Developing GIS Tools to Integrate MCDM Models for the Analysis of Bank Branch Closures

Lihua Zhao and Barry J. Garner
School of Geography, The University of New South Wales, Sydney 2052
Llihua_zhao@hotmail.com; B.Garner@unsw.edu.au

Abstract. In this research, MCDM methods have been integrated with a GIS to provide the means to prioritise branch closure procedures based upon a variety of different choice criteria and on the importance (weight) a decision maker might attach to these. Both MCDM and GIS are well established methods and fields of research. Their integration, however, seems at best an emerging field. This paper describes the tools developed to link, using loose coupling, the MCDM models in the CDP package with a GIS. Two ArcView GIS functions have been developed and used to link GIS and CDP packages through DDE data communication, and some menus and buttons have been added to the ArcView graphical user interface. The approach here is to represent the methodology for the development of effective spatial decision support environment (SDSS) for branch bank rationalisation by integrating MCDM and GIS. This decision making environment is designed to enable the decision maker to evaluate the applicability of the procedures and techniques in order to generate decision making scenarios and finally implement the decision process by re-evaluating different scenarios based on his/her own familiar concept and knowledge.

1. INTRODUCTION

Bank closures, an important part of branch network planning and management involving the process of selecting branches from a number of potential alternatives, is a complex decision making process. It involves conflicting quantitative and qualitative criteria and multiple decision makers. The decision making process can benefit from the use of Multi-Criteria Decision Making (MCDM) techniques that can be used to facilitate the decision making process by making the process more explicit, rational, and efficient (Hobbs *et al*., 1992).

A number of different models have been proposed to structure and solve multi-criteria decision problems and computational methods developed for their application. In this research the analysis is based on two models: the Simple Multi-Attribute Rating Technique (SMART) and the Analytical Hierarchy Process (AHP). There are two main reasons for choosing these particular models. Firstly, in principle, they possess all of the capabilities required to address the considerations involved in the context of branch closure decision making. For a review of the models, methods of implementation, and their application see Corner and Kirkwood (1991) for SMART and Saaty (1977; 1980; 1992; 1995) for AHP.

Secondly, using different methods to suggest alternative solutions provides consistency checks, stimulates insights, and helps resolve discrepancies in the results that assist decision-making. The results provide insights into the use of different techniques when confronting decisions based on multiple criteria. The approach recognizes that no single method is best for different users. The results confirm that scenarios generated by alternative MCDM methods can differ and that a multi-method approach helps build insight and confidence. This is consistent with suggestions made by various researchers of using two or more multi-criteria solution methods (see Corner and Buchanan, 1997; Hobbs and Horn, 1997; Salminen *et al*., 1998).

The highly spatial characteristic is one more critical element in banking business, branch closure decisions regarding customers, markets, profitability, branches, and performance relate to the market area where the bank and branches are located. So state-of-art GIS is the most important ingredient in the decision making system, instead of general DSS.

GIS has long been used for decision support, mainly for their map design, comparison, and spatial analysis capabilities. This capability can be further enhanced by integrating GIS with MCDM models to create a SDSS that will provide decision makers with easier access to GIS procedures, allow them to assess the performance of different MCDM techniques, evaluate the importance of the selected criteria, enable them to evaluate the applicability of the procedures and techniques in order to create decision making scenarios and, finally, to implement the decision process by re-evaluating alternative scenarios in the context of their own knowledge and understanding of the problem.

Within the framework of GIS, MCDM models have been increasingly applied in the last five years as a useful methodology for spatial decision support in land-use related problems. Several approaches to integrating GIS with MCDM models have been developed, ranging from a simple integration based on loose coupling of one or more MCDM models with a GIS (Carver, 1991; Pereira and Duckstein, 1993; Jankowski and Richard, 1994; Jankowski, 1995), to a closely integrated system where MCDM models become an integral part of the

GIS (Janssen and Rievelt, 1990; Eastman *et al*., 1993; Tkach, 1997).

The goal of this paper is to present the methodology used to integrate the DecisionPlus (CDP) MCDM package with ArcView GIS to develop a SSDS suitable for prioritising branch banks for closure based on a variety of different choice criteria and on the importance (weight) attached to these by decision makers. In the paper, Section 2 introduces the general decision support requirements for a SDSS and the various methods of software integration are reviewed. Section 3 introduces the software components that form the basis of the SDSS developed in this research and the approach adopted for integrating these to develop the system. Section 4 focuses on the interface design for the system, and a preliminary application of the integrated system is presented in Section 5.

2. DECISION SUPPORT ENVIRONMENT FOR BRANCH BANK RATIONALISATION

2.1 Approaches to systems integration

There has been a considerable discussion in the literature of the different methods of integrating external software packages with GIS, and a number of different viewpoints exist. The most widely accepted classification is based on the architectural characteristics of the method of integration according to the degree and form of data exchange or sharing between GIS and the external package(s) (Goodchild *et al*., 1992; Nyerges, 1992; Fedra, 1993; Goodchild *et al*., 1993). In this classification a basic distinction is made between loose coupling and close coupling (Figure 1).

In loose coupling, the two software systems exchange input and output files by means of an efficient interchange of data between the two packages. At this level of integration, no system modification or programming is required and the two systems run independently. Close coupling, on the other hand, involves writing some form of program to automate or facilitate the integration process. The systems share both the communication files and the common user interface. Close coupling normally involves modifying the operation of the GIS software itself and a variety of mechanisms are available in most GIS packages to assist with this.

Another approach to classification is that based on the direction of integration between systems which recognises the difference between one-directional, two-directional, and dynamic integration (Anselin *et al*., 1993). In one-directional integration, there is a single, one-way flow of information between the GIS and the decision support system and the flow may originate from either. In the system developed here, the data generated in GIS serves as the input data to the decision support system. In the case of two-directional integration, the systems are linked through a two-way flow of information. In most research employing this approach, the GIS generates data that is input to the decision support system for processing, the results of which are subsequently transferred back to the GIS and added to the existing attribute data base as new data which may then be further analysed or displayed. Dynamic integration is a more advanced form of two-directional integration that enables data to move back and forth between the two software modules in a more flexible way determined by the user's needs. This type of integration is especially useful when the decision-maker wants to revise the data or the decision scenarios after examining the results obtained from an intermediate iteration.

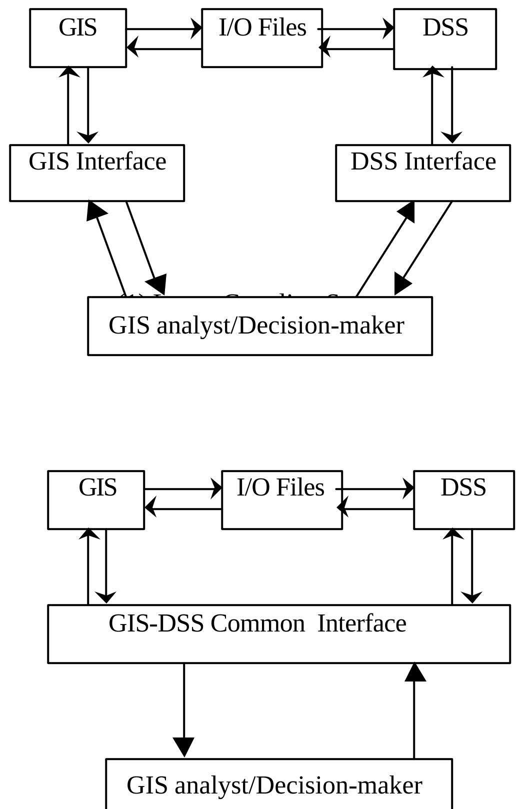


Figure 1: System integration - Loose and Close coupling

2.2 Why the loose coupling approach?

The aim of integrating GIS with MCDM models in this research is to develop a tool that meets the requirements for advanced application in identifying preferences for branch bank closure. The integration approach significantly contributes to the embedding of multi-criteria problem handling methods within a spatial information system and to fuse capabilities available in the individual systems to provide some desired level of usability. Several factors favour the choice of the loose coupling approach for developing the SDSS in this research.

