning process will be presented at the final class.

STRUCTURE OF THE MODEL

The model consists of the following eight sub-sectors:

- Sector for estimating demands for land;
- Environmental sector;
- Housing location sector;
- Commercial location sector;
- Industrial location sector;
- Population sector;
- Sector for adjusting plan and project alternatives to the model structure; and
- Sector for revising planning components.

The causal diagram of each sector is shown in Figure 1.

Table 1. Working Schedule for Workshop

Stage/Week	Objectives/Contents
1st Stage	Objective: Introductory Arrangement
1st Week	Basic data collection Examination of the present condition
2nd Week	Problem identification Goal formulation
2nd Stage	Objective: Computer Model Exercise
3rd Week	Studying the model structure
4th Week	Arrangement of input data
5th Week	Computer operation (Basic run)
3rd Stage	Objective: Master Plan Formulation
6th Week to 9th Week	- Estimation of demands for public services and facilities such as schools, parks, and utilities. - Formulation of master plan. - Forecasting the future land use pattern. - Evaluation of results
10th Week	Final presentation

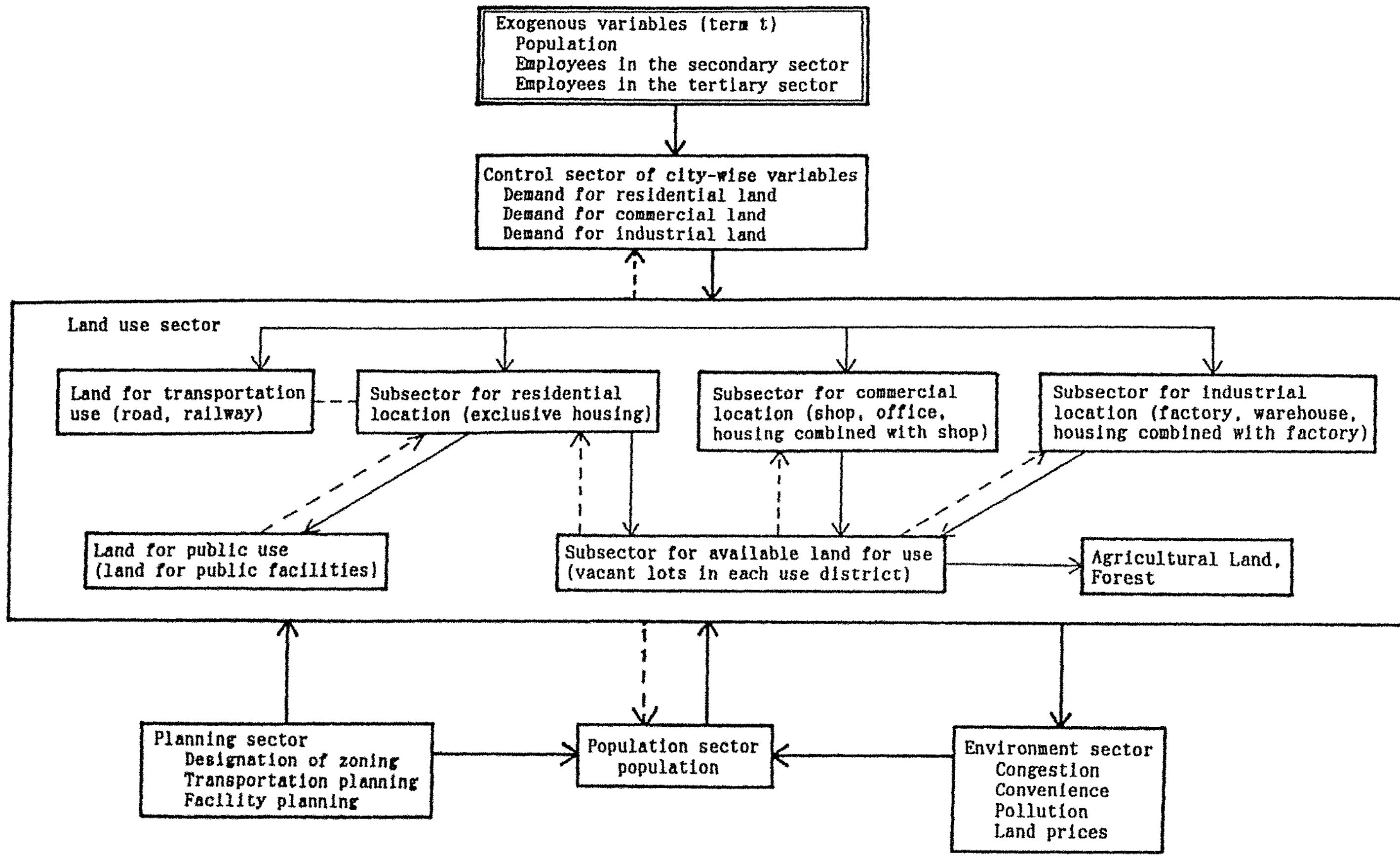


Figure 1. Casual Diagram

First, from exogenous variables such as population and employment structure, city-wise locational demand for various activities will be presented in the form of building floor area and land area. Secondly, the demand calculated will be allocated to each zone by applying locational attractiveness function which is defined by factors in each zone such as land prices, living environment conditions, land use control, available land area, and degree of concentration. Thus, land use pattern based on building and land area can be determined. With regard to population, building location can be directly connected with population location in case of houses for combined uses. In case of houses for exclusive use, the following procedure to determine population will be applied: a) On supply side, newly constructed houses will be temporarily registered on vacant house list; b) on demand side, vacant houses will be chosen by the selective function which consist of three variables such as distance from a station, price of the house, and environmental conditions; c) population will move into vacant houses; and d) the population moved in will be added to the population in the zone. Accordingly, final demand for housing can be separated from that of land developers. This procedure will also be able to present the situation of large-scale housing development in urbanization control area as well as the actual condition of vacant houses, difference between building density and population density.

When land use pattern and population are determined, they will influence the condition of living environment such as amenity, convenience and pollution index, and will change the function of location attractiveness, which will consequently be fed back to decision-making of land use pattern after the next term.

Exogenous factors such as land use control and facility arrangement planning will define the location function, and directly affect land use pattern and living environment including urban development projects, construction or improvement of urban facilities.

STRUCTURE OF LOCATION FUNCTION

Formularization of the function differs from one locational activity to another. The following three factors, however, are core elements:

- Land use control and land available for use;
- Location attractiveness (living environment, agglomeration); and
- Land prices and index of affordable land prices.

Land Use Control and Land Available for Use

First, a function will be formulized to show how much land is available in each zone for each land use category. Table 2 shows classification of land use categories.

According to this classification, land available for use seems to be either agricultural land, forest, land for other uses or undeveloped land. Besides, there are unused lots in residential land. Density will increase when these lots are devided into smaller lots.

Table 2. Land Use

Category	Symbol (area)
Land for housing	ALB
- Restricted residential land	ALH
- Commercial/residential land for commercial use	ALC
- Industrial/residential land for industrial use	ALI
Land for public use	ALG
- Roads and other land for transportation use	ALT
- Land for public facilities	ALP
Agricultural land and Forest (including residential land for agricultural use)	ALF
Land for other uses (rivers and marshy land)	ALO
Undevelopped land (parking, vacant land, etc.)	ALV
Total area	AL

Not all of land availble can be utilized for each activity. Possibility for utilization depends on zoning control placed on the land. For example, rates for locational possibility in each zone for different activities are defined as shown in Table 3, where α_{lk} indicates a rate for possibility for location activity (l) in use district (k). Because of the rough calssification of location activities, α_{lk} tends to be a rate which restrict types of activities. However, it indicates a rate for development permit in an urbanization control area.

Table 3 shows location controls. They are simplified, although they seem to be more restrict than actual. Therefore, we must be aware that the effect of these controls appears more intensively.

In identifying land available for each activity, it is necessary to make clear in what zoning the land exists. Land avalable in differnet zoning (V_{ik}) can be obtained from the following equation, after collecting data on land use category in each use district by applying a matrix shown in Table 4: 1/

$$V_{ik} = \Sigma_{j=1,8}\, \delta_{ij} * L_{ijk} \qquad (1)$$

subject to: $\delta_{i1} = \delta_{i2} = \delta_{i3} = V_i$
$\delta_{i4} = \delta_{i5} = 0$
$\delta_{i6} = \delta_{i8} = 0$
$\delta_{i7} = w$

where V_{ik} is land available in zone (i), use district (k); δ_{ij} is a rate of land available in land use category (j); and L_{ijk} is an area in zone (i), use district (k) and land use category (j) (Table 4).

Table 3. Rates for Locational Possibility in each Zone

Activities (1) / Zoning (k)		Residential Location: Detached House (1)	Residential Location: Apartment House (2)	Commercial Location: Shops and Dwelling Combined (3)	Commercial Location: Office (4)	Industrial Location: Small Factory & Dwelling Combined (5)	Industrial Location: Large Factory (6)
Urbanization Promotion Area Exclusive Residential Zone							
Category I	(1)	1.0					
Category II	(2)	1.0	1.0				
Residential Zone	(3)	1.0	1.0	α_{33}	α_{43}		
Commercial Zone Neighbourhood	(4)	1.0	1.0	1.0	1.0	α_{54}	
Commercial	(5)	1.0	1.0	1.0	1.0	α_{55}	
Quasi-industrial Zone	(6)	1.0	1.0	α_{36}	α_{46}	1.0	α_{66}
Industrial Zone/Exclusive Industrial Zone	(7)					α_{57}	1.0
Urbanization Control Area Land for Non-agricultural Use	(8)	α_{18}	α_{28}	α_{38}	α_{48}	α_{58}	α_{68}
Agricultural Land in Agricultural Promotion Area	(9)						

Note: α_{lk} can be regarded as a rate of development permission in case of l= 2, 4 and 6 in Urbanization Control Area, and in case of l=1, 3, and 5 on buildings outside of permission.

Table 4. Land Use Category in Each Zone

Zoning (k)		Urbanizing Promotion Area							Urbanization Control Area	Rate of land Available for Use
		Exclusive Residential Zone: Category I/Category II		Residential Zone	Commercial Zone: Commercial Zone	Neighbourhood Commercial Zone	Quasi-industrial Zone	Industrial Zone	Land Excluded Farmland	
		(1)ZHA	(2)ZHB	(3)ZHG	(4)ZCN	(5)ZCC	(6)ZIS	(7)ZII	(8)ZR	δ_j
Land Use Category (j)										
Land for Housing	/ ALB									
Exclusive Residential Land	(1)ALH	L_{11}	L_{12}	L_{13}				L_{17}	L_{18}	v_1
Commercial Land/Residential Land Combined with Commercial Use	(2)ALC	L_{21}	L_{22}					L_{27}	L_{28}	v_2
Industrial Land / Residential Land Combined with Industrial Use	(3)ALI	L_{31}							L_{38}	v_3
Land for Public Use	/ ALG									
Land for Transportation Use	(4)ALT									0
Land for Public Facilities	(5)ALP									0
Agricultural Land and Forest	(6)ALF									1 0
Land for Other Uses	(7)ALO	L_{71}	L_{72}							1.0
Undeveloped land	(8)ALV	L_{81}	L_{82}					L_{87}	L_{88}	w
Land Available in Each Use District		V_1	V_2	V_3	V_4	V_5	V_6	V_7	V_8	

Note: Agricultural lands in agricultural promotion area in urbanization control area are excluded as they cannot be converted into other uses.

V_i indicates the rate of aforementioned potential vacant land in resiential land. For example, it can be defined as the table function shown in Figure 3, by relating it with population density Pd_i. w indicates the rate of land available in land for other uses.

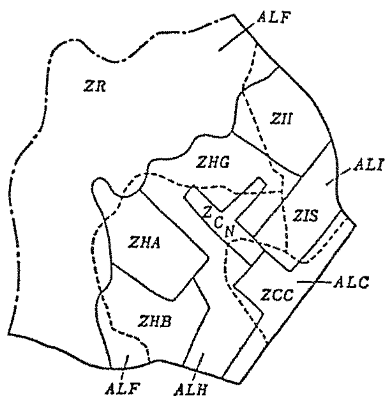


Figure 2. An Example of Classification of Land Use in Zone (i)

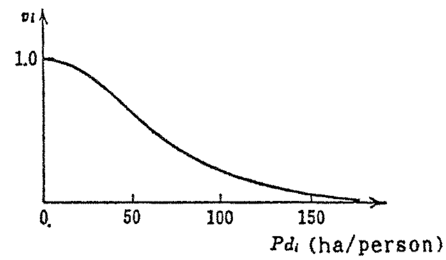


Figure 3. Rate of Potential Vacant Land

Accordingly, land available for each activity in zone (i) AV(l) can be described by using Table 4 and the effect of location control in use district can be presented by the following formulas:

$$AV_{il} = \Sigma_{k=1,8} X_{ikl} \quad (2)$$

$$X_{ikl} = \alpha_{lk} * V_{ki} \quad (\text{assumed } 0 \leqq \alpha_{lk} \leqq 1) \quad (3)$$

where AV_{il} is total land available in zone (i) by activity (l); X_{ikl} is potential land which can locate activity (l) in use district (k) in zone (i); and α_{lk} is the potential rate of location for activity (l) in use district (k) (Table 4).

Location Attractiveness

Regarding housing, attractiveness for location includes living environment condition (EL) and degree of maturity as residential area (MH) as shown in Figure 4. The degree of maturity is one of the attractiveness for concentration and presents condition of social unity such as neighbourhood relationship. There are various factors which influence the condition of living environment. Figure 4 shows the most typical factors. In accordance with Figure 4, an example of attractiveness function is formularized.

