Edith Cowan University

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A NATURAL LANGUAGE INTERFACE FOR DOS

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Summary

There have been many attempts to help non-expert users to use personal computers to accomplish the required information processing goals. In systems using menus, the processing goals are already prespecified. In command language systems, users have to learn several specific commands and there is always the possibility for error. The usefulness of manuals and/or on-line help facilities requires a fair amount of efforts by the user. Alternatively, the use of natural language to converse with an operating system is one application that people would actually be willing to use.

This paper describes a dialogue-based application of natural language understanding. The aim is to provide an intelligent natural language interface that allows naive users to communicate with DOS in English. Users can query the system for the correct syntax of a DOS command and/or issue natural language requests for specific tasks to be performed. The program developed is easy to use and utilizes information about the domain to help understand requests. It can handle most variations of a request and is able to deal with a request in context to some more recently issued request. The program can satisfy users' requirements regarding simple DOS functions and this will be useful to inexperienced or unfamiliar users.

Introduction

As personal computers (PCs) become widely accepted in our daily life, it is important that novice users be able to use them easily. There have been many attempts to help users to accomplish the required information processing goals. In systems using menus, the processing goals are already prespecified. Thus users can and need only select an allowable sequence to achieve their goals. In command language systems, more freedom within the capability of the systems is offered to users to achieve the targets. However, users have to learn several specific commands and there is always the possibility for error.

From the invention of computers, conversing with the machines in everyday English has always been the desire of a layperson in man-machine interaction (Pigford and Baur 1995). A natural language interface can act as the simple easy-to-use interface for ordinary users who want to achieve information processing goals without the need to worry about system components. The natural language can perform supervisory tasks of facilitating communication and data transfer between different software. With the availability of cheap computing power and the rapidly expanding hardware capabilities of the PC such as the vast increase in memory size and disk storage capacity and the enormous increase in

http://ro.ecu.edu.au/ecuworks/6866
processing power, it is now possible to incorporate the natural language technology to the current generation of the PCs.

This paper describes the DOS Consultant (DC), an experimental natural language interface that allows ordinary users to interact with the MS-DOS (Microsoft 1993) operating system in English. Users can query the system for the correct syntax of a DOS command and/or issue natural language requests for specific tasks to be performed. The program is easy to use and utilizes information about the domain to help understand requests. It can handle most variations of a request and is able to deal with a request in context to some more recently issued request. On-line help, pop-up menus, and a Wordstar-like full screen editor are also provided. The software package runs on IBM PC/AT or higher personal computers or compatible machines with 384K bytes of available RAM (Random Access Memory). It is written in the Turbo Prolog programming language (Rogers 1987) and requires MS-DOS version 3.1 or higher.

The Dos Domain

The communication of naive users with an operating system provides an attractive problem domain for the application of the natural language processing techniques (Allen 1995, Covington 1994 and Harris 1985). The problem domain, though a restricted linguistic domain, is complex enough to generate substantial subproblems. In addition, the domain is not so unbounded that it is not possible to obtain a useful working system without the need for a very large repertoire of knowledge.

The use of natural language to converse with an operating system is one application that people would actually be willing to use. A naive user of a system would be willing to communicate in English with a machine, since the alternatives are likely to be worse. The usefulness of manuals and/or on-line help facilities are limited since it requires in general a fair amount of sophistication and efforts by the user. Knowledgeable persons are rarely available and usually do not have the time to help.

The dialogue-based system also provides a 'soft-fail' option in that if the system did not give the correct or desired answer, the user would be no worse off than he/she would be otherwise. This is because he/she still has all the normal options of using the machine available to him/her. On the other hand, the system will be beneficial to the user if the required answer can be achieved.

Overview of DC

DC is a natural language interface for the MS-DOS environment. It allows naive users to communicate with the computer using conversational English. The design of DC as a natural language interface is based on the psychologists' model of humans as information processing systems (Harris 1985). The following factors are considered in designing the system:

- accessibility: to provide users with access to various DOS functions through some natural language requests. That is, for each common DOS operation, there should be at least one way to request it in English.
habitability: to recognize alternative English expressions of the same idea.

resilience: to be resilient to many types of errors in inputs.

verifiability: to verify with users any request it does not fully understand.

performance: to make the system run on a PC with a standard hardware configuration.