Firstly, both MCDM and GIS are well-established tools but essentially separate fields of research. The state-of-art software now available may be used directly when loosely coupled and this integration technique is the basis of most approaches that involves the integration of systems (Parks, 1993).

Secondly, GIS and MCDM software packages are typically proprietary systems and as such they are developed and maintained externally with limited opportunities for local modification. It is not necessary to start from scratch to develop a closely coupled integrated system. At a technical level, MCDM packages are of comparable size and complexity to a GIS, consequently re-implementation of a MCDM package within GIS would be a daunting and costly task.

Finally, an important feature of more recent GIS software development is that it is now much easier to customise them or loosely integrate them with other software packages for specific GIS-based applications. There is some value in determining the limits of integration possible using existing systems and in identifying the additional facilities which would facilitate the task of integration. An alternative form of the integration problem is that of coupling GIS and other systems to deliver the capabilities needed to satisfy the requirements of an application.

The above considerations has suggested that the loose coupling approach is appropriate for the task addressed here. Following the argument of Abel *et al*. (1994), the approach to the problem of systems integration adopted in this research is to loosely couple pre-existing systems to fuse a desired set of capabilities with some targeted degree of usability of the integrated system. A similar approach has been used in developing integrated systems for land use applications based on raster data (Janssen and Rievelt, 1990; Carver, 1991; Fedra, 1993; Nyerges, 1993; Jankowski and Richard, 1994). While the pre-existing software packages themselves are not actually modified, their integration typically involves the design of specialist linkage components to facilitate coupling. In this context, identifying the types of linkage components needed is one of the core issues of the systems integration problem.

2.3 Requirements and criteria for a SDSS by integrating GIS and MCDM

It is widely recognised that GIS has the potential to support additional types of analysis than the purely spatial but that this potential has not yet been fully realised (Goodchild *et al*., 1992). The development of SDSS based on the integration of GIS and MCDM models is an important one of these and a number of researchers have addressed the requirements and criteria for developing SDSS. An important contribution is that by Densham (1991) who lists the basic criteria for a decision support system. Carver (1991) argued that GIS typically contain spatial analysis techniques, DBMS, graphical display and tabular output, but ideally SDSS should provide a framework for the integration of these GIS functions with the expert knowledge or expertise of the decision maker and advanced analysis capabilities of MCDM.

Another characteristic of a SDSS is communication among the various software packages. The ability to pass data and instructions between different software packages is fundamental to the development of more sophisticated spatial analysis techniques that are invisible to the end user.

Heywood *et al*. (1995) have identified the criteria for integrating SDSS with multi-criteria modelling and suggest that, from the viewpoint of decision-makers, the multi-criteria modelling environment has to be transparent, robust, easy to use, and flexible. Some GIS-related software packages already have incorporated models for decision-making capability, for example IDRISI and DEFINITE.

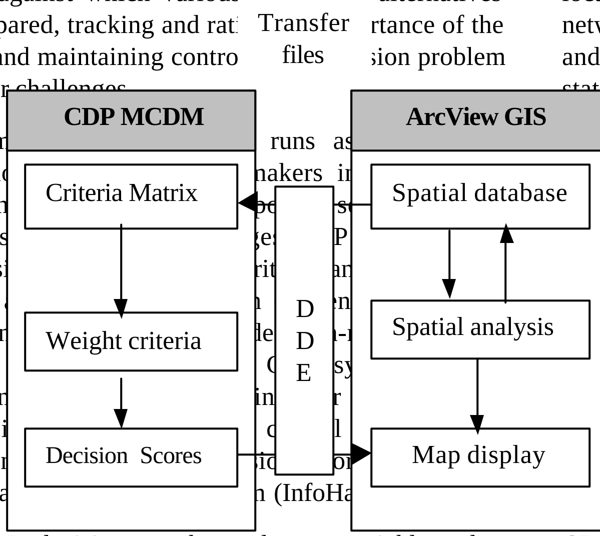
3. INTEGRATING GIS AND MCDM SOFTWARE

3.1 The ArcView GIS software

ArcView, developed by ESRI, is one of the most widely used commercial Windows GIS packages. It is primarily designed for the manipulation of spatial vector data, extended with optional modules for the analysis of network data (Network Analyst extension), raster data (Spatial Analyst extension), and other types of data. The object oriented Avenue script language supported by ArcView allows external programs or computer packages to be integrated into the ArcView environment to offer enhanced functionality for spatial analysis, and the customising facility ArcView GUI (Menus, Buttons, Tools) provides a user friendly approach to using the integrated tools. ArcView also has integration capabilities that allow users to access system resources (i.e. clipboard and system variables), issue operating system commands inside ArcView, and to support Dynamic Data Exchange (DDE) in the Microsoft Windows environment and Remote Procedure Call (RPC) in Unix.

3.2 Criterium DecisionPlus MCDM software

Much of the information typically needed for making decisions is incomplete, uncertain, or otherwise unavailable. This is complicated by the fact that obtaining better information is generally time consuming and/or expensive and therefore cannot be undertaken without careful consideration of the expected benefits of the investment. In other words, “if I had more or better information, what is the likelihood I would make a different decision?”. When facing the decisions which are difficult and involve many different criteria against which various options or alternatives are compared, tracking and rat… rtance of the criteria and maintaining contro… sion problem are major challenges.



Criterium … runs as … applicati… nakers in … presentin… can be us… ge… P … let decisi… rit… an … directly … mouse an… de… each of … inputs an… in… The deci… results ar… the packa… (InfoHa…

With CDP, decisions can be made more quickly and at lower cost than more traditional methods. The benefits of using CDP include:

- providing immediate feedback for ‘what-if’ analyses
- assisting in reducing and focusing data collection efforts, and allowing decision-makers to concentrate on the "critical few" criteria
- quantifying trade-offs and uncertainties
- facilitating consensus building
- documenting the decision process
- saving time and money.

3.3 Dynamic Data Exchange (DDE)

DDE is a Microsoft Windows protocol that lets two or more programs running under Windows simultaneously exchange data - a form of interprocess communication that uses shared memory to exchange data between applications. Applications can use DDE for one-time data transfers and for ongoing exchanges and updating of data.

DDE enables applications to be set up to pass both data and commands from one software package to the other. Normally one application requests the transfer and the other responds. The application that does the requesting is called the *client* application, and the application that responds is called the *server*. The information passing between client and server is called the *conversation*. A client application can use DDE to establish a link to an item in a server application. After such a link is established, the server sends periodic updates of the linked item to the client, typically whenever the value of the item changes. Thus, a permanent data stream is established between the two applications which remains in place until it is explicitly disconnected.