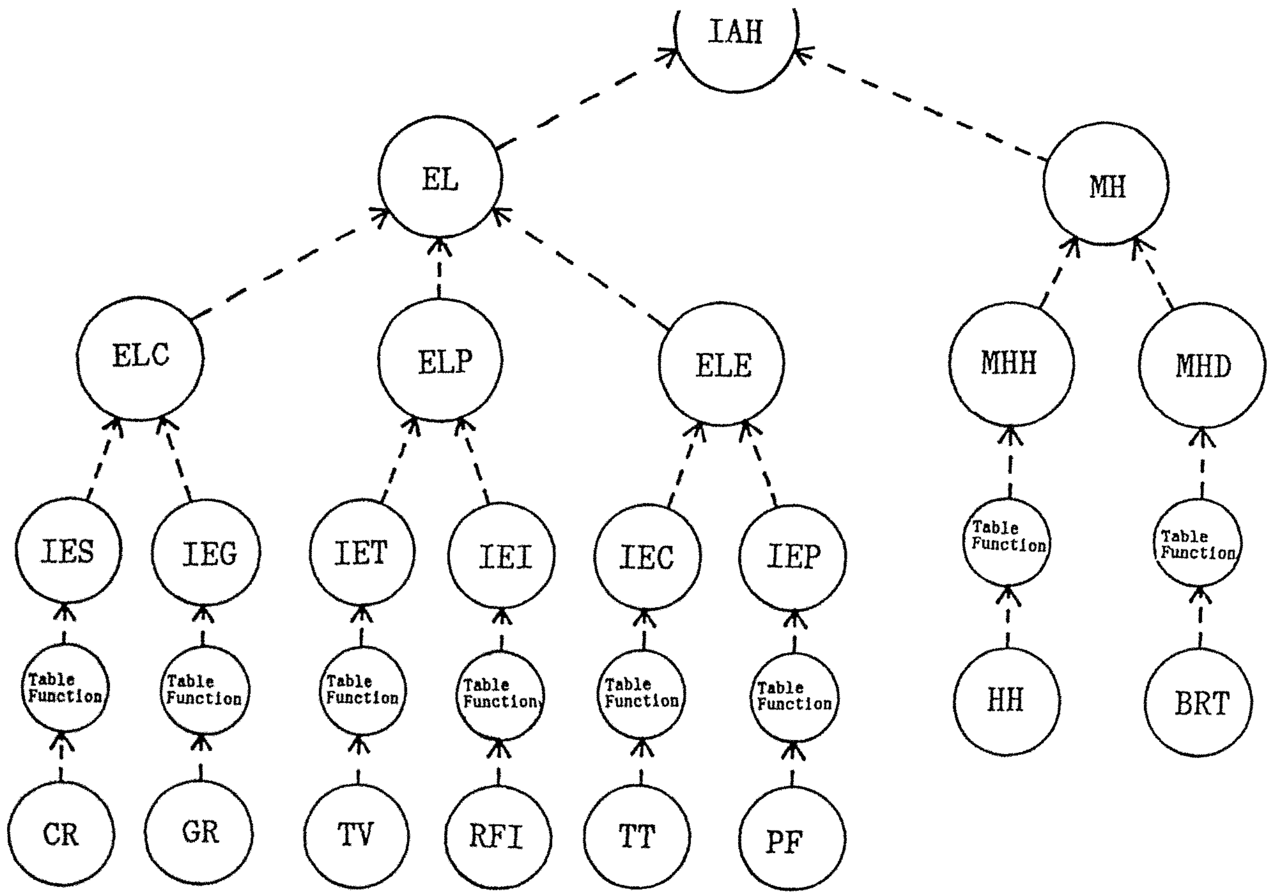


Figure 4. Structure of Attractiveness for Residential Location

$$
\begin{aligned}
IHA_i &= \beta * EL_i + \gamma * MH_i & (\beta + \gamma = 1) \\
EL_i &= \beta_1 * ELC_i + \beta_2 * ELP_i + \beta_3 * ELE_i & (\beta_1 + \beta_2 + \beta_3 = 1) \\
ELC_i &= \beta_{11} * IES_i + \beta_{12} * \mathrm{IEGi} & (\beta_{11} + \beta_{12} = 1) \\
IES_i &= TABLE(CR_i) \\
IEG_i &= TABLE(GR_i) \\
ELP_i &= \beta_{21} * IET_i + \beta_{22} * IEI_i & (\beta_{21} + \beta_{22} = 1) \\
IET_i &= TABLE(TV_i) \\
IEI_i &= TABLE(RFI_i) \\
ELE_i &= \beta_{31} * IEC_i + \beta_{32} * IEP_i & (\beta_{31} + \beta_{32} = 1) \\
IEC_i &= TABLE(TT_i) \\
IEP_i &= TABLE(PF_i) \\
MH_i &= \gamma_1 * MHH_i + \gamma_2 * MHD_i & (\gamma_1 + \gamma_2 = 1) \\
MHH_i &= TABLE(HH_i) \\
MHD_i &= TABLE(BRT_i)
\end{aligned}
\qquad (4)
$$

IAH: Attractiveness for residential location
EL : Environment condition
MH : Degree of maturity as residential area
ELC: Amenity
ELP: Health
ELE: Convenience
MHH: Degree of exclusiveness for housing
MHD: Degree of development
IES: Sunlight index
IEG: Business index
IET: Transportation pollution
IEI: Industrial pollution
IEC: Accessibility to CBD
IEP: Degree of convenience to facilities
HH : Rate of houses for exclusive use
BRT: Rate of land for housing
CR : Coverage ratio
GR : Green area ratio
TV : Total milage
RFI: Rate of industrial floor area
TT : Time needed for Transportation
PF : Rate of facilities provided

Shape of each table function is shown in Figure 5 (example of Tsuchiura-shi). Because the shapes differ for city by city, not only parameters of above equations should be decided but trial and error including sensitivity analyses is necessary.

Regarding attractiveness for commercial location, it may be enough to consider market accessibility and attractiveness for concentration (Figure 6). However, problem remains in determining the extent of trading area for market accessibility. If the model includes only one city, accessibility should be determined by regarding the whole city as a market, because it is impossible to take into account all the market outside the city. For purchasers from other cities, because they can be considered as passengers getting on and off at major stations, accessibility to the market can be regarded equal to accessibility to those stations.

$$IAC_i = \phi_1 * DM_i + \phi_2 * MC_i \qquad (\phi_1 + \phi_2 = 1)$$
$$DM_i = \phi_{11} * DMP_i + \phi_{12} * DMS_i \qquad (\phi_{11} + \phi_{12} = 1)$$
$$DMP_i = TABLE(PP_i)$$
$$DMS_i = TABLE(D_{i i_0}) \qquad (5)$$
$$PP_i = \Sigma_{i'=1,n} \frac{P_i}{D_{ii'}^2}$$
$$MC_i = TABLE(AFC_i)$$

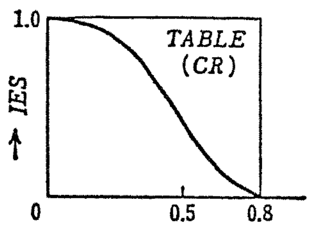
IAC_i : Attractiveness for commercial location
DM_i : Attractiveness for market accessibility $(0 \leqq DM \leqq 1)$
MC_i : Attractiveness for concentration $(0 \leqq MC \leqq 1)$
DMP_i : Attractiveness for market accessibility in a city
DMS_i : Attractiveness for market accessibility in other cities
PP_i : Market accessibility in a city
$D_{ij'}$: Distance between zones (i_0 shows a zone which has a major station)
$P_{i'}$: Population in zone (i')
AFC_i : Commercial floor area in zone

Regarding attractiveness for industrial location, location of large factory and that of small factory combined with residential use should be considered separately because the need for their location is totally different. (Figure 7). In case of large factories, locational factors are: level of supply and treatment facilities (U) provided such as water service for industrial use and convenience of sewage; and accessibility to main road/railway to deliver materials and products (DR). On the other hand, for small factories, accessibility to market (household consumption) (DIP) is an important factor for individual service factory. For factories depending on subcontract among those in the same trade, degree of concentration (AFI) is important.

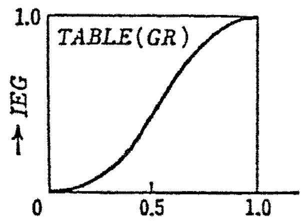
Formularization of the above can be as follows:

$$IAIL_i = \rho_1 * UI_i + \rho_2 * DRI_i \qquad (\rho_1 + \rho_2 = 1)$$
$$UI_i = TABLE(U_i)$$
$$DRI_i = TABLE(DR_i)$$
$$IAIS_i = \sigma_1 * DIP_i + \sigma_2 * MI_i \qquad (\sigma_1 + \sigma_2 = 1) \qquad (6)$$
$$DIP_i = TABLE(P_i)$$
$$MI_i = TABLE(AFI_i)$$

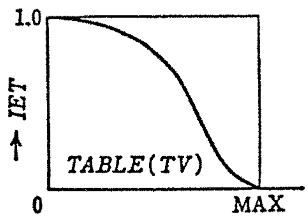
IAIL: Attractiveness for large factory location
UI: Attractiveness for provision of supply and treatment facilities
DRI: Attractiveness for accessibility to trunk transportation network
U: Level of provision of supply and treatment facilities
DR: Distance from trunk transportation network
IAIS: Attractiveness for small factory location
DIP: Attractiveness for accessibility to market
MI: Attractiveness for concentration



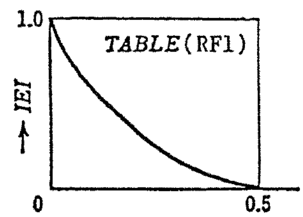
Coverage Ratio (CR)



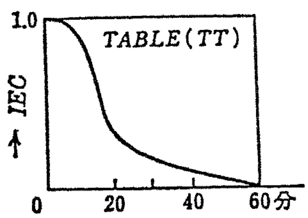
Green area Ratio (GR)



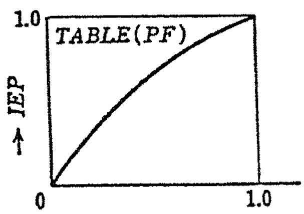
Total Milage (TV)



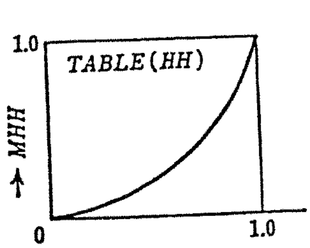
Rate of Industrial Floor Area (RFI)



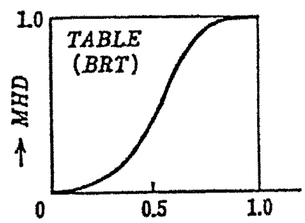
Time Needed (TT) for Transportation



Rate of Provision of Facilities (PF)



Rate of Houses for Exclusive Use (HH)



Rate of Land for Housing (BRT)

Figure 5. Table function of attractiveness for residential location

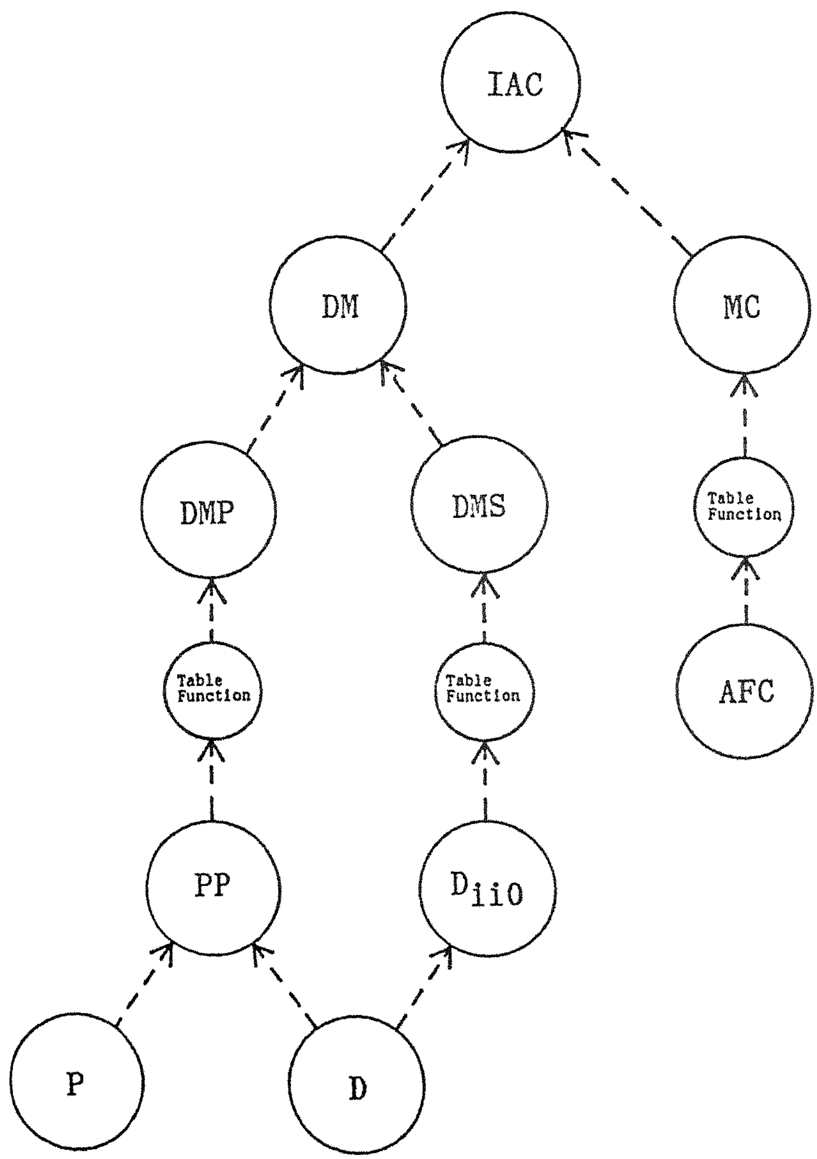


Figure 6. Attractiveness for Commercial Location

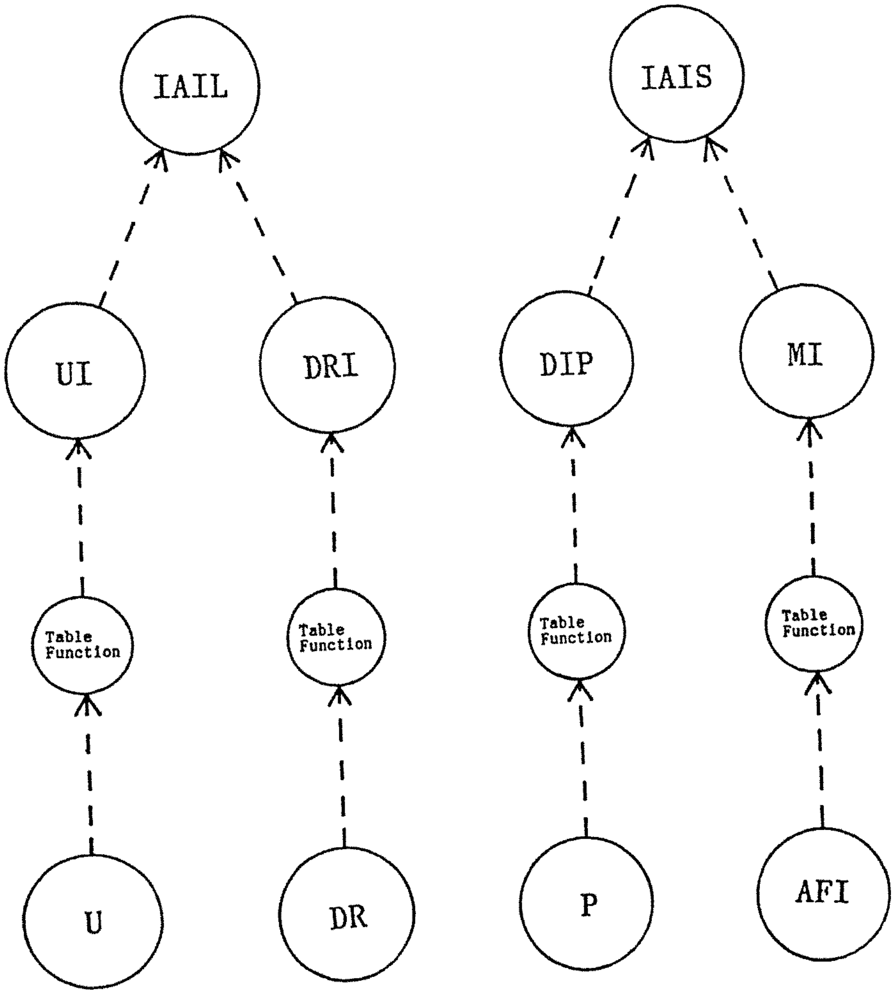


Figure 7. Attractiveness for Industrial Location

Land Prices and Affordability for Land

This section explains how land prices are described, how land prices correspond to land available in use district and attractiveness for location in formulating location function. Mechanism of change in land prices, however, will not be considered here.