Fig. 1 shows the components of DC of which the major modules include the Morphological Analyzer, the Semantic Analyzer, the Syntactic Analyzer and the System Driver. Conceptually, the user's input string in the form of typed text is entered via the window interface. The tokenizer then converts this string into a list of tokens. With the Turbo Prolog inference engine in the background facilitating searching, backtracking and database access, the input list is parsed by the Syntactic Analyzer. For the case of unsuccessful parsing of the list, it is further processed by the keyword matching submodule. If a pattern is found, the system will seek confirmation from the user before proceeding further.

Essentially, the semantic analyzer produces a semantic list which is processed by the dynamic memory submodule to recall any unresolved verb or object from the previous request. The full semantic list is passed to the domain specific solver which in turn activates the appropriate DOS request frame. The outcome of the request is then output to the window interface by the output generator.

The Morphological Analyzer
The fundamental function of the Morphological Analyzer is to recognize each morpheme, determine its structural function, and associate with it the semantic information and return the system's interpretation of the word. Basically, the Morphological Analyzer consists of two submodules: the dictionary and the Lexical Analyzer.

The Dictionary
The dictionary or the lexicon contains a vocabulary list of domain-specific verbs and objects required by the Lexical Analyzer. Since the DOS domain is action-oriented, the lexicon consists of all possible instructional-verbs that correspond to or imply a DOS semantic. All verbs with the same semantic are grouped together. The format of the dictionary is as follows:

\[ v([\text{Verb list}], \text{System interpretation}) \]

For example, any of the instructional-verbs in the following verb list is interpreted as 'remove'.

\[ v([\text{remove,delete,destroy}], \text{remove}) \]

The main feature of the dictionary is that the verb list contains only root words. Each root word is chosen to be the singular present tense of all possible inflections of a given word. Using the approach of root words, it is possible to minimize the lexicon size and yet able to handle words with many different forms due to tenses and plurals.

The Lexical Analyzer
This submodule determines the root word of an input verb using some morphological rules. The Lexical Analyzer can recognize words with various inflected forms such as those ending with 's', 'es', 'd', 'ed', and 'ing'. These words are known as explicitly differentiable. Using this approach, a lexicon should contain only root words and other forms of these words that are not explicitly differentiable. If the root verb is found from the lexicon, the module returns the appropriate interpretation.

The Semantic Analyzer
This module primarily interprets the list from the Syntactic Analyzer to determine the meaning of any domain-specific verb found. The Semantic Analyzer is designed in such a way that it is possible for a user to issue a request in context to some more recently issued request (See requests 4 and 5 in Section 7: A SAMPLE DIALOGUE).

This facility is achieved through the dynamic context memory submodule by recalling previous action-verb (or simply action) or DOS object (or simply object). The semantic list used by this module is of the form \[ [\text{Act,Obj,'how']} \] or \[ [\text{Act,Obj,'x'}] \] where 'how' implies a query and 'x' denotes a command. The processed list is then passed to the domain specific solver in the system driver module.
The System Driver

This module which accesses DOS internals exploits heavily the Turbo Prolog facilities and DOS interrupt routines (Miller 1986, Borland 1987a, Borland 1987b, and Rogers 1987). It describes the semantic model of DOS. The system driver is essentially composed of action-triggered frames. Each frame is a network of predicates characterized by a predefined action word. An action word signifies a distinct category of DOS operations. As an example, the action word 'Change' corresponds to the following tasks: Changing the date, time, default drive, disk label, directory, and various DOS status. Upon activation of a frame, the driver either performs the task requested or provides the precise DOS syntax of a command enquired by a user. Other action words provided are Remove, Clear, Refresh, Show, Edit, Create, Print, Run, Format, Copy, and Rename.

In addition to action words used to describe the tasks to be performed, object keywords such as 'file', 'dir', 'screen', 'date', 'time', and 'disk' are used to determine the subtasks involved. File and directory names are enclosed in angle brackets (<>) before being passed to the system driver.

Because of the use of action words and object keywords, the system allows users to issue simplified commands consisting only of an action and an object. For example, the following two requests are equally valid:

(i) I want to delete a file.
(ii) Erase file (Simplified version)

Other features of the system include the provision of a full screen editor with the Wordstar-like interface as an alternative to the DOS editor EDLIN in response to the action word 'edit', and the provision of messages of the system errors that are more meaningful than those issued by DOS.
A Sample Dialogue

The following dialogue illustrates the kinds of requests allowed and the responses generated by DC (shown in redlines). The number in square brackets indicates the number of requests made so far.