This mechanism enables two applications to continuously and automatically exchange data and create a relationship between data stored in one application with data stored in another. Both applications must support DDE to be able to participate in this data exchange, and all applications must be located on the same machine: DDE will not run over a network. Basically, DDE allows the automation of cut and paste actions, the export of files, calculation of statistics for specific locations. From an end user endpoint, automation via DDE creates an easy to use, seamless application.

The integration between software packages is generally platform dependent. DDE is supported by all the Microsoft Windows operating systems (Windows 3.1x, Windows 95 and Windows NT). Communication can take place between any software applications that support DDE. ArcView fully supports DDE either as a client or as a server (ESRI, 1995).

DDE is essential to developing a SDSS that utilises several different applications in the context of the problem being addressed. DDE enables ArcView and CDP software packages to have conversations with each other (ESRI, 1995; Razavi, 1995; Alexander *et al*., 1997; Zhao and Garner, 2001). During these conversations, data can be passed between applications, calculations performed and the ‘value-added’ data passed back to the client application. In addition, all of these transfers are transparent to the end user.

3.4 The framework of the system integration

The SDSS developed in this research is designed around the integration of the Criterium DecisionPlus 3.0.3 (CDP) software with ArcView GIS 3.2 using Dynamic Data Exchange (DDE) in the Microsoft Windows environment (Figure 2). Following the arguments by Jankowski (1995), the loose coupling architecture is used for linking together the two software packages by means of a bi-directional data transfer in which ArcView is the visualisation engine and DecisionPlus the criteria data analysis engine. Its main objective is to provide an efficient way to gather spatial criteria, evaluate branch alternatives, and display the results of spatial and multi-criteria analyses.

In this system, GIS database management functions are used for managing data derived from different sources and formats, and integrating data based on spatial relations. The analytical functions facilitate spatial manipulation and generate data based on spatial analysis, and the visual display functions are used for displaying the results of spatial analysis and the decision scores from the MCDM models.

The multiple criteria evaluation process is realised using the CDP software, the functions of which include the enumeration of criteria preferences, selection of aggregation functions, the generation of decision scores, and sensitivity analysis.

Figure 2: GIS_MCDM System Integration.

The results of analysis from ArcView can be presented in a standard attribute table (the decision table), the rows of which contain the set of branch alternatives, the columns the set of decision criteria, and the table elements the criteria scores. Then the decision table can be exported to CDP where the multi-criteria decision-making analysis is performed. A weighted decision score is then calculated for each candidate branch bank by using the AHP or SMART models, and these are exported to ArcView for display.

In the system presented here, both ArcView and CDP support DDE. ArcView is used as the client application and sends data to CDP. When acting as a client, ArcView can pass commands to other applications, instructing them do such things as open files, select records, or transfer data to ArcView. The decision table in ArcView can be exported directly to CDP using DDE and a program written in Avenue. The following sub-sections explain the DDE conversation, how data is imported to CDP, and theArcView Avenue script at a more technical level.

3.4.1 Data conversation in DDE

Two basic concepts are essential to the understanding of how a DDE conversation works:

(1) definition and
(2) (2) data exchange methods.

There are two components that define a conversation in DDE: the application name and the topic (ESRI, 1995). Each application has a unique name, generally this is the name of the application without its extension (e.g. ArcView, EXCEL or ACCESS). A topic refers to the subject of the conversation. The subject could be a file name or a more general topic (e.g. system). Together, the application name and topic uniquely define each conversation.

Once the conversation is initiated, specific methods are available in DDE for exchanging information. These methods are application specific. ArcView supports three basic data exchange methods: Execute, Request and Poke. Execute sends a command string from the client to the server application. Here ArcView acts as the client application and sends commands to CDP. Request instructs ArcView to get data from CDP for processing (a flow from server to client) and Poke activates a reverse flow enabling ArcView to send data to CDP (a flow from client to server). The application in this research demonstrates the use of all three DDE methods of exchanging data.

3.4.2 Data imported to DecisionPlus from an ArcView attribute table

In the CDP software, DDE is implemented using the Paste Link option from the Edit menu, which is only available when data has been copied to the clipboard. The Paste Link command is similar to the Paste command except that a DDE link is set up between the CDP and ArcView that puts the data into the clipboard. This allows the data to be transferred immediately between the applications. There are two ways of importing data from ArcView: (1) pasting tables of data to ‘Brainstorm’ and (2) creating a DDE link to the hierarchy spreadsheet.

3.4.2.1. Pasting Tables of Data to Brainstorm

Brainstorm is a CDP mode allowing alternative criteria to be quickly considered when building a model. Brainstorm results can be saved and recalled when needed. Though a stand-alone capability, brainstorm graphs are most often used to prepare a hierarchy.

A Paste Special menu item exists in the Brainstorm window's Edit menu. This menu command permits the pasting of a table of data, consisting of criteria names, alternative names, and ratings, into a Brainstorm. The pasted data is used to create Brainstorm blocks and alternatives. The rating values are retained and when the Brainstorm is converted into a hierarchy, the rating data is transferred and may be viewed from the rating screen. When a Brainstorm file is saved with such pasted data, the data is stored with the file and is available when Open File is used the next time. The data imported into Brainstorm this way cannot be ‘linked’ back to a source application: only the end result of processing data in CDP can be Poked back to ArcView.

There are restrictions on Data format when importing data to Brainstorm. The decision criteria data that are in an attribute table must be organised in a tabular format with either alternative names as column headings and criteria names as row headings or vice versa (Table 1). The body of the matrix contains rating data, which must be numeric. If some of the information in the ArcView attribute table is unknown, those cells are left blank.

Table 1: Data formats when importing data to Brainstorm

	Alt 1	**Alt 2**	**Alt 3**	**etc...**
Cri 1	2.0	3.1	1.3	
Cri 2	106	190	155	

etc...				

	Cri 1	Cri 2	etc...
Alt 1	2.0	106	
Alt 2	3.1	109	
Alt 3	1.3	155	
etc...			

3.4.2.2. Creating a DDE Link to the Hierarchy Spreadsheet

Elements of a decision are organized to form a tree structure in CDP. This visible structure of a decision is called a Decision hierarchy. In addition to the usual graphical representation of the hierarchy model, the model information also can be put into a spreadsheet format (a Hierarchy Spreadsheet). This allows the user to review and edit the values of the weights and ratings directly, view the associated priorities, and cut and paste data to and from the spreadsheet. A block of cells containing ratings of alternatives may be imported from a spreadsheet that supports DDE links into the Hierarchy Spreadsheet.

If some data in ArcView are changed after the data have been imported into Brainstorm, the changed cells can be updated through the DDE link in the Hierarchy Spreadsheet between the two packages.

Because ArcView only supports Manual link - data exchange does not occur automatically; the destination (CDP) must request the new data from the source (ArcView). In the integrated system, attribute data in ArcView need to be exported to Excel, then a 'hot' DDE Link is created from an Excel spreadsheet to the CDP Hierarchy spreadsheet. This means that if data in Excel changes, the changes will be automatically forwarded to CDP, and all calculations updated. This is efficient when doing "what if" analysis to get different ranking priorities based on different sets of criteria.

There are some special requirements when linking data to a CDP Hierarchy Spreadsheet:

- Only one 'live' link is supported at a time. Creating a new link destroys the existing link.
- Data cannot be entered or copied into a range of a data set that is receiving information from a DDE link, that is, a cell cannot be receiving values from two different links simultaneously.
- If a model is closed, the link must be recreated by hand when the model is next loaded. Information on the last link may be found in the Notes of the Goal block.
- When a data set is saved, information about DDE is also saved.