In a general zone-wise distribution model, one land price is set to one zone as an average land price. Therefore, difference of land prices in one zone cannot be shown. This indicates that there is an assumption that difference among zones is much larger than that within the zone However, land prices actually vary in a zone which consists of different land uses such as commercial, residential and agricultural land. Therefore, averaging the land prices or choosing one land price for major use in a zone may result in lacking consistency with precise formularization of zoning. If this is the case, this model may lose accuracy as a model to simulate formulation of land use policy in an urban area.

A land available for an activity location can be given in each use district in a zone as X_{ikl} by the equation (4). Land price is indicated as LP_{k} in each use district.

It is not easy to collect data on land prices in each small zone and in each use district from general data. Data on land prices, either collected from declared value or standard price, are based on the prices observed only at limited districts in residential or commercial area. Therefore, it is necessary to supplement the data on prices with data on street values or by identifying similarity patterns.

On the other hand, every activity has a limit in their affordability for land because of budget constrain. This limit of affordability is shown as LP_l .

By applying interrelationship between land prices and affordability, the following equation can be defined:

$$\Delta_{ikl} = \begin{cases} 1 & (LP_{ik} \leqq LP_l^{\cdot}) \\ 0 & (LP_{ik} > LP_l^{\cdot}) \end{cases} \quad (7)$$

where Δ_{ikl} is a dummy variable indicating whether or not activity (l) can be located in use district (k) in zone(i) when land prices are fixed.

Three factors defined above can be integrated as control totals. A location function distributing demand for location of each activity (l) (DM_l) in each zone of the city can be defined as follows:

Location Potential

$$L_{il} = Z_{il} * \Sigma_k \frac{\Delta_{ikl} * V_{ikl}}{LP_{ik}} \quad (8)$$

Location (Distribution) Function

$$F_{il} = \frac{L_{il}}{\Sigma_i L_{il}}$$

where Z_{ij} indicates aforementioned attractiveness for location.

The equation (8) shows that activities will select zones with larger attractiveness and cheaper land price in land available for location within their affordability. Volume of location can be calculated with the following:

$$\Delta AL_{ij} = DM_j * F_{ij} \tag{9}$$

subject to:

$$\Delta AL_{ij} \leqq AV_{ij}$$
$$\Sigma_j \Delta AL_{ij} \leqq \Sigma_k V_{ki} \tag{10}$$

EXAMPLE OF APPLICATION: K-SHI IN CHIBA PREFECTURE

Figure 8 shows an example of the result of the model operation. This model operaton aims to forecast future population distribution in each district and change in land use pattern, after a waste incineration plant is newly located. Attractiveness function for residential location described in Figure 5 is modefied by taking into account deterioration of amenity with emergence of a disturbing facility and affect on health by SOx produced in the plant.

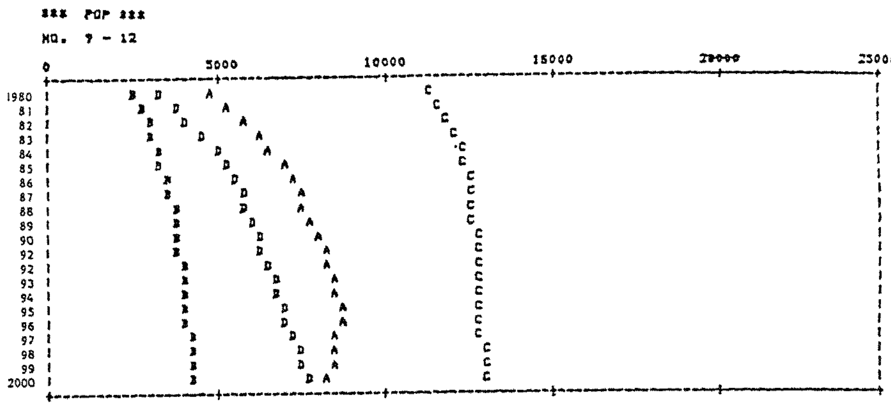
Figure 8 shows population (POP), land use (LNDU), pollution (POL), living environment condition (EL) and land prices (YLP) in zone No.9 where the plant will be located and in the zones (No.10-12) around zone No.9. It shows that population growth and land price increase are suppressed in zone No. 9 compared with other zones.

CONCLUSION

Urban planning is a very complex work. It needs an integration of tremendous number of components as well as estimation of future condition influenced by them.

Use of a computer model should , therefore, be encouraged in urban planning. Needless to say, the model can only deal with a partial number of factors in an abstract manner and, therefore, can be applied to a limited process of decision making. It is obvious that the applicability of the model to planning process must be remarkably increased if the model can cover as many components as possible. However, it is not easy to develop such a comprehensive and practical model to include many factors. This is because the more components a model covers, the more difficult it becomes to prove the causal relations and the less valid the model becomes. Making a model more comprehensive as well as practical often goes opposite from making it valid and scientific.

The model proposed in this paper is not an exception. Although some important elements inputted in the model such as population based on the past data are valid, individual causal relations remain unproved. They are gradually adjusted with experiences so that the total balance of output is achieved. As a training tool, it works reasonably and contributes to students to give an insight into their planning exercises.

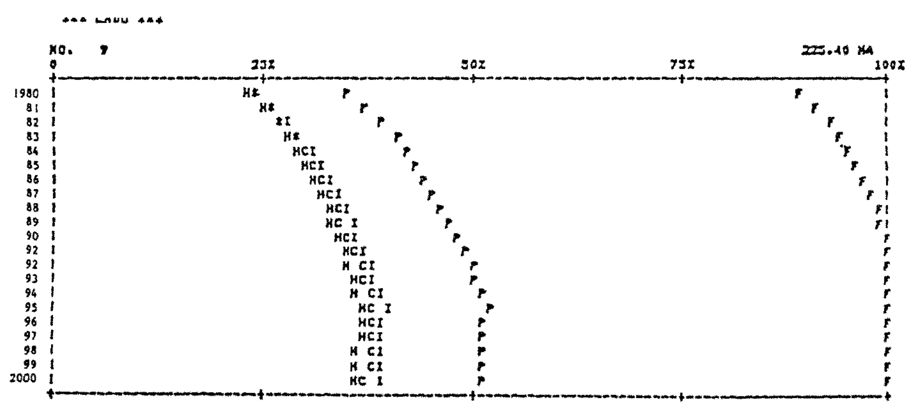


	A	B	C	D
1980	4726.	2303.	11347.	3273.
81	5479.	2772.	11693.	3815.
82	5938.	3083.	11918.	4234.
83	6353.	3203.	12129.	4635.
84	6749.	3390.	12327.	5017.
85	7003.	3494.	12421.	5267.
86	7277.	3611.	12533.	5535.
87	7512.	3703.	12615.	5764.
88	7727.	3784.	12684.	5973.
89	7902.	3842.	12724.	6144.
90	8077.	3900.	12745.	6314.
92	8251.	3938.	12808.	6483.
92	8403.	4006.	12837.	6633.
93	8559.	4034.	12867.	6782.
94	8712.	4103.	12898.	6930.
95	8858.	4153.	12930.	7077.
96	8783.	4204.	12964.	7223.
97	8708.	4235.	12998.	7367.
98	8634.	4306.	13034.	7510.
99	8560.	4339.	13072.	7651.
2000	8487.	4377.	13074.	7773.

Figure 8 (a). Population Change in Zone No.9, 10, 11, and 12

Note: A: Zone No.9
B: Zone No.10
C: Zone No.11
D: Zone No.12

Population in Zone No.9 decline from year 1995.

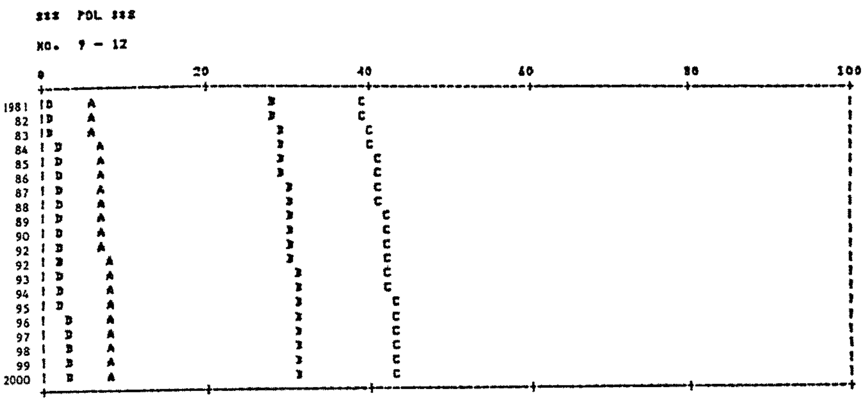


	H	C	I	P	F
1980	22.97	0.30	0.22	10.89	34.14
81	23.86	0.39	0.38	11.03	33.92
82	27.22	0.44	0.30	11.14	33.73
83	28.58	0.57	0.41	11.24	33.31
84	29.87	0.70	0.72	11.34	33.12
85	30.76	0.78	0.77	11.41	33.10
86	31.70	0.84	0.84	11.49	33.85
87	32.52	0.92	0.92	11.34	32.42
88	33.29	1.00	0.97	11.42	33.40
89	33.93	1.07	1.01	11.48	32.22
90	34.36	1.13	1.03	11.72	31.46
92	35.28	1.20	1.09	11.77	30.42
92	35.78	1.27	1.13	11.84	49.31
93	36.33	1.23	1.16	11.90	47.48
94	36.72	1.37	1.17	11.73	48.49
95	37.49	1.39	1.19	12.00	47.98
96	27.31	1.39	1.19	12.08	48.37
97	37.13	1.39	1.19	12.09	48.13
98	36.72	1.37	1.19	12.00	48.42
99	36.78	1.39	1.19	12.09	48.41
2000	36.68	1.39	1.19	12.09	48.42

Figure 8 (b). Change in Land Use Pattern

Note: H: Residential Land
C: Commercial Land
I: Industrial Land
P: Public use Land
F: Agricultural Land

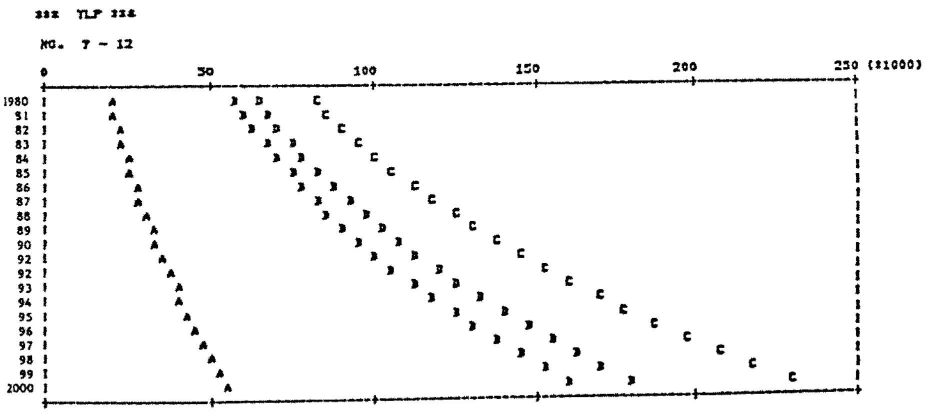
After year 1990, there will be no land for other uses.



	A	B	C	D
1981	6.30	28.13	39.02	1.55
82	6.42	28.45	39.73	1.78
83	6.65	29.03	40.26	1.95
84	7.08	29.39	40.70	2.12
85	7.31	29.74	41.14	2.27
86	7.44	29.94	41.40	2.37
87	7.58	30.17	41.68	2.47
88	7.70	30.36	41.90	2.56
89	7.80	30.33	42.11	2.44
90	7.88	30.46	42.27	2.70
92	7.96	30.80	42.44	2.76
92	8.04	30.93	42.62	2.82
93	8.11	31.05	42.76	2.87
94	8.18	31.17	42.90	2.93
95	8.23	31.29	43.04	2.98
96	8.25	31.42	43.17	3.04
97	8.25	31.55	43.31	3.07
98	8.23	31.68	43.45	3.13
99	8.23	31.82	43.60	3.21
2000	8.23	31.95	43.74	3.27

Figure 8 (c). Change of Pollution Index in Zone No.9, 10, 11 and 12.

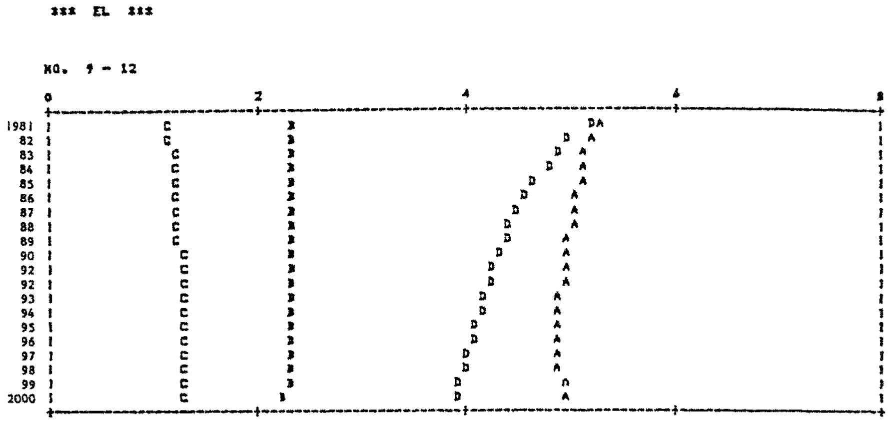
Note: Although population index shows deterioration, large change cannot be not observed.



	A	B	C	D
1980	20.30	38.00	83.10	43.00
81	21.28	41.04	87.46	68.41
82	22.73	44.28	92.08	72.03
83	23.70	47.68	96.92	75.84
84	25.21	71.25	102.03	77.87
85	26.33	75.02	107.40	84.97
86	27.73	78.74	113.05	88.32
87	29.45	83.12	118.99	93.17
88	30.90	87.49	125.24	98.09
89	32.41	92.10	131.82	103.23
90	34.23	96.94	138.75	108.68
92	36.14	102.03	146.04	114.37
92	38.04	107.39	153.71	120.41
93	40.04	113.03	161.79	126.74
94	42.13	118.97	170.28	133.40
95	44.37	125.22	179.22	140.41
96	46.70	131.80	188.63	147.79
97	49.15	138.72	198.54	155.55
98	51.73	146.01	208.97	163.73
99	54.44	153.68	219.94	172.33
2000	57.30	161.75	231.49	181.39

Figure 8 (d). Change of Land Prices in Zone No.9, 10, 11 and 12.

Note: Land price in Zone No.11 rises remarkably.



	A	B	C	D
1981	5.2854	2.3467	1.1584	5.2043
82	5.2321	2.3421	1.1838	5.0333
83	5.1731	2.3395	1.2027	4.9128
84	5.1575	2.3336	1.2204	4.8029
85	5.1234	2.3329	1.2344	4.7040
86	5.1048	2.3323	1.2471	4.6298
87	5.0801	2.3315	1.2581	4.5487
88	5.0533	2.3307	1.2673	4.4796
89	5.0288	2.3294	1.2753	4.4170
90	5.0085	2.3295	1.2816	4.3644
92	4.9884	2.3285	1.2880	4.3134
92	4.9470	2.3284	1.2940	4.2634
93	4.9313	2.3279	1.2976	4.2187
94	4.9340	2.3274	1.3050	4.1750
95	4.9171	2.3247	1.3104	4.1322
96	4.9044	2.3256	1.3153	4.0903
97	4.9306	2.3233	1.3203	4.0479
98	4.9347	2.3218	1.3248	4.0065
99	4.9785	2.3203	1.3291	3.9666
2000	5.0018	2.3182	1.3336	3.9272

Figure 8 (e). Change Condition Index of Living Environment in Zone No.9, 10, 11 and 12

Note: In Zone No.9 and 12, the index decreases remarkably.

FOOTNOTE

1/ Formularization of System Dynamics (SD) model is usually described with DYNAMO language. This model, however, is described with simplified symbols because it deals with many districts simultaneously and, therefore, its formularization is complicated.

EMERGING PERSPECTIVES ON COMPUTER-AIDED PLANNING

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ABSTRACT

Rapid advances in the area of microcomputer technology present the planning profession with a unique set of opportunities and challenges. Developments to date have fortuitously implemented many of the lessons of the failure of the large-scale modeling efforts of the 1960s. Severely limited software development resources have required that computerized planning models are simple and utilize available methods and information to address concrete policy issues. The "what-if" metaphor exemplified by electronic spreadsheets has made the provisional nature of future predictions clearer and the need for explicitly incorporating policy variables more obvious. And increasingly powerful and easy-to-use software tools for exploratory data analysis, computer-aided design, geographic analysis and mapping, and knowledge engineering promise to transform planning practice.

Negatively, the widespread availability of sophisticated analytic tools has increased the potential for their misuse or abuse, imparted a false faith in computer-generated analytic results, and threatened to distort the analysis process. As a result, software developers must thoroughly document the assumptions and limitations of their models and make explicit the normative and political choices that underlay model results. Planning academics and practitioners must abandon the naive attempt to develop a single "correct" forecast for explicit procedures for estimating forecast error, preparing a range of alternative forecasts, and adversary modeling. Only then can we begin to prepare truly planning models that do not merely continue past trends to predict an unknowable and uncontrollable future but rather incorporate explicit procedures for selecting a desired future, identifying the actions needed to achieve it, and revealing the decisions that underlay these choices.

WINDOWS ON ORDER AND CHAOS
THE ROLE OF MICROCOMPUTERS IN PLANNING AND MANAGEMENT

by
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We live in exciting times, intellectually no less than politically -- "at the edge of history", as Bill Thompson (1972) liked to say -- so much so that there is a real danger of one change obscuring others. Today, for example, we are so preoccupied by the socio-technical impact of microcomputers over the last decade that we may overlook another, more subtle but probably more significant revolution that has also occurred in the last ten or fifteen years. This is the revolution created by "chaos". It is arguably the most significant discovery of this century. For it is a revolution that could undermine ideas and beliefs that have dominated Western science and philosophy for nearly 300 years.

Twenty years ago, I saw scrawled on a wall in the University of Copenhagen the words, "Anarchy or Chaos." Then, it was no more than an anarchist slogan. Today, it is a profound and important scientific question.

The purpose of this paper is to discuss the meaning and implications of chaos theory for planning and management. In doing so, I will present some simple BASIC programs that will allow anyone with a microcomputer to experiment with the onset of chaos for himself or herself. The main theme of the paper is that chaos theory lends new respectability to non-comprehensive strategies of planning and management (Cartwright 1987).

1.0 The Meaning of Chaos

The idea behind chaos theory is profoundly unsettling. In simple terms, chaos is order without predictability. In other words, there are systems, physical and probably social too, that are well understood (in the sense that they can be fully described by means of a finite set of conditions or rules) and yet that are essentially unpredictable.

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Thus, chaos is not anarchy or randomness. Chaos is order -- but it is order without predictability. Nor is chaos just a case of "noise", or outside interference, or even inadequate understanding. What chaos implies is an inherent "uncertainty principle" -- not just in how we perceive the world but in how the world actually works. It may be possible, under conditions of chaos, that free will and determinism can be made compatible with each other.

Of course, it will come as no surprise to urban planners and environmental managers to hear that prediction is not always easy. But what is surprising is the idea that these difficulties are inherent rather than situational. No matter how much data we gather, no matter how global and complete our models, no matter how rigorously we test them -- even so, according to chaos theory, prediction may still in some cases be beyond our grasp.

Many theorists -- among them David Braybrooke and Charles Lindblom (1963), Andreas Faludi (1973), and Yehezekel Dror (1983) have argued that we need to learn to plan under uncertainty and have developed strategies and techniques for planning with incomplete information. But they have done so largely for pragmatic reasons: because there is not always time to get all the facts; because it is sometimes too expensive to do so; or because we lack the necessary means or skill. No doubt these factors often compound the difficulties of planning and management. But what chaos theory suggests is that planning based on prediction is not just impractical in some situations: it is logically impossible, because of the very nature of cause and effect. Order, in short, can beget disorder. Which is a pretty staggering idea.

I want to illustrate this transition from order to disorder by taking a simple, dynamic model -- that is, a model that is completely defined by a set of rules -- and examining its behaviour under varying conditions. At first, the model will behave in a "normal" fashion; i.e. in such a way that we can predict its behaviour. Then, under different conditions, the same model will generate results that defy ordinary prediction. In other words, while the model continues to operate in accordance with fixed rules, its behaviour cannot be predicted in a comprehensive way.

The study of chaos in this way, as a form of "experimental mathematics", has become possible thanks to advances in computer technology. Although mathematicians suspected the existence of chaos in the early part of this century (Gleick 1987; Moon 1987), contemporary interest dates from work in the 1960s and 1970s by people such as Edward Lorenz (1963) and Robert May (1974, 1976). Perhaps its most elegant manifestation to date has been in the "fractal" images associated with Benoit Mandelbrot (1983) and others.

I will use as a model one of those used by Robert May in his studies: the "logistical difference" equation. This is a model with two main characteristics:

- o periodic rather than smooth and continuous growth; and
- o a fixed growth rate whose impact is attenuated by proximity to some sort of overall limit to growth (i.e. growth "levels off" as it approaches a limit).

Such a model is sometimes called a model of constrained growth. It could be applied to economic growth based on a given level of technology, urban growth based on existing levels of infrastructure, population growth subject to the carrying capacity of its environment, and other such cases. For the sake of argument, let us think of a population in a finite environment, which is in fact the area where May first developed his ideas about chaos.

In terms of population modeling, therefore, what we are modeling is a situation where population in the next time period (next week, next year, next generation, or whatever) is a function of the population in the current time period. This relationship is defined by two factors:

(a) a fixed rate of growth and

(b) a factor that reflects how close the current population is to some sort of limit.

In practice, the existence of such a limit might be reflected in shortages of food, the incidence of disease, growing numbers of predators, the effects of crowding, and so on. Thus, the basic logistical difference model for population growth might look like this:

$$Pop(t+1) = Pop(t) * Rate * (1-Pop(t))$$

where "Pop(t)" is the population in time "t" and "Rate" is the presumed growth rate. Note that population is expressed as a ratio of the limit (or capacity) of the environment, so that "1-Pop(t)" represents the proportionate residual or "unused" capacity of the environment in time "t" and can be used as the limiting factor.[*]

Now, what we want to do is select various growth rates and "run" the model through a number of time periods (weeks,

---

* Perceptive readers will note that the logistical difference curve is, in fact, the equation of a parabola, which is normally written -- y = 4 * lambda * x * (1-x). In our model, we use a fixed growth rate instead of "4 * lambda", with the result that "Rate" has a maximum value of 4 not 1.

months, years, generations, etc.) to see what happens to the population: does it die out? does it settle down at some "equilibrium" level? does it swing back and forth like a pendulum between two (or perhaps more) levels?

The answer is that the logistical difference model exhibits all of the above patterns and more. The easiest way to show this is by using a computer. Listing 1 is a program in BASIC that plots population on the vertical (or y-) axis over time on the horizontal (or x-) axis. In each "run" of the model, the user inputs the number of generations or time periods and the desired growth rate. Repeated "runs" of the model for different growth rates reveal that it goes through four distinct regimes (Figure 1):

1.1 Extinction (0 < Rate <= 1)

A growth rate of unity or less is insufficient to maintain the population in the long term. Since there is always some positive constraint on growth, the minimum "replacement" rate must be greater than unity. At any lower rate, the population approaches zero in a smooth asymptote. In reality, as soon as the population falls below the minimum level of reproduction (presumably at or above one male and one female), the population dies out. The higher the growth rate and/or the larger the initial population, the flatter the curve and the longer it takes for extinction to occur. The ultimate outcome is nonetheless inevitable.

1.2 Stable Equilibrium (1 < Rate <= 2)

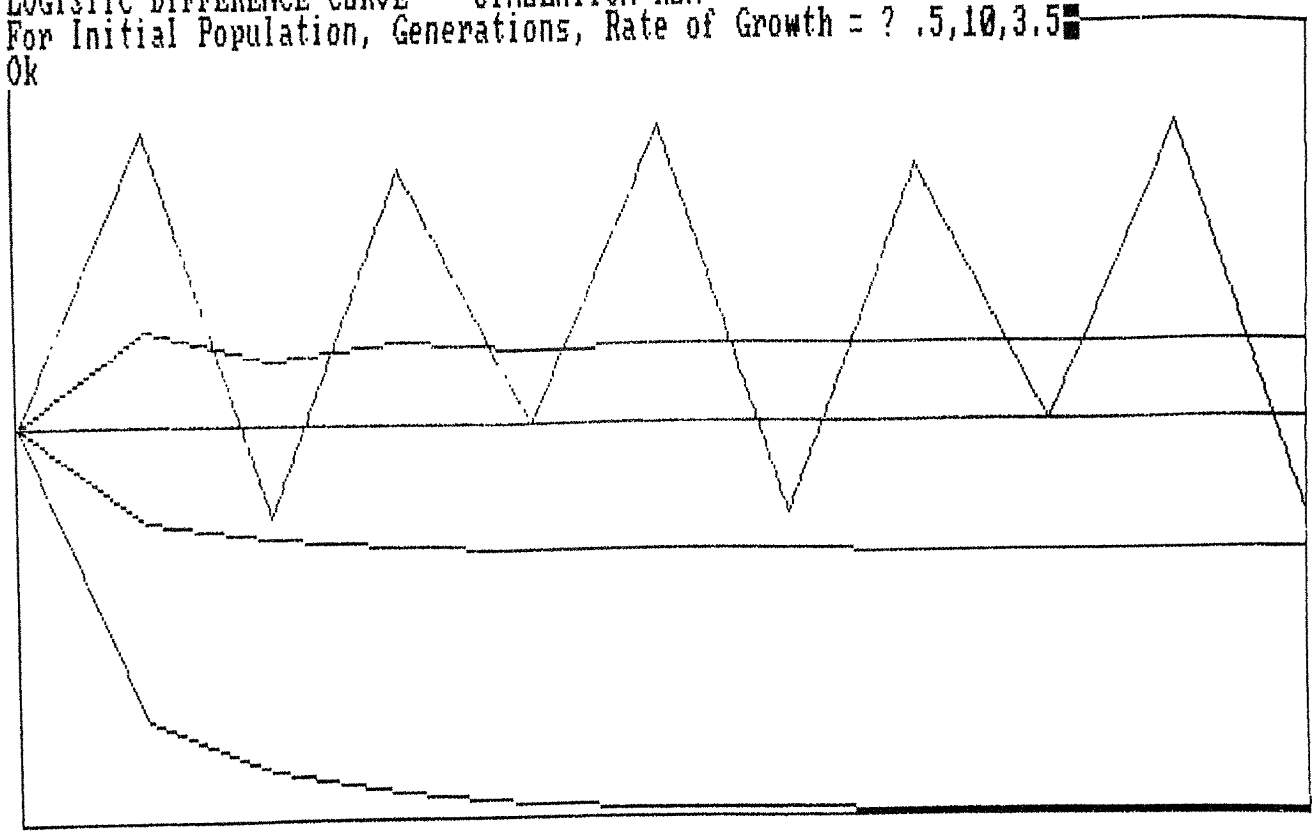
With growth rates of between unity and double, the population always reaches a stable equilibrium level. This equilibrium level depends entirely on the growth rate in effect and is given by the formula,

$$1 - 1/\text{Rate}$$

to a maximum of 0.5 when "Rate" is exactly 2.

While the equilibrium level itself is independent of the initial population size, initial size does affect how equilibrium is reached. For initial populations at or below a level of 0.5, the approach to equilibrium is always a smooth curve. The same is true in the special case (for each growth rate) where initial population is exactly equal to equilibrium population. In all other cases, the aproach to equilibrium is smooth as long as the initial population is not "too close" to the limit. Where it is too close (i.e. where the residual capacity is less than the eventual equilibrium level), population will drop below equilibrium after the first time period before taking a smooth upward curve towards equilibrium.

```
run
LOGISTIC DIFFERENCE CURVE -- SIMULATION RUN
For Initial Population, Generations, Rate of Growth = ? .5,10,3.5
Ok
```



1.3 Dynamic Equilibrium (2 < Rate <= 3)

In this regime, population again proceeds to a non-zero equilibrium given by the formula,

1 - 1/Rate

to a maximum of .67 (2/3) when "Rate" is exactly 3. In this case, however, the approach to equilibrium is one of damped oscillations. The size of the initial swing and the rate at which the swings diminish vary directly with the growth rate. Neither the equilibrium level nor (after the first few swings) the approach to it is affected by the initial size of the population in this regime.