3.4.2.3. The ArcView Avenue Script and ArcView application framework

Avenue is an object oriented programming language and development environment that is part of ArcView. Avenue provides a high degree of uniformity, stability, and reusability. As in all object-oriented systems, the emphasis in Avenue is on identifying objects and then sending them requests (ESRI, 1994). ArcView's objects are members of a class hierarchy that are organised into functional categories related to all aspects of the application and it can be used to create ArcView applications.

Developing ArcView GIS applications requires familiarity with its object model that describes objects and their attributes, operations, and relationships to other objects. ESRI has adopted the graphical notation used in Object Modelling Technique (OMT) to present these relationships (Rumbaugh *et al*.,1991; Razavi, 1995).

4. INTERFACE DESIGN FOR A GIS-BASED MULTI-CRITERIA DECISION MAKING SYSTEM (GIS-MCDMS)

4.1 Development methodology for an ArcView GIS application

The development methodology is one of the most important parts of implementing a GIS project. Razavi (1995) has proposed the structured methodology for developing ArcView GIS applications, which comprises the following stages:

1. Requirement analysis
2. Prototyping
3. Construction
4. Structured testing

The four stages constitute the bedrock of effective GIS application development. The purpose of requirements analysis is to acquire a complete understanding of the problem and to specify the specific requirements of the software to be used to resolve the clearly defined problem. Prototyping begins with customisation of the interface controls and project components and further define and diagram the data flow. In the construction phase, the Avenue scripts required for the application are developed. The scripts are usually linked to a control interface and perform their work independently. The purpose of structured testing is to identify application software defects and to resolve as many of these as possible.

The techniques and procedures in Razavi's (1995) structured methodology have been applied in developing many software applications, details about which are provided in (Demarco, 1979; Davis, 1990; Martin, 1991; Rumbaugh *et al*., 1991). The interface prototyping of the integrated system will be described and illustrated briefly in the remainder of this Section.

Section 5 will present a demonstration to test the system .

4.2 Developing the ArcView Application Interface

During the process of application development, human interaction with ArcView program is considered and lets users control the application through the program interface that provides a flexible, friendly interaction.

Interaction with ArcView takes place through the Graphical User Interface (GUI), also known as document GUI (DocGUI). ArcView has five types of document GUIs: views, tables, charts, layouts, and scripts. Each ArcView DocGUI can be created/modified and controls to the ArcView interface may be added either interactively through the Customise dialog box, or dynamically using Avenue script (ESRI, 1994). A diagrammatic representation the object model for the user interface in which a DocGUI class is the starting point for the model is shown in Figure 3. A DocGUI class models the controls used in accessing ArcView GIS documents. The document GUI object consists of the menus, buttons, tools and pop up menus that can be customised. Generally, button bars consist of frequently used menu items and a tool bar is a set of mutually exclusive tool buttons that associate a specific procedure with the cursor.

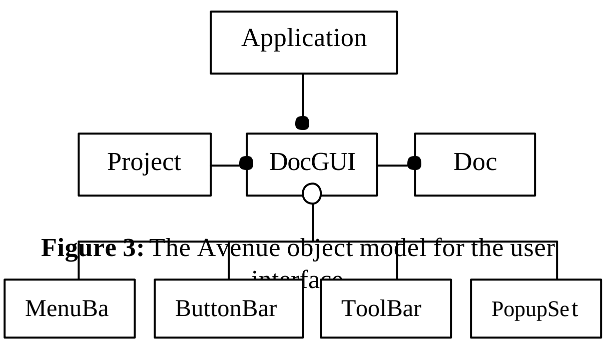


Figure 3: The Avenue object model for the user interface

4.3 Customising and modifying the ArcView Interface

ArcView provides the tools to create and customise the interface for an application. In this application, interface design is in the ARC/VIEW software, the Avenue language can be used to customise the menus and icons as well as to develop the connection between GIS software and CDP software. The Customise dialog box in ArcView is used to customise the user interface. Menus, button bars, tool bars, and pop up menus can be customised so that they contain the controls that meet the user's requirements for a particular application.

View Document GUI and Table Document GUI have been modified to suit the application. The menu system, tailored for the analysis of branch bank closures, has been added to the view document GUI. The menu (Figure 4) consist of the commands which will be used most often for a ranking analysis of branch banks to identify candidates for closure, such as getting the branch trading area data, calculating distances between branches and shopping centres, et cetera. Button Bars consist of frequently used menu items, and create a fast method for executing the same commands available through the menu. The button bars add to the view GUI are based on the Branch Analysis Menu.

In Table GUI (Figure 5), a DDE menu has been added to provide the user with the ability to set up DDE link between the ArcView and CDP packages and transfer data between them. The controls in the menu are based on Avenue scripts. Another Xtool menu has been added to provide some easy to use controls for handling the attribute table data. Some of the more frequently used menu items have been added as Button bars also.

In addition to customising the user interface for ArcView GUI, the project window can be tailored too. A well designed user interface and project window makes an application consistent and easier to use. The customised interface is stored with the project in ArcView. This will change the ArcView system to one that is customised for the particular branch bank closure application environment.

5. DEMONSTRATION

The SDSS outlined above has been applied in a number of pilot studies to test its efficiency. The results reported here are based on a random sample of 49 Commonwealth Bank branches in the Sydney Metropolitan area in 1995, some of which had been closed by 2000. The test of the success of the SDSS is whether or not it can identify these as candidates for closure.

The criteria listed in Table 2 are used in combination as a basis for deciding whether or not a particular branch is a candidate for closure. The criteria are sorted hierarchically by level. Two levels are used in this demonstration.

Some criteria data are generated based on GIS spatial manipulation and analysis. The database management functions in ArcView are used for managing data derived from different sources and formats, and integrating data based on spatial relations. The results produced by ArcView are presented in a standard attribute table (the decision table), the rows in which contain the set of branch alternatives, the columns the