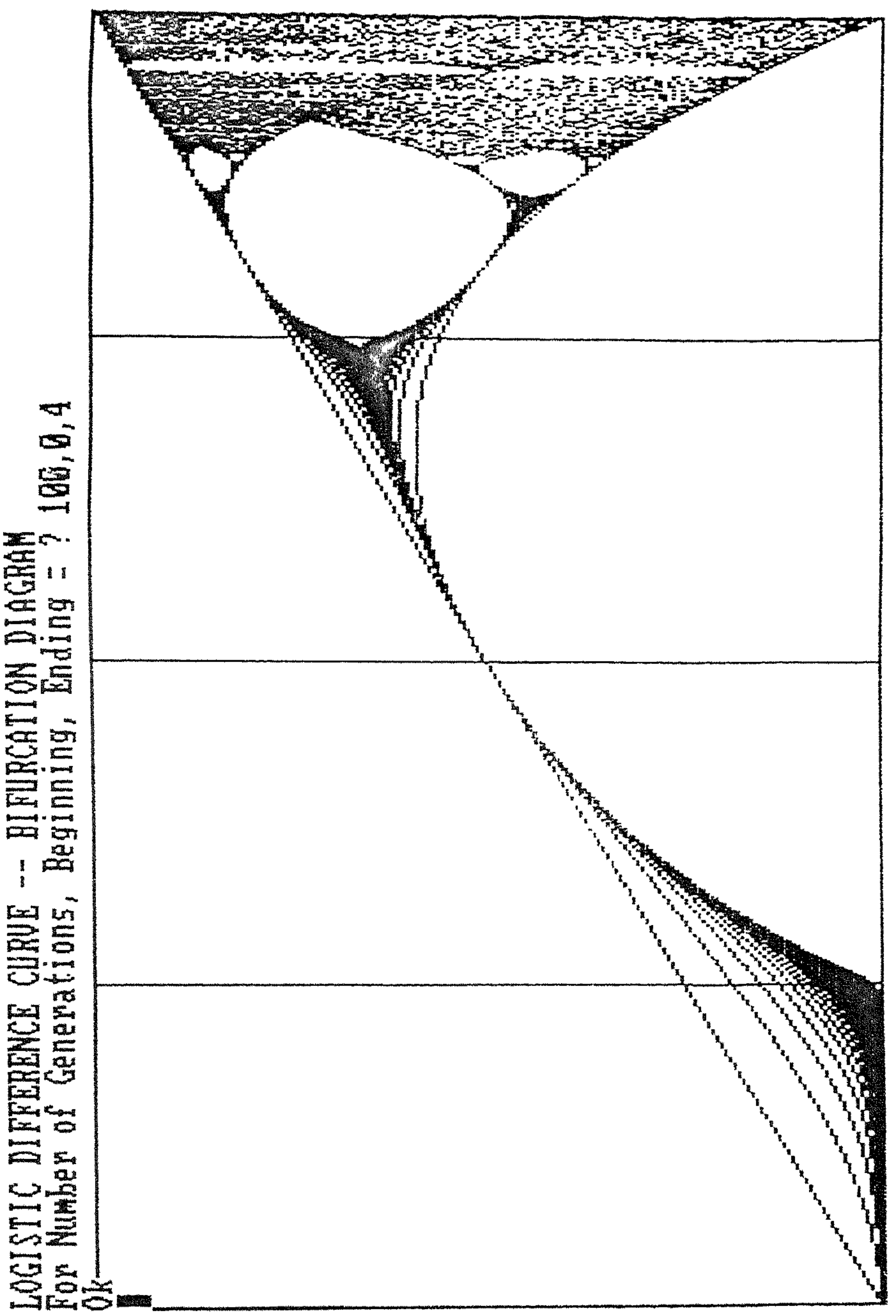
1.4 Transition to Chaos (3 < Rate <= 4)

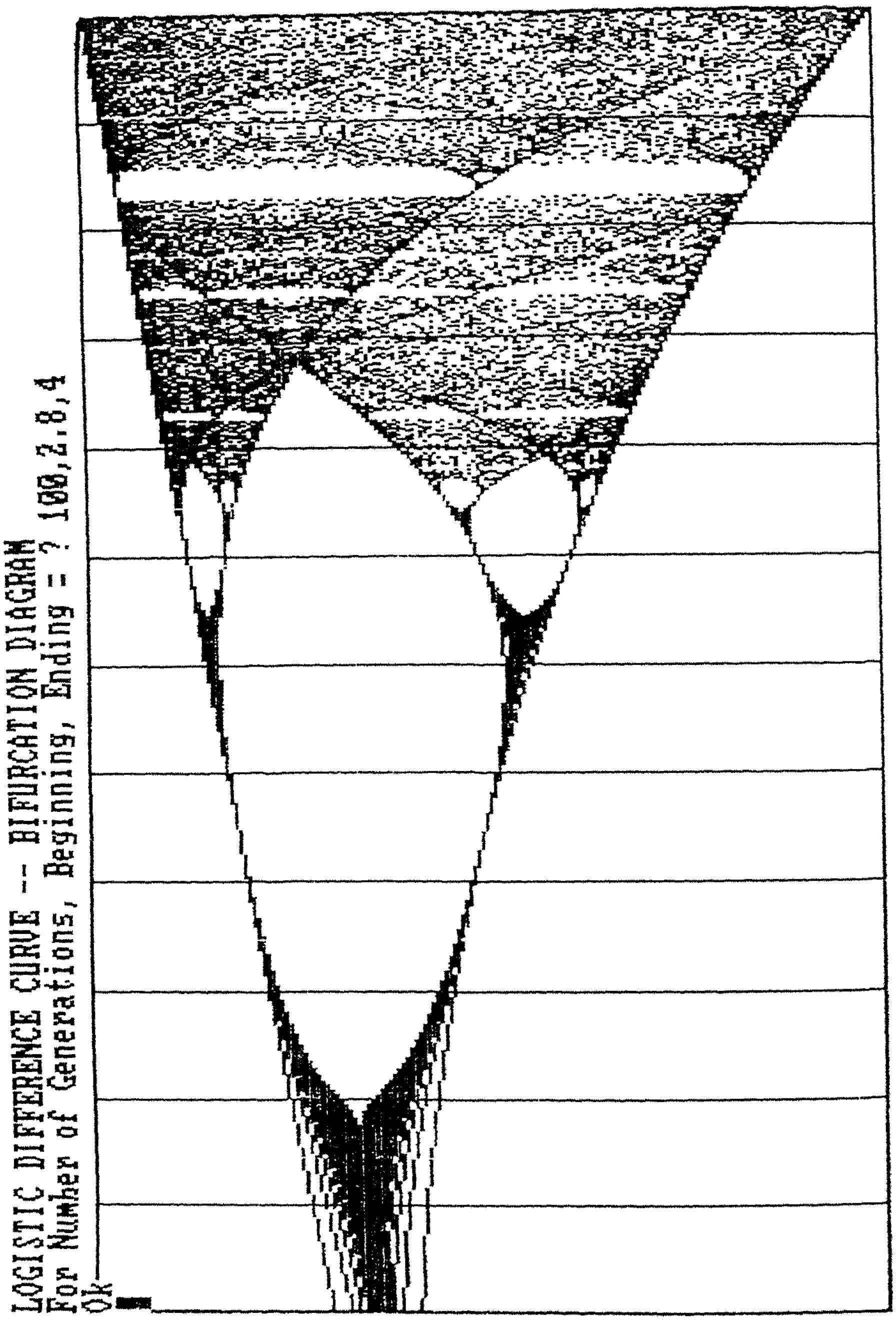
As soon as the growth rate goes above 3, oscillations in the population level cease to be damped and no longer seem to follow any consistent pattern. At first, the population alternates regularly (or periodically) between two equilibrium levels. As the growth rate continues to rise, the two equilibrium levels diverge, until (around 3.5) there seem to be four equilibrium levels instead of two. Soon these divide into eight, and those into sixteen. After that, if there is a pattern, it becomes progressively harder to discern.

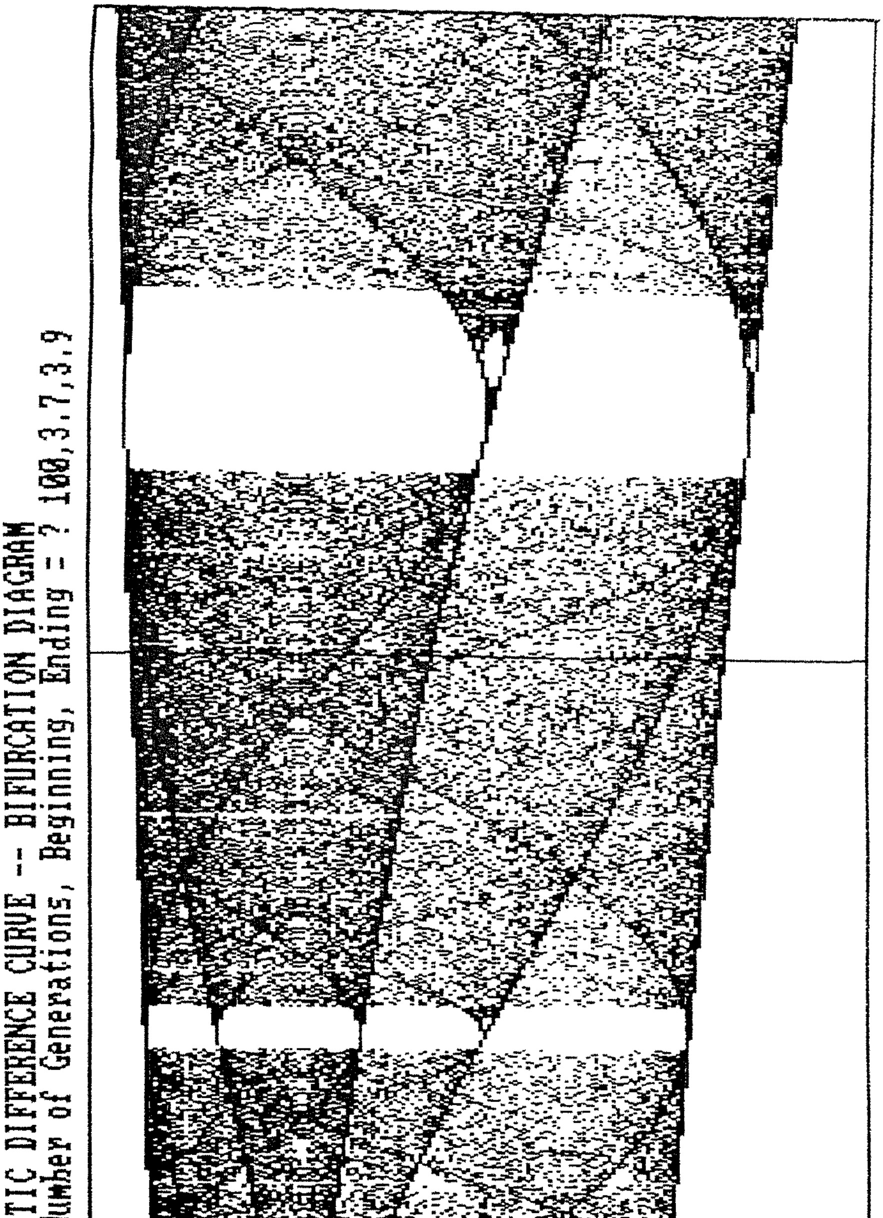
2. The Nature of Chaos

To get a clearer idea of what is happening, we need to look at the model from another perspective. Instead of seeing how population evolves over time for a given growth rate, we want to see how population varies over different growth rates. In other words, we want a "profile" of the population levels achieved for each growth rate, rather as if we looked at the previous graphs from the "end" instead of from the "side". To do this, we will plot population on the vertical (or y-) axis over growth rate on the horizontal or (x-) axis. Thus, at each point on the x-axis (growth rate), there will be a set (column) of points marking the population levels achieved at that growth rate.

Listing 2 is a BASIC program to do this. For each run, the user inputs the number of generations to be plotted for each growth rate and the range of growth rates (0 to 4) for which the model is to run. Whatever range is specified, the program divides it into 638 discrete growth rates (one for each available pixel across the computer screen) and plots the population levels achieved at each rate during the specified number of generations. The result is a dramatic picture (Figure 2) of the transition to chaos described above.


LOGISTIC DIFFERENCE CURVE -- BIFURCATION DIAGRAM
For Number of Generations, Beginning, Ending = ? 100,0,4
Ok


LOGISTIC DIFFERENCE CURVE -- BIFURCATION DIAGRAM
For Number of Generations, Beginning, Ending = ? 100,2.8,4
Ok



LOGISTIC DIFFERENCE CURVE -- BIFURCATION DIAGRAM
For Number of Generations, Beginning, Ending = ? 100,3.7,3.9
Ok

Using the range 0 to 4, we can clearly see the four regimes described above. The thick "rope" of plots on the x-axis reflects the regime of extinction (0 < Rate <= 1). The thinner, single-line plot rising towards the middle reflects the regime of single equilibria (1 < Rate <= 2). The thickening line of plots that begins to level off represents the regime of damped oscillations tending towards equilibria (2 < Rate <= 3). Finally, the area on the right where the line splits into a complex "mesh" of lines represents the regime of transition to chaos (3 < Rate <= 4).

Using the range 2.8 to 4, we can study the transition to chaos more closely. This type of transition is sometimes called a "period-doubling route to chaos", because the model passes through a phase where the tendency towards a single equilibrium is replaced by oscillation between two equilibria, then four, then eight, then sixteen, and so on. Each of these stages is shorter in duration than its predecessor, until the stages ultimately dissolve into chaos.

Even after chaos has been reached, however, the pattern is not entirely consistent. For there appear to be a number of zones of relative calm within the chaos. Using the range 3.7 to 3.9, for example, we can see two or three places where the model oscillates between a small number of equilibrium points rather than many. In turns out that, no matter what area of the chaotic regime is examined, chaos occasionally and briefly (sometimes very briefly) gives way to more ordered calm.

3. Order in Chaos

As staggering as all this is, there is still another surprise. Even in the chaotic regime, there is still order. The order is not so easily visible, for it is order of a "local" rather than global nature.

Consider the area of chaos, where it seems impossible to predict on an overall basis how the model will behave. Within this area, however, it turns out that you can predict the next state if you know the current state. You may not know where the model is going in the long run (or where it has come from in the past, for that matter). But, if you know where it is now, you can make incremental predictions about where it will go in the next time period.

To illustrate how order survives in chaos, we will look at our population model from a third perspective: by plotting the population in each time period over (or in relation to) the population in the immediately following period. In other words, we will make the x-axis "Pop(t)" and the y-axis "Pop(t+1)".

Listing 3 is a BASIC program that will do this. The user inputs the starting growth rate and the computer automatically sets the other parameters. That is, the computer defines 33 growth rates (every sixth pixel in the vertical dimension of the screen) between the starting rate selected by the user and the maximum rate (4), scales the screen appropriately for the data to be displayed, and then plots the populations for 500 generations at each growth rate.

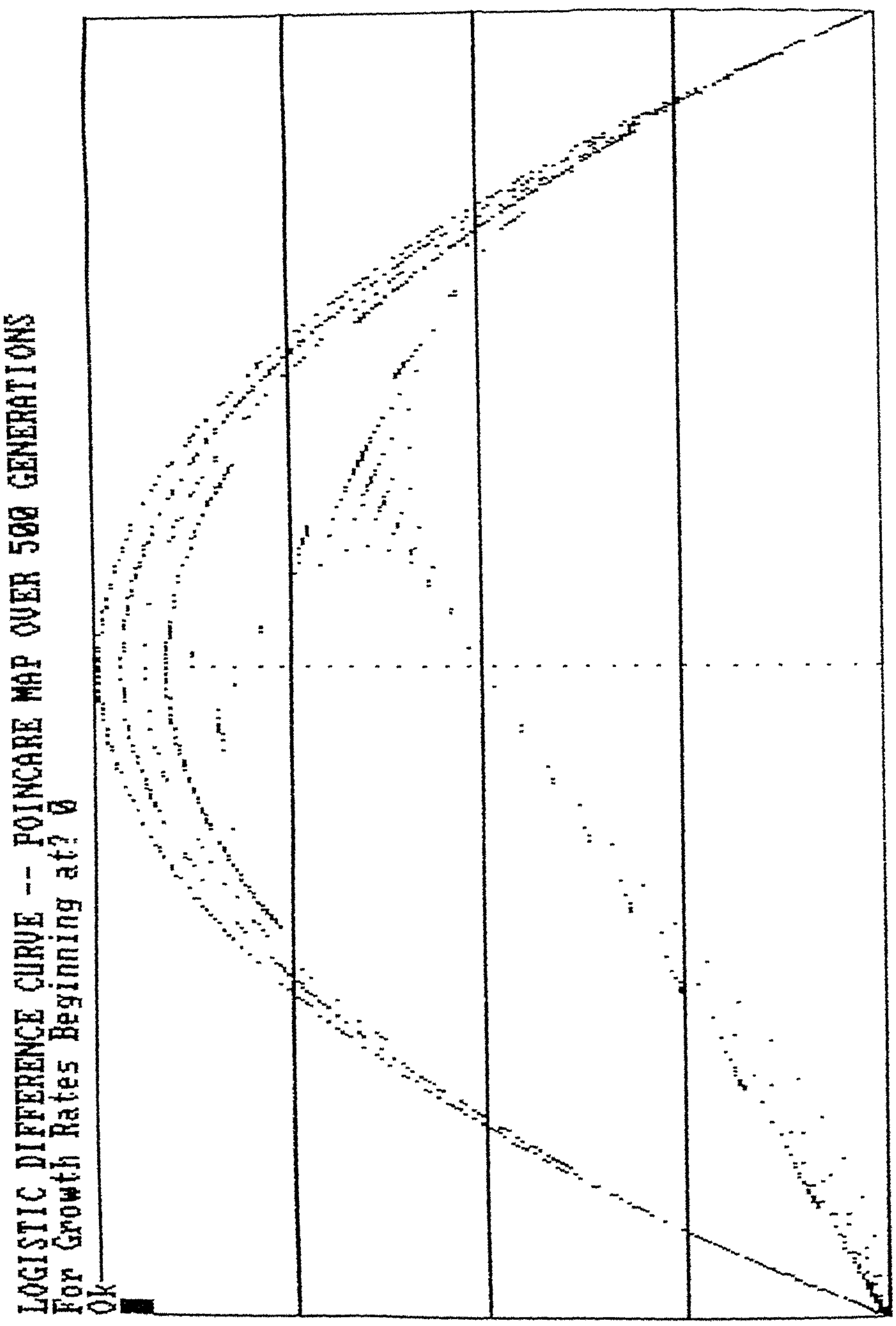
Figure 3 shows two different runs of the program. The first run shows the full range (0 to 4) of growth rates, with the result that the four regimes described above are clearly visible. The second run (3.5 to 4) shows most of the chaotic range. Strikingly, the disorder of Figure 2 over this range has been replaced by order in Figure 3. Figure 3 is a family of full or partial parabolic curves, with each separate growth rate yielding its own, discrete curve. It turns out that, no matter how fine a plot you make of these parabolas, they remain distinct and never overlap. This geometric property is sometimes called a fractal structure (Moon 1987).

Thus, the paradox of chaos. In this regime, you cannot predict the long-run evolution of the model at a particular growth rate; that is, you cannot predict the overall placement and sequence of the points along any particular parabola. On the other hand, what you can do in the chaotic regime is predict where the model will go next if you know where it is now. That is, if you have a point on the x-axis (i.e. the population in time "t"), then you can find the corresponding point (for a particular growth rate) on the y-axis (i.e. the population in time "t + 1"). In short, while global prediction is impossible in the chaotic regime, local prediction is quite feasible.

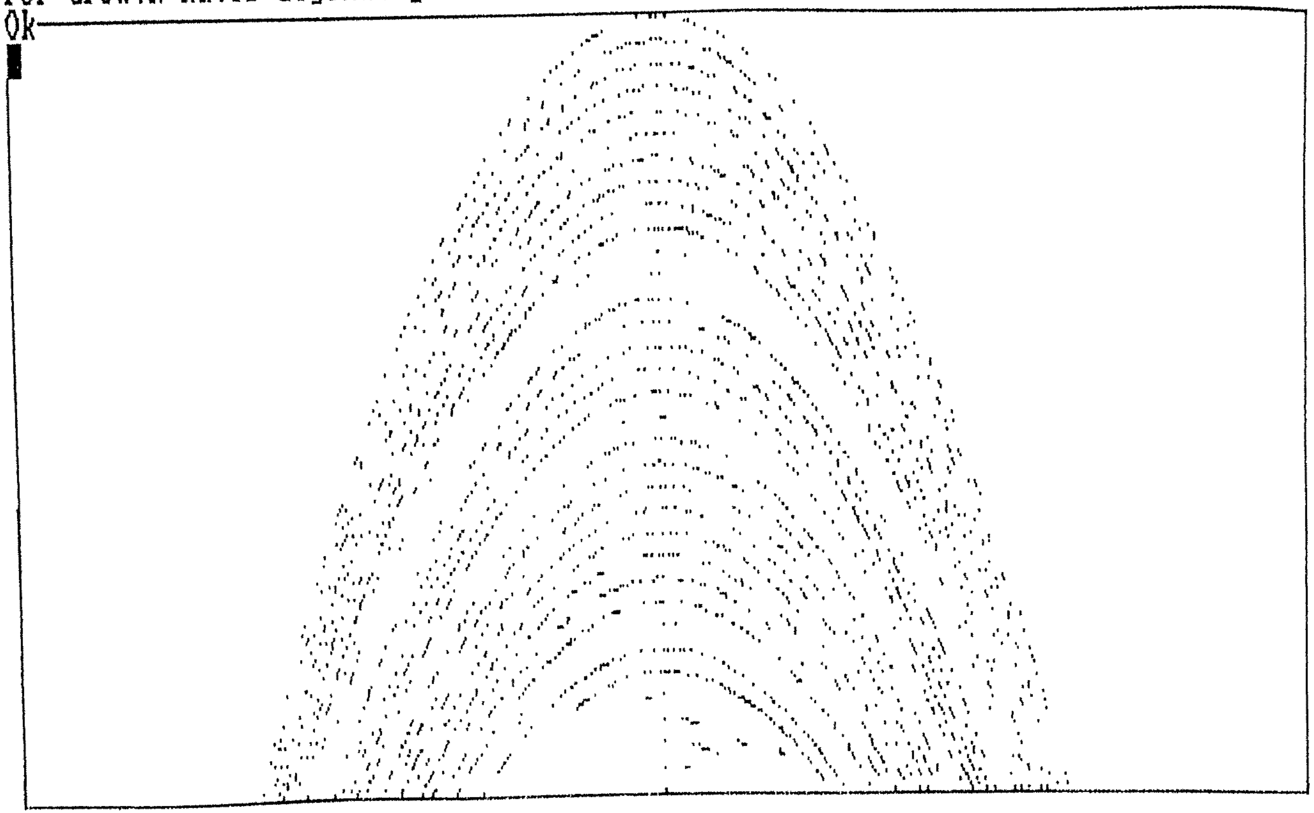
4. The Relevance of Chaos

Before looking at the implications of these findings, I want to deal with one other matter. This is the argument that the logistical difference model is not (or not always) appropriate for modeling population -- or other phenomena in which planners and managers may be interested. That may be indeed be the case. Like any model, the logistical difference model is an approximation to reality; so the appropriateness of the model to any empirical situation will depend both on the situation itself and on the purpose for which it is being studied. In any case, the purpose of this paper is not to argue that the logistical difference equation is useful for modeling but rather to show that even in a dynamical model as simple as that one, there may be a chaotic regime.

The full range of models having chaotic regimes is not yet known. A key characteristic of such models seems to be that they contain some "feedback" or "self-referential" ele-


LOGISTIC DIFFERENCE CURVE -- POINCARE MAP OVER 500 GENERATIONS
For Growth Rates Beginning at? 0
Ok

LOGISTIC DIFFERENCE CURVE -- POINCARE MAP OVER 500 GENERATIONS
For Growth Rates Beginning at? 3.5
Ok



ment, such as the factor "1 - Pop(t)" in the logistical difference model; but whether this is always a necessary or sufficient condition for chaos is not yet fully understood. Certainly, the effect of feedback is exponential, for it is compounded at every subsequent time period.

Thus, it can be shown that several variations on the logistical difference model used here do have chaotic regimes. For example, if you "lag" the contraint on growth by one or more time periods -- so that "Pop(t+1)" is constrained by "1 - Pop(t-1)" instead of "1 - Pop(t)" -- the chaotic regime still occurs, albeit at an earlier point (May 1976). Similarly, if you use the so-called Rucker model --

Pop(t+1) = Pop(t) * exp(Rate * (1 - Pop(t)))

-- where the effects of both the growth rate and the constraint are exponential rather than multiplicative, there is also a chaotic regime.

In any case, if relatively simple, dynamical models can have chaotic regimes, presumably so can more complex models. There is no reason to believe the model we have looked at is unusual or special in any way, except perhaps in respect of its self-referential nature. Thus, it seems reasonable to conclude that many non-linear models have chaotic regimes -- that we are, so to speak, surrounded by chaos.

5. The Implications of Chaos

The idea that order and disorder can be compatible with each other has at least four major implications for urban planners and environmental managers.

First, chaos means that prediction is a good deal more problematical than, as interventionists, we like to think. Behind many plans, there is the assumption that, given enough information, we can anticipate what is going to happen and, therefore, we know how to act to promote, defer, deflect, or divert it, as we may wish. What chaos suggests is that, on the contrary, some systems are inherently unpredictable. Gathering more information or constructing more elaborate models about such systems will do little to help. James Crutchfield and his colleagues (1986, p. 49) describe an idealized game of billiards on a perfectly shaped table where the balls, once struck, move without loss of energy.

> For how long could a player with perfect control over his or her stroke predict the cue ball's trajectory? If the player ignored an effect even as minuscule as the gravitational attraction of an electron at the edge of the galaxy, the prediction would become wrong after one minute!

In his recent best-seller, James Gleick (1986) discusses recent efforts to interpret data in terms of the chaotic tendencies of non-linear systems. Among the most interesting is the work of William Shaffer and others, who have applied chaos theory to modeling the lynx population in northern Canada (1984) and measles and mumps epidemics in New York and Baltimore (1985).

Second, relatively small differences in the parameters or initial conditions of such systems can have a radical effect on system behaviour. In the logistical difference model, for example, tiny changes in the growth rate can mean the difference between oscillation among a few equilibrium points and chaotic fluctuations among many. This is sometimes called the "butterfly effect", after Edward Lorenz suggested that a butterfly waving its wings in Tokyo could affect the weather in New York a few months later. Microcomputer enthusiasts have their own equivalent in the story of how Digital Systems lost out to Microsoft in the competition to produce the operating system for the IBM PC because Digital kept an IBM Vice-President waiting too long. Still another more substantial application of this principle is reflected in the work of Gottfried Mayer-Kress and others (1988, 1989), who have argued that relatively minor disturbances in the global power balance could have catastrophic results. Perhaps this is a salutary reminder that, when it comes to urban planning and environmental management, the details can be just as important as the broad strokes.

Third, chaotic systems exhibit what is called "loss of information about initial conditions". Just as prediction is more problematical in chaotic systems, so is "reverse engineering". That is, it is difficult to infer from its present state how a chaotic system has got there. One area where this is clearly the case is urban form: how do cities get to have the shape and nature they do? Among those who are working on this problem using chaos theory are Michael Batty and Paul Longley (1987, 1988).

Finally, and perhaps most important of all for planners and managers, is that chaotic systems are predictable on an incremental or local basis. On a global or comprehensive basis, chaotic systems are unpredictable because of the cumulative effects of feedback; but on an incremental basis, the effects of feedback from this time period into the next can be perfectly clear. This is one of the most powerful arguments yet made for planning and management strategies that are incremental rather than comprehensive and that rely on a capacity for adaptation rather than on blueprints of results (Cartwright 1989).

For these reasons, chaos theory promises a revolution in planning and management at least as great as that started by microcomputes. As Francis Moon has written (1987, p. 36),

> The view that order emerged from an underlying formless chaos and that this order is recognized only by predictable periodic patterns was the predominant view of 20th century dynamics until the last decade. What is replacing this view is the concept of chaotic events resulting from orderly laws, not a formless chaos, but one in which there are underlying patterns, fractal structures, governed by a new mathematical view of our "orderly" world."

In the face of this revolution, we are going to have to adapt not just the techniques we use but possibly the whole way we think about our urban and environmental futures and how we try to change them.