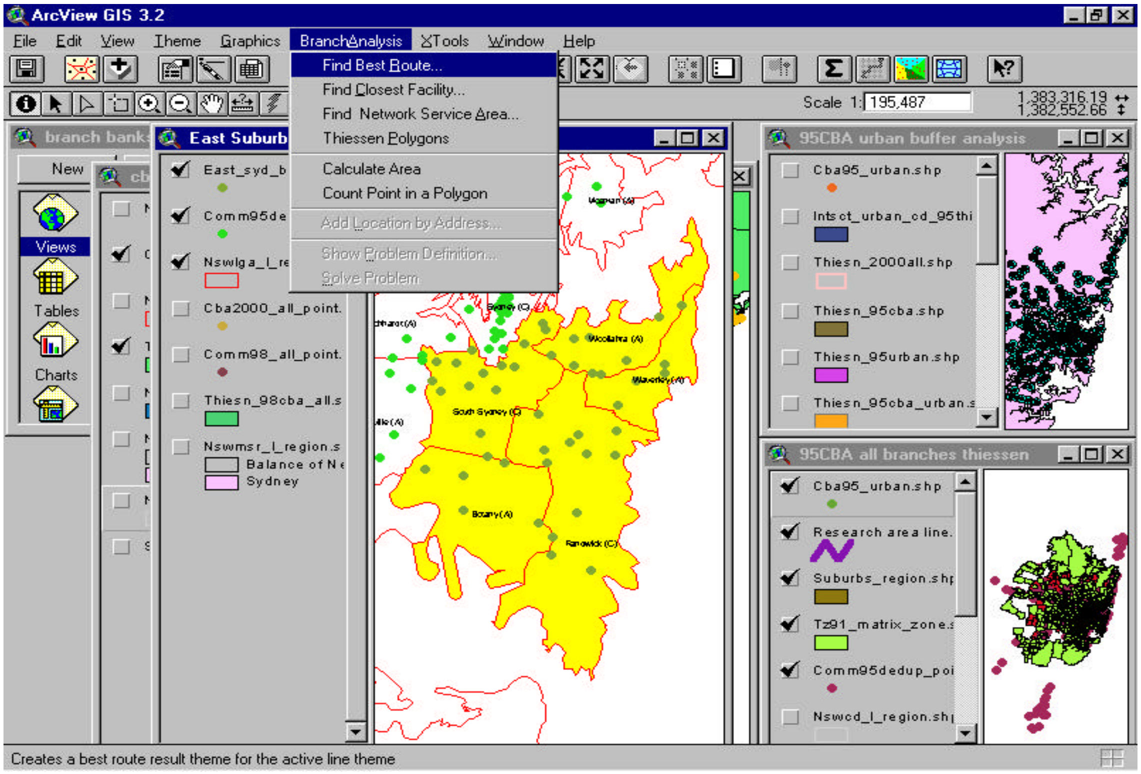


Figure 4: Example of Menus and Buttons Added to View GUI

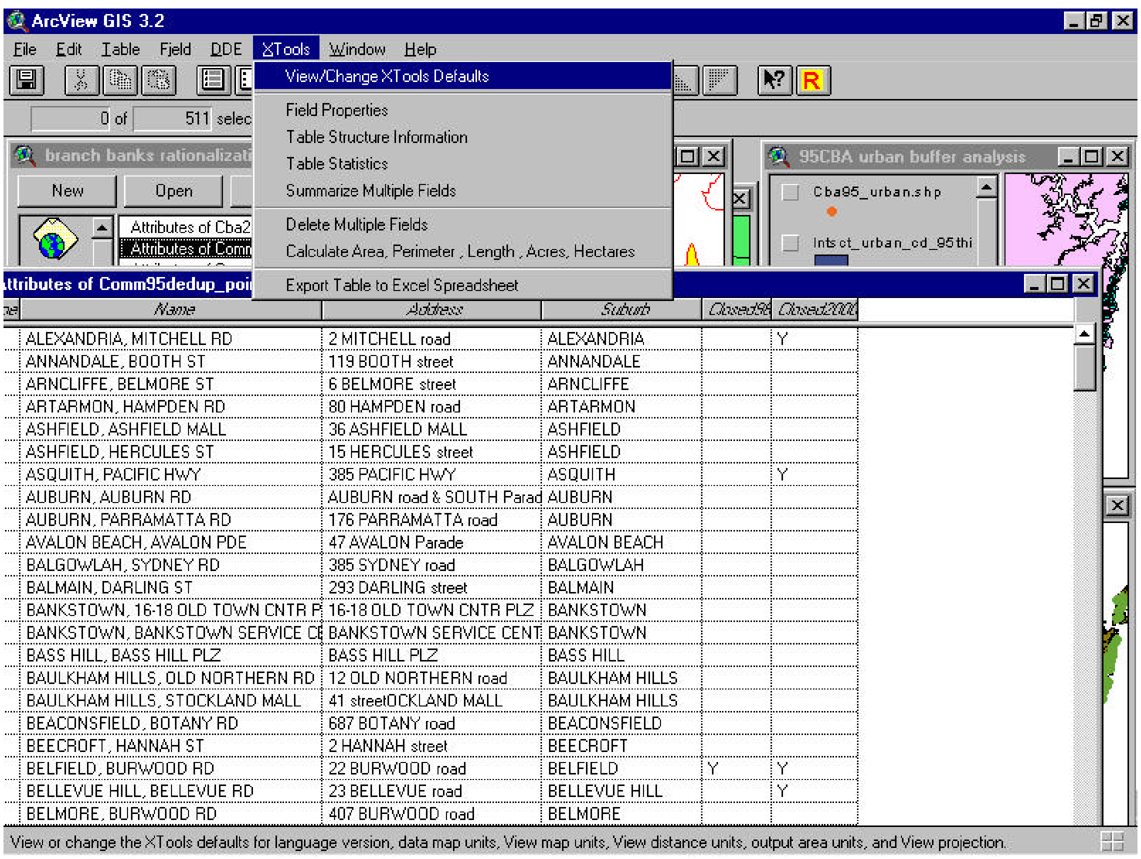


Figure 5: Example of Menus and Buttons Added to Table GUI

set of decision criteria, and the table elements the criteria scores. The decision table can be exported directly to CDP through DDE and a program written in Avenue. The multi-criteria decision-making analysis is performed in CDP, a weighted decision score is then calculated for each candidate branch bank.

Table 2: The Principle Social and Demographic Criteria Determining Branch Profitability

Criteria	Attributes (Subcriteria)
Catchment area specific variables	Banking population (age 15 & over)
	Population (over 15) growth rate
	Competitor's branches
	Average annual family income
	Average age
	Employed people
	Total (small) business No.
	Catchment area
Location specific variable	Small business in 200m buffer zone
	Competitor's branch No. in 200m buffer
	Working population in 200m buffer
	Same bank's branches in 500m buffer
	At shopping centre
	Shopping centers Within 500m buffer
	Present of a free car park
	Proximity to public transport (within1km)

The following steps are involved in importing attribute tabular data from ArcView to Brainstorm:

1. Open the attribute table in ArcView which contains the criteria data.

2. Select Export Data to CDP from DDE menu. This process, implemented through the Avenue script, will run the procedure to select export fields (including criteria and alternative names), create or locate a table of data that fits the above description, export selected data and place Tab Delimited Strings tables onto the Clipboard. The link between the two packages is also established.

3. In CDP, select the Paste Special menu option from Brainstorm's Edit menu. From the Paste Special dialog box (Figure 6), indicate whether the rows represent criteria and the columns alternatives or vice versa by selecting the appropriate option button. The alternatives and criteria from Arcview are exported to the Brainstorm.