Listing 1

```
10 ' LDSIM.BAS -- Logistic Difference Curve Simulation Run
11 ' tjc/toronto/890630
20 CLS                                    ' delete if overlays desired
30 KEY OFF:DEFINT G,I:SCREEN 2            ' for high resolution (640x200)
40 PRINT"LOGISTIC DIFFERENCE CURVE -- SIMULATION RUN"
50 PRINT"For Initial Population, Generations, Rate of Growth = ";
60 INPUT POP,GEN,RATE                     ' get parameters for run
70 VIEW (1,20)-(638,198),,1               ' define boundaries of plot
80 WINDOW (0,0)-(GEN,1)                   ' define scale of plot
90 LINE (0,.5)-(GEN,.5)                   ' plot pop=.5
100 PSET(0,POP)                           ' plot initial population
110 FOR I=0 TO GEN                        ' for each generation
120 LINE-(I,POP)                          ' plot current population
130 POP=RATE*POP*(1-POP):NEXT I:END       ' compute next generation
```

Listing 2

```
10 ' LDBIF.BAS -- Logistic Difference Curve Bifurcation Diagram
11 ' tjc/toronto/890630
20 CLS                                    ' delete for overlays
30 CLEAR:KEY OFF:DEFINT G,J:SCREEN 2      ' for high resolution (640x200)
40 PRINT "LOGISTIC DIFFERENCE CURVE -- BIFURCATION DIAGRAM"
50 PRINT "For Number of Generations, Beginning, Ending = ";
60 INPUT GEN,START,STOPP                  ' get parameters for run
70 DIF=(STOPP-START):PIX=DIF/638          ' select rate for each pixel
80 VIEW (1,20)-(638,198),,1               ' define boundaries of plot
90 WINDOW (START,0)-(STOPP,1)             ' define scale of plot
100 IF DIF>=.1 THEN GOSUB 200             ' if able, plot 0.1 grid marks
110 FOR I=START TO STOPP STEP PIX         ' for each growth rate
120 POP=.5                                ' set initial population
130 FOR J=1 TO GEN                        ' for each subsequent generation
140 POP=I*POP*(1-POP)                     ' compute population
150 PSET (I,POP):NEXT J,I:END             ' plot it; end both loops, program
200 FOR I=0 TO 4 STEP .1:LINE (I,0)-(I,1):NEXT I:RETURN
```

Listing 3

```
10 ' LDMAP.BAS -- Logistic Difference Curve Poincare Map
11 ' tjc/toronto/890630
20 CLS                                    ' delete if overlays desired
30 KEY OFF:DEFINT G,I:SCREEN 2            ' for high resolution (640x200)
40 PRINT"LOGISTIC DIFFERENCE CURVE -- POINCARE MAP OVER 500 GENERATIONS"
50 PRINT"For Growth Rates Beginning at";
60 GEN=500:INPUT START                    ' get parameters for run
70 VIEW (1,20)-(638,198),,1               ' define boundaries of plot
80 EDGE=START/16:SHOW=START/4             ' set scaling parameters
90 WINDOW (0+EDGE,SHOW)-(1-EDGE,1)        ' define scale of plot
100 FOR J=.25 TO .75 STEP .25             ' plot grid marks at rate=1,2,3
110 LINE (0,J)-(1,J):NEXT J
120 FOR RATE=START TO 4 STEP (4-START)/33 ' for each rate (every 6th pixel)
130 POP=.5                                ' set initial population
140 FOR I=1 TO GEN                        ' for each generation
150 PSET(POP,RATE*POP*(1-POP))            ' plot current,next population
160 POP=RATE*POP*(1-POP)                  ' set current=next population
170 NEXT I,RATE:END                       ' end loop
```

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THE ORGANISATION'L AND MANAGEMENT IMPLICATIONS OF COMPUTER USE IN U.K. LOCAL AUTHORITY PLANNING DEPARTMENTS

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During the last decade in particular much has been written about computer use in planning (see for example Bardon, 1988; England et al, 1985; Newton and Taylor 1986). A great deal of this writing has focused upon issues relating to equipment, software characteristics and applications development. Increasingly, however, it has been recognised that human and organisational factors play at least as important a role as technological influences in shaping the trajectory of developments. See for example Baddley et al, 1983; Barrett and Leather, 1983; Department of the Environment, 1987; Masser and Campbell, 1988. Such work has stressed the need to understand the complex interactions between technical, human, organisational and political variables as they influence choices of direction. Nevertheless, experience in the U.K. shows that the managers of local authority planning departments have been slow to recognise this, with the result that such understanding is frequently not manifest in practice.

This paper presents a necessarily brief summary of some key organisational and management implications arising from computer use in local authority planning departments. The perspectives presented draw upon a research programme grant-aided by the Economic and Social Research Council 1983-1985 (Bardon, 1985) which involved a postal survey of all local authority planning departments in the U.K. and eight case studies; a number of short courses organised for local authority officers concerned with managing information technology and; my experience of working with planners developing a range of computer applications over the last fifteen years.

I will first outline a number of broad categories of computer use in order to draw out some key organisational implications. These will then be discussed as part of a continuum which also embraces strategic management questions. The need for a comprehensive information strategy is argued and these strategic matters are considered in this context. Finally I will conclude with a call for further practically based comparative studies.

APPLICATION AREAS

As in the U.S.A (Whited, 1982) and Australia (Newton and Taylor, 1986), the use of computers in British planning can be grouped into four inter-related areas each of which poses operational questions and challenges to management:

1 Administrative and managerial activities include personnel records, report writing facilities, staff diary systems, accounting and budgetting systems. In some cases these developments have enabled more central control. In other instances, they have faciliated greater local autonomy supporting decentralised cost centres such as subject, local plan or development control teams. Management structures and organisational politics govern such decisions rather than equipment configurations and technical capabilities.

2 Statutory functions such as development control and building control systems have often been introduced first in district councils and have been justified on the grounds of increased efficiency and effectiveness. Such systems support, first and foremost, the administrative processing of applications. Typically files are created which contain individual records giving details of planning or building control applications received and action taken by the authority. Administrative documents produced include acknowledgement and consultation letters, the planning register and other public notices, committee agendas and reports and decision notices (Farthing, 1986; Grimshaw, 1985). Most systems allow the progress of applications to be monitored, on-line application enquiries and searches, and the generation of a range of management information. Such information could include an appraisal of staff work loads, analyses of development pressures, land use change and land availability, and the completion of statistical returns. Thus in recent years, systems initially designed for administrative purposes have provided the basis for the development of professionally orientated applications.

These developments have had significant impacts upon staff and office practices. The resulting changes have impacted upon job content and boundaries sometimes causing changes in operational processes and management structures.

3 Research and intelligence activities cover a wide range of applications concerned with plan generation and monitoring. Traditional 'number crunching' applications such as survey analysis, forecasting and modelling have been around for some years. In the last decade a new type of information system has been developed using enhanced text and graphics facilities.

These systems, often pc based, have transformed the research and intelligence capabilities of many planning departments by enabling the production of up-to-date, well presented and detailed analyses.

4 Information service provision and liaison activities have expanded as a consequence of the enhanced information (content and presentation) provided by computer systems dealing with statutory functions and analytical activities. A number of larger local authorities have invested in networking and telecommunication facilities providing public and private information services. In some cases the planning department acts as an information centre within an authority managing and administering such services. Typically the information includes development control and land availability analyses, social and demographic trends and economic activity and performance indicators.

ORGANISATIONAL IMPLICATIONS

The eight case studies carried out in the U.K. between 1983 and 1985 (Bardon, 1985) brought out a number of inter-related key points which are common to many departments and cut across activity boundaries such as those which from the basis of the above classification. The adoption or enhancement of information technology:

- Facilitated the movement of tasks from professional to clerical areas and the 'blurring' of technical and clerical responsibilities.

- Created a range of new tasks especially relating to data administration and system support.

- Caused a decrease in typing volume handled by secretarial staff
and an increasing volume handled by professional staff.

- Presented the opportunity to restructure and streamline the handling of simple delegated decisions.

- Caused a decrease in work effort involved in some clerical activities when supported by a computer system.

- Emphasised the need for training and/or updating and decisions to be taken as to what training is applicable and appropriate to which members of staff.

- Could be an important influence on job satisfaction. For example, the use of menu-driven options with a high level of prescription was seen by some to de-skill and thus downgrade tasks.

- Can significantly enhance the control and analytical activities often performed by middle management/professionals. Moreover, these tasks could be carried out automatically or by senior staff.

- Could be used to introduce and enforce more rigorous and standardised practices and procedures (eg. standard planning application forms and land use and property codes). This could be applied within a department, authority or between organisations (eg. across a county).

In summary, computer use has many implications which range from specific and operational details to strategic management questions. Operational matters such as system support and maintenance, data administration, managing user access and producing and promoting standards of good practice extend into other arenas such as developmental work. Here issues such as data and system standards and equipment compatibility within departments and across authorities are important. As such they demonstrate the existence of an important continuum whereby operational details can influence strategic management choices.

DEVELOPING A STRATEGY

Until recently most British planning departments had not considered producing a strategy aimed at managing the use and development of computer facilities. Exceptions to this generalisation, often led by the local authority Treasurer, have usually concentrated almost exclusively upon technical matters. As has been indicated above, however, the evidence suggests that developments are a result of complex interactions between technical, political and organisational factors. Indeed, Barrett (1984) believes that

"the main factor determining the use made of IT will not be the technology itself, but the degree to which potential developments are enabled fostered or inhibited by

i) the structure of control and accountability ie the management system dominating the operational environment and;

ii) the availability of relevant data and attitudes to the use of, and access to, information."

As Kraemer et al (1981) also argued from studies in the U.S.A., an appropriate strategy therefore needs to embrace computing, information, human and institutional factors. Fundamental to this is the concept of information as a resource, as essential as personnel or finance. A strategy needs to provide a framework for promoting the effective use of information resources throughout an organisation. As such it "needs to address the relationships between the desired pattern of communication and the use of information, the hardware, software and skills to assist the organisation to achieve it" (Baddley et al 1983). In other words it should discuss the organisation's philosophy and policy stance; key application areas and information priorities; procurement and integration; training; implementation and the management structure for the control and operation of systems.

If the strategy is about resource management it will undoubtedly reveal the centralising and decentralising potential of computer systems. Discussions in the past (in simulation exercises and case study organisations) have focussed upon issues of possession and control over systems, development priorities and procurements. These have produced a divergence of interests and tensions between service and user departments. Users are typically most concerned with their needs and applications and information sharing is low on their list of priorities. Service departments are on the otherhand often on the defensive advocating central coordination and control. At a recent BURISA workshop (Stothers and Shaw, 1988) it was argued that the significance of corporate data management in the U.K. public sector was increasing. Five factors were cited as being particularly influential:

i) The increasing range and complexity of computer systems; continually growing quantity of stored data; and more complex retrieval requirements to serve the expanding demand for administrative and policy making purposes.

ii) The changing cost of computing. The real costs of hardware and software have declined whilst personnel costs (especially important in terms of design and maintenance) are increasing.

iii) U.K. local government structural and legislative changes have increased the need for more information to be readily available (Community Charge, Compulsory Competitive Tendering, Education and Housing reforms).

iv) Enhanced financial accountability and the need for information to evaluate perfomance.

v) Common information requirements of different departments within an oranisation demonstrating that good data management can improve efficiency and effectiveness.

Despite these influences, it is clear from the workshop proceedings that middle and senior managers in local authorities remain to be convinced (or educated) as to the benefits of corporate data management. For many the benefits are too long term and outweighed by the costs involved (in terms of staff morale and finance). Thus U.K. case study evidence shows very limited corporate data management in local authorities.

CONCLUSIONS

Perhaps one of the keys to understanding the use of computers in planning in the last decade is to realise that one has been dealing essentially with the management of change within organisations. Thus the "push and pull" life of local authority managers has frequently been highlighted together with questions of 'who does what', job content and job boundaries between the different groups involved. The case studies I have been involved in show clearly that the politics of computing are at least as important as technical considerations. Moreover, they show that a continuum exists between small scale and pragmatic operational issures and strategic management questions. These views are supported by other studies in Britain (Baddley et al 1983; Masser and Campbell, 1988) and the U.S.A. (Danziger et al, 1982; Kraemer et al, 1981; King and Kraemer, 1985). This case study evidence could, however, be usefully extended and updated. Certainly in Britain the initial stampede to acquire computer systems is over and a period of consolidation and 'organic growth' is occuring. It would therefore seem an appropriate time to embark upon additional case study work. Further international comparative research is required such as that being carried out at Sheffield University (Masser and Campbell, 1988) which is building upon the findings of a series of studies carried out at the University of California at Irvine (King and Kraemer, 1985). This conference is an encouraging sign of further developments in this direction which will hopefully lead to further comparative studies which address the managment of computer use in different organisational settings. It is important that this does not remain an academic province, but that planning practitioners take part in and learn from this comparative work in order that the lessons learned may be applied.

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EVALUATING THE IMPACT OF COMPUTERS ON URBAN PLANNING ACTIVITIES

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INTRODUCTION

There is a growing literature on computers in planning but a discussion of the impacts and the evaluation of systems is rarely undertaken. Instead the literature tends to be concerned with describing system developments, identifying potential feasible uses for systems or promoting and advocating developments. Currently judging by an examination of recent literature there is much interest amongst planning academics and practitioners in expert systems, geographical information systems, computer-aided design and supercomputers.

Ortalano and Perlman (1987) discuss what expert systems are and identify tasks they might be applicable to. Cullen (1986) sees expert systems as a novel set of tools for use in planning analysis that overcome the inflexibility and intolerance of uncertainty characteristic of traditional urban planning models. Leary (1987) applies expert systems to development control situations because of the fairly well-defined legal and administrative rules applying to the decision-making in the British system and Guise and Clark (1987) have developed an expert system to offer design guidance on appropriate design solutions for 'infill development'.

Another area of current interest is geographical information systems. Once again there are papers offering clarification of the concept of GIS (eg Dueker 1987) for the benefit of planners. In Britain , the Chorley Committee (HMSO 1987) set out to promote the use of geographical information systems whilst acknowledging that there were human and organisational barriers to the introduction of technology. The Economic and Social Research Council responding to the same situation has set up Regional Research Laboratories which have the tasks of storing and integrating regional and sub-regional data bases from diverse sources; of making data available to researchers; and of providing training in GIS. Masser (1988) has suggested that these laboratories will be a resource base for planners without specifying clearly the benefits likely to flow. Indeed some doubt has been expressed about how this initiative will assist local planning authorities in their planning functions (Town Planning Review 1986).

In relation to the developing technology of supercomputers Harris (1985) has explored their use in urban and regional modelling and Openshaw (1987) qualified these suggestions and indicated areas where existing supercomputers could be used with immediate success.

Where an evaluative perspective is adopted by commentators, a somewhat limited view is taken. Questions have been raised about whether a system such as computer-aided drafting and design (CADD) does what planners want of it, with the assumption that 'what planners want' is not problematic: Teicholz and Smith(1987) ask whether CADD on a PC is a 'productive tool' or a 'toy'. Evaluation, too, for planners is often concerned with the relative merits of different packages for particular purposes. For example Brown and Schoen (1987) evaluate three CADD packages for their usefulness in environmental analysis, plan preparation, plan analysis and presentation and make recommendations about the best software for the job.