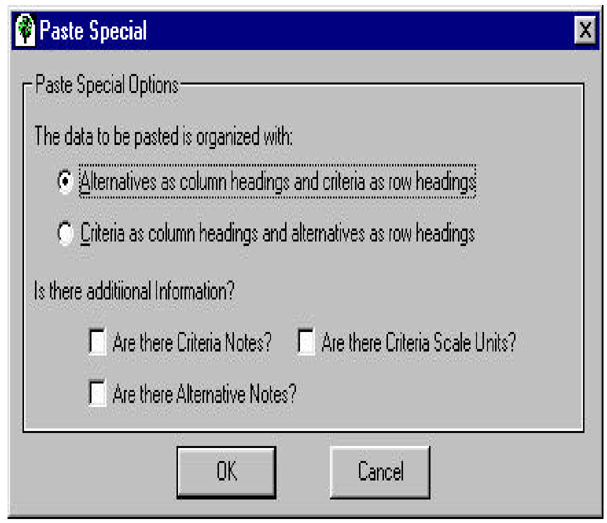
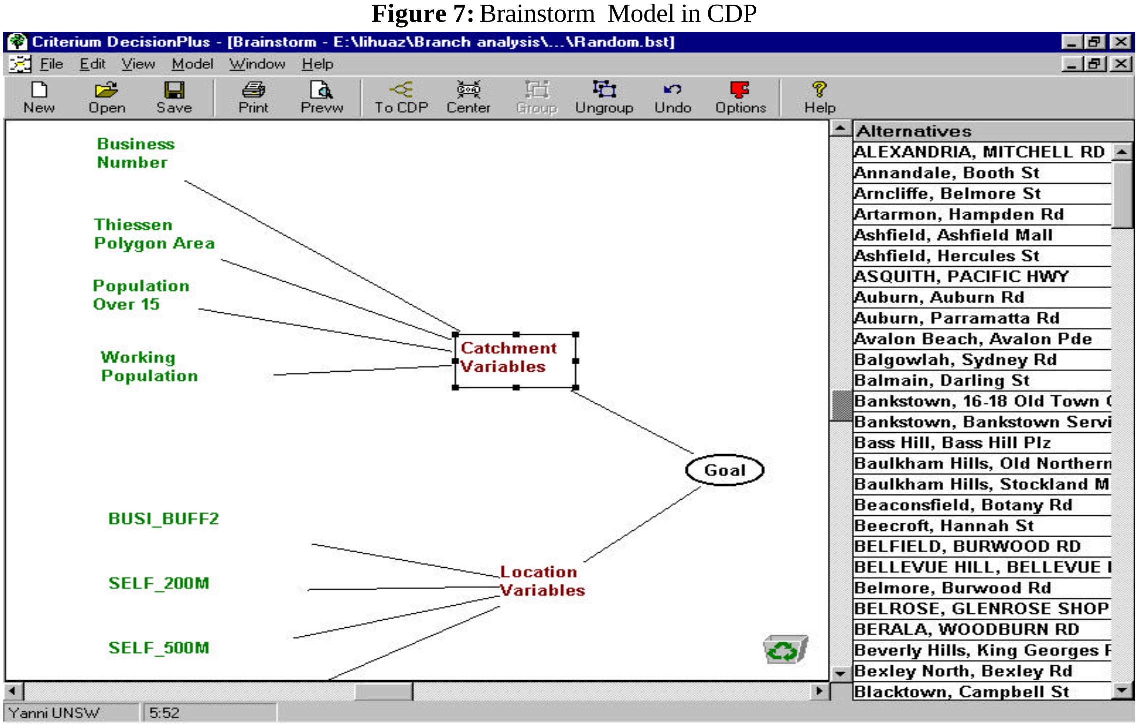


Figure 6: Paste Special Dialog Box in CDP

4. Delete, add notes, connect, and add additional criteria as in any Brainstorming session to set up decision hierarchy, and then save the brainstorm model (Figure 7).

Figure 7: Brainstorm Model in CDP



After setting up the decision hierarchy, if some data is changed in ArcView for doing 'what if' analysis which involves changing criteria in order to create different scenarios, a hot link needs to be set up and data imported to the hierarchy spreadsheet in CDP. The hot link is implemented using the following procedures written in Avenue:

1. In the source application (in this case ArcView) select the relevant fields and alternatives, export the data to Excel, select and copy the relevant cells, which must contain only numerical data, this places the information in the Windows Clipboard.

2. In the CDP Hierarchy window, from the View menu, select Hierarchy Data. Using the mouse, select the corresponding block of cells making sure that the dimensions and ordering are exactly the same as for the cells in the Excel application.

3. From the Edit menu choose Paste Link. This copies the information from the Windows Clipboard to DecisionPlus, and creates a hot link between the Excel application and DecisionPlus. Information on that Link (source application, topic, time of update) is automatically placed in the Notes of the Goal. A message is posted indicating the successful establishment of the link.

Using these criteria and weights, the SMART model in CDP generates the decision score for each candidate bank (Figure 8), the ordering of which is taken to be the preference ranking. Branches with a high score (eg. Caringbah, Kingsway, 0.681) are considered to be viable and are therefore not likely candidates for closure. On the other hand, branches with a low score (eg. Brookvale, Old Pittwater Rd., 0.178) are associated with a particular combination of weighted criteria suggesting that the branch might be considered as a candidate for closure.

A comparison of the branches identified by the model as likely candidates for closure with those that actually have been closed since 1995 clearly indicates that many of the branches with low scores have been closed. For example, of the 14 branches which score less than 0.260 in the SMART model, 9 have closed. There are however exceptions: some banks have been closed which the model suggested are viable.

6. CONCLUSION

This research primarily focuses on the methodology for developing a GIS-based Multi-Criteria Decision Making system (GIS-MCDMS) for application in the retail banking environment, rather than on the development of entirely new software to address this task. The emphasis is on establishing the general mechanisms, both as a contribution to the development of a methodology for system integration and as a first step in developing tools to simplify the task.

To date there have been few examples of GIS and MCDM integration which is still an emerging field of research. The argument is that multiple rather than a single MCDM technique should be used to generate recommendations for the branch closure. The techniques should be selected to best assist the generation and evaluation of the plan alternatives and consideration of the implementation aspects.

REFERENCES

Abel, D. J., Kilby, P. J. and Davis, J. R. (1994) "The systems integration problem", *International Journal of Geographical Information System,* vol. 8, no.1, pp. 1 - 12.

Alexander, M., Groff, E. and Hibdon, L. (1997) "An automated aystem for the identification and prioritization of rape suspects", *1997 ERSI International User Conference*, ESRI, San Diego, California.

Anselin, L., Dodson, R. F. and Hudak, S. (1993) "Linking GIS and spatial data analysis in practice", *Geographic Systems,* vol. 1, pp. 3-23.

Carver, S. J. (1991) "Integrating multi-criteria evaluation with geographical information systems", *International Journal of Geographical Information Systems,* vol. 5, no.3, pp. 321-339.

Corner, J. L. and Buchanan, J. T. (1997) "Capturing decision maker preference: Experimental comparison of decision analysis and MCDM techniques", *European Journal of Operational Research,* vol. 98, no.1, pp. 85-97.

Corner, J. L. and Kirkwood, C. W. (1991) "Decision analysis applications in the operations research literature 1970 - 1989", *Operations Research,* vol. 39, no.2, pp. 206-219.

Davis, A. M. (1990) *Software Requirements: Analysis and Specification*. Prentice-Hall, Inc: Englewood Cliffs, NJ.

Demarco, T. (1979) *Structured Analysis and System Specification*. Prentice-Hall, Inc: Englewood Cliffs, NJ.

Densham, P. J. (1991) "Spatial decision support systems", in Maguire, D. J., Goodchild, M. F. and Rhind, D. W. (eds), *Geographical Information System: Principles and Applications*, Longman Scientific & Technical: London, pp. 403-412.

Eastman, J. R., Kyem, P. A. K. and Tolendano, J. (1993) "A procedure for multi-objective decision making in GIS under conditions of conflicting objectives", *Proceedings of the Fourth European GIS Conference (EGIS'93)*, EGIS Foundation: Utrecht.

ESRI (1994) *Avenue: Customization and Application Development for ArcView*. Environmental Systems Research Institute Inc.: Redlands, CA.

ESRI 1995: ArcView2: Working with Visual Basic, in *ESRI White Paper*, Redlands, CA, .

Fedra, K. (1993) "GIS and environmental modelling", in Goodchild, M. F., Parks, B. O. and Steyaert, L. T. (eds), *Environmental Modelling with GIS*, Oxford University Press: New York, pp. 35 - 50.

Goodchild, M. F., Haining, R. and Wise, S. (1992) "Integrating GIS and spatial data analysis: problems and possibilities", *International Journal of Geographical Information Systems,* vol. 6, no.5, pp. 407 - 423.

Goodchild, M. F., Parks, B. O. and Steyaert, L. T. (1993) *Environmental Modelling with GIS*. Oxford University Press: New York.

Heywood, I., Oliver, J. and Tomlinson, S. (1995) "Building an exploratory multi-criteria modelling environment for spatial decision support", in Fisher, P. (eds), *Innovations in GIS 2: Selected Papers from the Second National Conference on GIS Research UK*, Taylor & Francis: London, pp. 127-136.

Hobbs, B. F., Chankong, V., Hamadeh, W. and Stakhiv, E. Z. (1992) "Does choice of multicriteria method matter? An experiment in water resources planning", *Water Resources Research,* vol. 28, , pp. 1767 - 1779.

Hobbs, B. F. and Horn, G. T. F. (1997) "Building public confidence in energy planning: A multimethod MCDM approach to demand-side planning at BC gas.", *Energy Policy,* vol. 25, no.3, pp. 357-375.

InfoHarvest (2000) *Criterium DecisionPlus User's Guide*. InfoHarvest Inc: Seattle.

Jankowski, P. (1995) "Integrating geographical information systems and multiple criteria decision-making methods", *International Journal of Geographical Information System,* vol. 9, , pp. 251-273.

Jankowski, P. and Richard, L. (1994) "Integration of GIS-based suitability analysis and multicriteria evaluation in a spatial decision support system for route selection", *Environment and Planning B: Planning and Design,* vol. 21, no.3, pp. 323-340.

Janssen, R. and Rievelt, P. (1990) "Multicriteria analysis and GIS: an application to agricultural landuse in the Netherlands", in Scholten, H. J. and Stillwell, J. C. H. (eds), *Geographical Information Systems for Urban and Regional Planning*, Cluwer Academic Publisher: Dordrecht,

Martin, J. (1991) *Rapid Application Development*. Macmillan Publishing Co.: New York.

Nyerges, T. (1992) "Coupling GIS and spatial analytical models", *Proceedings of 5th International Symposium on Spatial Data Handling*, Humanities and Social Sciences Computing Laboratory, University of South Carolina: Columbia, South Carolina, pp. 534 - 543.

Nyerges, T. (1993) "Understanding the scope of GIS: its relationship to environmental modelling", in Goodchild, M., Parks, B. and Sayert, L. (eds), *Environmental Modeling and GIS*, Oxford University Press: New York, pp. 75 - 93.

Parks, B. O. (1993) "The need for integration", in Goodchild, M. F., Parks, B. O. and Steyaert, L. T. (eds), *Environmental Modelling with GIS*, Oxford University Press: New York, pp. 31 - 34.

Pereira, J. M. C. and Duckstein, L. (1993) "A multiple criteria decision-making approach to GIS-based land suitability evaluation", *International Journal of Geographical Information Systems,* vol. 7, no.1, pp. 407 - 424.

Razavi, A. H. (1995) *ArcView developer's guide*. Onword Press: Santa Fe.

Rumbaugh, J., Blaha, M., W.Premerlani, Eddy, F. and Lorensen, W. (1991) Objected-Oriented Modelling and Design. Prentice-Hall, Inc: Englewood Cliffs, NJ.

Saaty, T. L. (1977) "A scaling method for priorities in hierarchical structures", *Journal of Mathematical Psychology,* vol. 15, pp. 234 - 281.

Saaty, T. L. (1980) *The Analytical Hierarchy Process*. McGraw-Hill: New York.

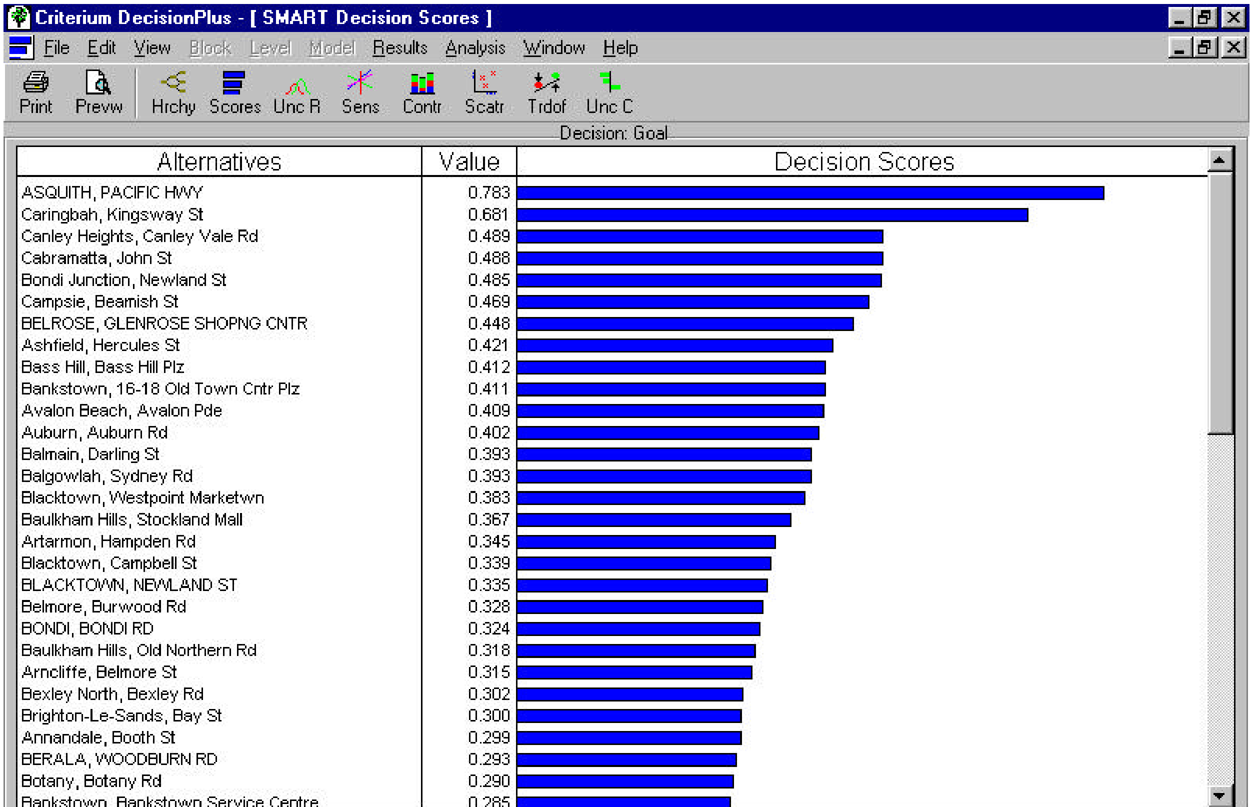
Saaty, T. L. (1992) *Multicriteria Decision-making, The Analytical Hierarchy Process*. RWS Publications: Pittsburg.