Clearly, in much discussion of innovations in planning there is either implicitly or explicitly an assumption that the innovation in question will produce 'better decisions' or better planning which will in turn help to solve problems or improve the quality of the environment. The early computer modelling efforts of the 1960s and 1970s for example were introduced to help solve society's problems and were based on the belief that computer models were political and value-neutral decision support mechanisms. But as Klosterman (1987,444) suggests: "In fact computer models, analyses and forecasts are based not on universally accepted bodies of theories and uncontested facts, but rather on tentative hypotheses, preliminary assumptions and incomplete data. As a result, computer modelling and analysis necessarily involves numerous choices in the selection of data, the application of computational procedures, and the analysis, presentation and distribution of results. These choices are inherently political because they help shape the analysis results, the perception of problems and the definition of potential solutions - thereby determining 'who gets what, when and how'".

There are a whole series of different 'production' and 'consumption' interests in relation to the quality of the environment and different groups with different perceptions of problems. Which of these interests or groups has benefitted most or was intended to benefit most from computerisation? Kennedy in a rare discussion of these issues in relation to Bradford City Council's corporate policy on new technology places the emphasis on ensuring 'that developments in new technology do not further disadvantage the poor, the handicapped and the elderly in society. Instead the policy was designed to ensure that new technology was used to help those very groups'(Kennedy 1987,29).

In the same way that the use of computer systems may have potential consequences in the wider environment that planning is seeking to control, within organisations, such as planning agencies, it also seems appropriate to see the introduction , development and use of new computer systems as inherently 'political'. Pettigrew(1980) describes how interest groups within organisations may develop from the way functions and activities are divided up; and how interest groups evolve in response to intra-organisational and environmental changes. Organisations therefore are to be seen as being composed of competing interest groups 'each with its own form of rationality and each competing for space in the problem solving and strategy formulation processes of the organisation' (Pettigrew 1980,41). A computer system represents a scarce resource over which groups may compete for control but it also threatens to disturb and disrupt working practices by automating and changing information-processing activities with consequent implications for the quality of working life.

There is a considerable literature on job satisfaction and computerisation. Mumford and Weir (1979), for example, have noted how even where the same computer system was being implemented in different places for the same purpose, some of the jobs produced had much more interest and variety than others even though they dealt with the input and output of the same system. But there is a noticeable gap in the planning literature on the implications and impacts of the introduction of computer systems on the work experience of planners and others and on the organisation and management of planning functions. If new developments in computer and communications technology are to be appropriately evaluated then I am suggesting that such intra-organisational effects need to be considered and incorporated into the evaluation process. This is based on the assumption that the impact of new technology is not deterministic and that organisations have choice (whether they recognise it or not) about the objectives to be pursued and the means of achieving them. Even allowing for the existing power relations within organisations, by considering the jobs of planners and others at the design stage the issue of work design and job satisfaction may get on the agenda.

This paper looks at the findings of a research project carried out in the mid 1980s which attempted to assess the impact of package systems for processing planning applications in a sample of District Planning Departments in England and Wales. The focus for research were the staff in development control sections of the planning authorities. Typically there were also forward planning sections and sometimes separate research and design sections. Though the research looked at the impacts and implications in other sections of the planning department, the report here is restricted to development control. The research was based on participant observation in four departments and depth interviews with key actors in 7 other departments and is described in detail elsewhere (Farthing 1986a). The research was motivated by a desire to take a user perspective on computerisation, one in which people actually using or affected by the system were asked to assess what had been achieved in relation to their work rather than to take the perspective of the system sponsor (ie the person or persons who decided that a new system was needed). In what follows there is a brief description of the typical strategy adopted for implementation in the authorities studied; an examination of what contributes to job satisfaction for staff in planning departments; the identification of those jobs changed by the introduction of the computer system; a description of how jobs were changed and some conclusions about the impact on job satisfaction.

STRATEGIES FOR IMPLEMENTATION

An analysis of the strategies adopted in the case-study authorities for the introduction of computer systems in development control suggested that strategy for implementation followed the following model. First, after some preliminary discussion of the scope for computerising planning activities and an examination of the available systems including in-house developed software, a decision was taken on the software to be used (sometimes within hardware constraints imposed centrally). Second, the consequences in terms of jobs were identified (job losses, changes in job content and the need for training) sometimes in association with trade union representation. Finally, the system was installed and problems were tackled as they arose.

The lessons from this account are that objectives for computerisation tended to be implicit rather than explicit. Where there were objectives they tended to be dominated by efficiency and cost-cutting which reflected the pressure local government was under in the early to mid-1980s in Britain to reduce capital and revenue expenditure. Sometimes planning was seen as a guinea pig/test-bed for office automation from which lessons could be applied elsewhere in the authority. Though job satisfaction (and the elimination or reduction of time consuming and repetitive tasks) were mentioned by a number of authorities in their statement of objectives, in practice this was not consciously planned for during the process of designing staffing changes for the post-implementation period. O&M units and Management Services departments defined their work as seeking maximum efficiency gains. There were no plans for major organisational re-design and re-consideration of how planning functions could or should be carried out. The assumption was made that the organisation and management of planning for development control was as good as it could be. The computer would give the final polish to a very good system.

JOB SATISFACTION AND WORK EXPERIENCE

Job satisfaction has been defined by Mumford and Weir (1979) as a good 'fit' between an employee's job expectations and the job requirements as defined by the organisation. Without wishing to apply their extended model of job satisfaction (or their methodology for measuring it), it was decided to investigate in an exploratory way factors contributing to job satisfaction for staff in development control sections of planning departments. Investigation focused on what Mumford and Weir call task-structure 'fit', that is the nature of the demands made on the employee by his/her job. Key components of satisfaction are likely to relate to the number of skills used, targets and feedback mechanisms, the identity of the task and its separation from others, and the degree of autonomy and control in the performance of work. These are the areas most likely to be affected by changes in technology.

There seemed to be differences between, on the one hand, clerical and administrative staff and, on the other, professional planners. For clerical and administrative staff, three broad components seemed to structure their work and contribute to their satisfaction:(i) the content of their routine activities (typing, filing, form filling... etc); (ii) dealing with enquiries and 'phone calls from applicants or their agents seeking planning permission (especially those agents who were seen as 'problem agents' in terms of the way they dealt with the department during negotiations); (iii) relationships with professional planners, including interpersonal relationships.

For professional planners in development control whose main task was making recommendations on proposals for various types of development, the following factors seemed to be important: (i) negotiating with applicants/ agents over the details of planning applications (ii) the challenge produced by the nature of planning applications themselves (for example, whether they were politically contentious, whether 'design' was an issue, whether there were policies to cover the type of application etc);(iii) relationships with senior officers (the backing they gave to staff and the support in framing recommendations); (iii) relationships with other professional planners in the section.

The implication of these findings were that the tasks undertaken by clerical and administrative staff, as would be expected, were more likely to be affected by potential computerisation and automation of routine document production and record-keeping than those undertaken by professional planners. The latter had jobs which required interpretive skills and judgements and the ability to negotiate deals with applicants.

THE DISTRIBUTION OF JOB CHANGES

Some tasks/activities are eliminated by the introduction of the computer; others remain unchanged; yet others are created. The balance between these changes in activity is determined by choices made within the organisation about the objectives of introducing computers systems. The way the post-installation activities are grouped together into 'jobs' and the way these 'jobs' are re-distributed to new and existing staff determine the impact of computerisation on job satisfaction.

In the authorities studied establishments were being reduced at the time of the introduction of the computer as part of general public expenditure cuts. In some cases the computer also played some part in justifying job losses in activities where it could be seen as a direct replacement of human labour. Typically, these were in the areas of document and letter production, and the production of statistics of various kinds. In general though the short-term aim was not to reduce staff numbers partly because it was recognised that introducing a computer system was a major organisational innovation that might create extra work (at least during the installation phase); partly because maintaining existing staff was seen as part of the 'tactics' of implementation which would maximise support for the new system; and partly because opportunities were seen for capturing more information (records of past applications for example) on the computer system. For most authorities therefore there was considerable continuity of staffing over the period of introduction of the computer and an opportunity to assess the impact of job changes on job satisfaction.

Whose jobs were changed by the introduction of the computer? There are a variety of roles in relation to a computer and therefore a variety of different 'users' (Langefors 1978). The traditional common sense view of a computer user is a system operator, someone who interacts directly with the computer via a VDU. In general, a higher percentage of clerical and administrative staff than professional planners were found likely to interact directly with the computer. Once again, it is possible to see the exercise of choice producing variations between authorities. In one small rural authority a conscious decision was made to spread interaction with the computer amongst as wide a group of clerical and administrative staff as possible, in another large urban authority, only one person was able to use the computer. This choice was bound up in part with the way that 'computer skills' were perceived. Restriction on computer use was linked to the way in which some jobs were upgraded to recognise the new skills of system operators.

Where planners did interact with the new computer system it was more likely to be through a human intermediary. Planners tended to fall into the category of information consumers, where the computer system generated information useful to their work, or information suppliers, where reports and data they produced were fed into the computer.

HOW JOBS ARE CHANGED

Clerical and Administrative staff

Where 'clerical and administrative jobs were changed', they were likely to be re-defined substantially in relation to direct use of the computer.

Typists become word processing operators, for example. Others were given responsibility for the new task of inputting data into the system or for outputting pre-defined standard letters, reports, lists etc. Not surprisingly, therefore, the experience of using the computer (how easy it was to use, the extent of user support, the quality of training) become important to their experience of work and therefore their job satisfaction.

Professional planners

In general where planners' jobs were changed they were unlikely to be re-defined significantly in terms of direct interaction with the computer. As information consumers they tended to receive infrequent outputs from the system. Unlike many clerical and administrative staff, they were 'voluntary' users of the system in the sense that they had alternative ways of obtaining the information necessary for their jobs (making recommendations on applications for development). These alternative manual means such as card indexes, maps, and files predated the computer system and in most authorities continued to be maintained despite the introduction of computer technology In one authority where attempts were made to discontinue the manual system to force use of the computer system, this was extremely unpopular and led to the maintenance of secret manual systems. (For a general discussion of why planners did not use the data stored on computer systems for decision support purposes see Farthing(1986).

The nature of the experience of direct interaction with the computer was determined by whether it contained the information they wanted and how easy it was to retrieve the information. Because they used the system infrequently they tended to forget how to use it or found that because of system changes that 'a different set of buttons' had to be pressed). Because the system was peripheral to their main job, it did not have a big impact on their experience of work and any limitations of the system were not central to them.

One exception to the generalisation about the impact of the computer on planners' work experience relates to the experience of the systems administrator, usually a planner whose job was in part or in whole re-defined in terms of responsibility for implementing and managing the computer system and for giving support to other users in the department. For the most part new skills in designing and manipulating systems had to be acquired and applied by these planners providing a new challenge and new career opportunities for some in data management.

IMPACT ON JOB SATISFACTION

Clerical and administrative staff

Amongst clerical and administrative staff who interact directly with the computer there appear to be variations in experience between individuals depending on their general attitudes towards the computer before its introduction. The results of the research also suggest that job satisfaction may be a function of the stage of implementation of the system with the early stages of implementation being the most stressful and threatening for staff directly involved since extra work may be involved and new skills may have to be learnt and applied. The capacity of computer systems to do what was expected of them in terms of speed of processing and in the functionality of software was a third factor affecting the experience of working with them and therefore job satisfaction. Finally, decisions on job content and design taken during the implementation can affect the experience of work. Having said this it is possible to identify a number of positive and negative consequences for clerical and administrative staff whose jobs have been redefined to include computer interaction:-

Positive
- computer relieves monotonous typing
- computer is a more pleasant way of working
- more variation in job (bit of typing, printing etc)
- using the computer is a bit of a challenge
- enhanced status and pay

Negative
- computer introduces different type of monotony
- loss of control over job (as the pace of the machine controls pace of work)
- health problems (eye strain, headaches etc)
- re-scheduling of working hours to fit in with the availability of the computer

For those clerical and administrative staff who do not interact with the computer, the impact on job satisfaction appears to be essentially negative. There is reduced status, fear of redundancy, and less opportunity for sharing work amongst staff since special skills are needed to use a VDU.

Professional planners

Turning to the impact of job changes on the job satisfaction of planners, once again it is possible to distinguish between those who interact with the computer directly and those who don't. Amongst the former group, there were very positive impacts for the systems administrator. He/she faced a new and absorbing challenge which increased his/her power within the organisation as people became dependent on his/her skills. The job gave ample opportunity for autonomy, variety and feedback in work experience. This did, however, raise job boundary issues with traditional computing and programming staff in other sections in local government.

Other planners who used the computer on an infrequent basis found that the introduction of the computer had a negligible impact on their experience of work and job satisfaction.

For the majority of planners in development control who did not directly use the computer but who supplied information to the system perhaps through the 'case reports' and recommendations which were input by clerical staff there was also little impact on their job satisfaction. However there was some resentment at attempts in some authorities to get planners to re-schedule their work (by for example producing case reports earlier in the Committee cycle) to allow a more even flow of reports and recommendations to the staff who had to input this material into the computer. There was, then, some resentment at having to work to the pace of the computer and at the potential loss of control over their work.

CONCLUSION

Planners are currently neglecting evaluative issues in their enthusiasm for geographic information systems, expert systems, computer-aided design. It may be that current concerns in the literature reflect the current stage of the cycle of computer adoption. Barrett and Leather (1984,15) describe a cycle in the 1970s of 'motivation/innovation generated by computer technology, followed by what might be characterised as a mixture of over-enthusiasm and demand outstripping supply, then disillusion or learning and new development and back to the beginning of the cycle with a new array of possibilities to excite new potential users.' We may therefore be at the stage of enthusiasm in relation to these technologies and the more reflective stage has yet to be reached. However it is worth learning the lessons of previous experience with the implementation of computer systems.

This paper has suggested that the introduction of computer systems has impacts on job contents and job boundaries for a range of staff in planning departments. Planners have, by and large, managed to avoid any undesirable consequences and some have achieved substantially enriched jobs. The innovations currently being advocated will also have impacts on working practices which may bear more closely on planners since they are aimed directly at them. These issues should be addressed at an early stage in the implementation process rather than neglected.

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IMPLEMENTATION OF GEOGRAPHIC INFORMATION SYSTEM TECHNOLOGY (GIS) FOR USE IN URBAN PLANNING AND MANAGEMENT

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ABSTRACT

Many urban planning and urban management institutions are increasingly looking toward geographic information system (GIS) technology as a means of efficiently handling data base analytical and maintenance needs.

Those responsible for reviewing and procuring a system for their organization are faced with many technical and implementation issues which must be addressed during the selection of appropriate geographic information system technology. Some of these issues include selection of the appropriate hardware platform (many alternatives exist today and they are rapidly changing); selection of software (should it be developed in-house, or should one of the many commercial packages which offer a variety of data models and functionality be procured); data conversion (data base design and pilot testing are critical before large-scale data conversion takes place); and, finally, what are the institutional and staffing ramifications of bringing this technology into an organization.

This paper will review these issues using experience gained from several recently installed GIS systems in urban planning and management-related organizations.

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