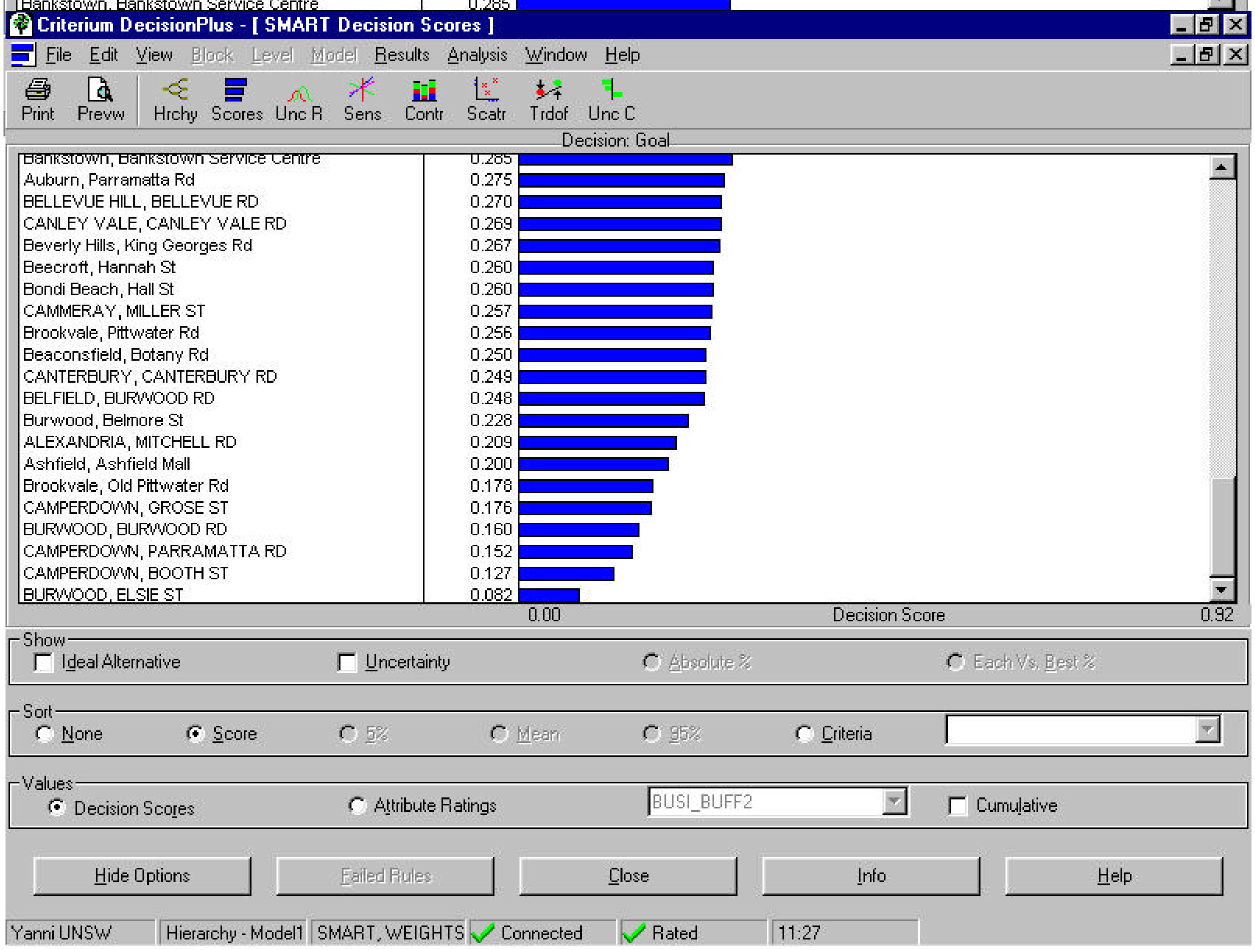
Saaty, T. L. (1995) *Decision Making for Leaders*. RWS Publications: Pittsburgh.

Salminen, P., Hokkanen, J. and Lahdelma, R. (1998) "Comparing multicriteria methods in the context of environmental problems", *European Journal of Operational Research,* vol. 104, no.3, pp. 485-496.

Tkach, R. J. (1997) "A new approach to multi-criteria decision making in water resources", *Journal of Geographic Information and Decision Analysis,* vol. 1, no.1, pp. 25 - 43.

Zhao, L. and Garner, J. B. (2001) "Towards the development of a Spatial Decision Support System (SDSS) for identifying the closure of branch banks", *2001 Geography, A Spatial Odyssey: Proceedings of NZGS and IAG Joint Conference*, Dunedin, New Zealand (in press).


Criterium DecisionPlus - [SMART Decision Scores]
File Edit View Block Level Model Results Analysis Window Help
Print Prevw Hrchy Scores Unc R Sens Contr Scatr Trdof Unc C
Decision: Goal
Alternatives
Value
Decision Scores
ASQUITH, PACIFIC HWY 0.783
Caringbah, Kingsway St 0.681
Canley Heights, Canley Vale Rd 0.489
Cabramatta, John St 0.488
Bondi Junction, Newland St 0.485
Campsie, Beamish St 0.469
BELROSE, GLENROSE SHOPNG CNTR 0.448
Ashfield, Hercules St 0.421
Bass Hill, Bass Hill Plz 0.412
Bankstown, 16-18 Old Town Cntr Plz 0.411
Avalon Beach, Avalon Pde 0.409
Auburn, Auburn Rd 0.402
Balmain, Darling St 0.393
Balgowlah, Sydney Rd 0.393
Blacktown, Westpoint Marketwn 0.383
Baulkham Hills, Stockland Mall 0.367
Artarmon, Hampden Rd 0.345
Blacktown, Campbell St 0.339
BLACKTOWN, NEWLAND ST 0.335
Belmore, Burwood Rd 0.328
BONDI, BONDI RD 0.324
Baulkham Hills, Old Northern Rd 0.318
Arncliffe, Belmore St 0.315
Bexley North, Bexley Rd 0.302
Brighton-Le-Sands, Bay St 0.300
Annandale, Booth St 0.299
BERALA, WOODBURN RD 0.293
Botany, Botany Rd 0.290
Bankstown, Bankstown Service Centre 0.285


Criterium DecisionPlus - [SMART Decision Scores]
File Edit View Block Level Model Results Analysis Window Help
Print Prevw Hrchy Scores Unc R Sens Contr Scatr Trdof Unc C
Decision: Goal
Bankstown, Bankstown Service Centre 0.285
Auburn, Parramatta Rd 0.275
BELLEVUE HILL, BELLEVUE RD 0.270
CANLEY VALE, CANLEY VALE RD 0.269
Beverly Hills, King Georges Rd 0.267
Beecroft, Hannah St 0.260
Bondi Beach, Hall St 0.260
CAMMERAY, MILLER ST 0.257
Brookvale, Pittwater Rd 0.256
Beaconsfield, Botany Rd 0.250
CANTERBURY, CANTERBURY RD 0.249
BELFIELD, BURWOOD RD 0.248
Burwood, Belmore St 0.228
ALEXANDRIA, MITCHELL RD 0.209
Ashfield, Ashfield Mall 0.200
Brookvale, Old Pittwater Rd 0.178
CAMPERDOWN, GROSE ST 0.176
BURWOOD, BURWOOD RD 0.160
CAMPERDOWN, PARRAMATTA RD 0.152
CAMPERDOWN, BOOTH ST 0.127
BURWOOD, ELSIE ST 0.082
0.00
Decision Score
0.92
Show
Ideal Alternative
Uncertainty
Absolute %
Each Vs. Best %
Sort
None
Score
5%
Mean
95%
Criteria
Values
Decision Scores
Attribute Ratings
BUSI_BUFF2
Cumulative
Hide Options
Failed Rules
Close
Info
Help
Yanni UNSW
Hierarchy - Model1
SMART, WEIGHTS
Connected
Rated
11:27