User [01] > Show me the time.
    The time is 12:30:15.
User [02] > How can I delete a file?
    To delete any file, type 'del [drive:][path]filename'.
User [03] > Move a file?
    To move any file, type 'copy [drive:][path]filename [drive:][path]filename'.
    If you omit the second filename, the copy is created with the same filename on the drive or directory you specify.
User [04] > How might a directory be created?
    To create a directory, type 'mkdir [drive:][path]'.
User [05] > a file?
    There is no direct way to create a file under the DOS environment. You may however use the line editor EDLIN to create and then edit the file.
    You may prefer to use the DOS consultant natural command like 'please create a file' as an alternative.
User [06] > How can I edit <letter.doc>?
    To edit 'letter.doc', type 'edlin letter.doc'.
User [07] > How can I print it?
    To print 'letter.doc', type 'print letter.doc'.
User [08] > I want to remove a file.
    Please key in the file name of press ENTER to select from list: c:\ws\memo.doc
    The file C:\WS\MEMO.DOC has been removed.
User [09] > Show me <c:\ws\report.doc>.
    (remark: the file REPORT.DOC in the directory WS of drive C will be shown. User to press ESC to return to user window.)
User [10] > Print it.
    Please confirm whether to print 'C:\WS\REPORT.DOC'.
    Press 'y' to go ahead or any other key to abort -->

The sample dialogue shows that DC is capable of handling a request in context to some more recently issued request. One example involves requests 4 and 5. Another example is in the last request where DC determines that 'it' refers to the file 'report.doc' rather than some command issued earlier. This is because the immediately preceding request has brought this file into focus. DC is also able to handle most variations of a request. For example, asking 'What is the way to modify a file?' or "How can I edit a file?" will result in the same response from DC.
Conclusion
An experimental natural language interface to DOS has been described. The dialogue-based system allows ordinary users to interact with the computer using ordinary English. The program can handle most variations of a request and has a dynamic recall capability where a request can be issued in context to a preceding request. The system also provides more meaningful error messages than those issued by DOS. In addition, on-line help is available by pressing a certain key. Other features include the use of pop-up menus, windowing and the provision of a full screen editor. The program can satisfy users' requirements regarding simple DOS functions and this will be useful to inexperienced or unfamiliar users. It is planned to extend the capability of the package by expanding the vocabulary in the dictionary and to enhance the internal representation of the semantic list to cater for the more complex DOS operations.

Acknowledgement
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References


DESCRIBING THE ANALYSIS AND INTERPRETATION PROCESS OF AN IS ETHNOGRAPHY RESEARCH EXPERIENCE

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Abstract
IS has been traditionally known as a positivist's field (Orlikowski and Baroudi, 1991). However, practitioners are now pushing for different approaches to research (Alavi and Carlson, 1992). Interpretivism, a paradigm becoming a favourable alternative in organisational related research (Morgan and Smircich, 1980) has been adopted in this research, manifested through an interpretive-qualitative methodology known to social researchers as ethnography. The data collection process of the research has been described in Rusli and Marshall (1995) and this paper looks specifically at the analysis and interpretation stage. A methodological challenge was faced by the writer in adopting this holistic descriptive emic approach to be applied on a focused problem within the organisation.

Introduction
This paper is part of an ethnographic research report studying an Information Systems (IS) division at an Indonesian organisation which consisted of more than 280 staff members. It deals specifically with two main activities which are quite inseparable; (1) bringing order to the data, organising them into patterns, categories and basic descriptive units (analysis), (2) attaching meaning and significance to the analysis, explaining descriptive patterns and looking for relationships and linkages (interpretation) (Patton, 1980).

In this paper, the writer describes a number of important analytical steps which were taken during the course of the research. Before performing analysis steps, the writer believes that a researcher must be clear and aware of the philosophical underpinnings of the methodology, specific biases of the methodology and personal biases of the researcher. The writer sees these three elements as the invisible controller of the whole research, i.e. the soul of the research process.

This paper is aimed for prospective IS researchers interested in qualitative methods based on the interpretivist paradigm (interpretive-qualitative), especially for those whom are in the middle of designing their research, and trying to foresee the analysis steps that they may take. The main problem with most qualitative research papers is that they generally talk about ideals of the research paradigms without providing insights about the actual practice (Patton, 1980).
The structure of the paper is divided as follows. The first section discusses the methodology of ethnography and its philosophical basis, followed by a brief section on the focus of the research. The main section of the paper follows afterwards, which is the description of the analysis process, and followed by the writer's evaluation on the research process to date. The writer is then considers possible future research steps, followed by the conclusion.

Ethnography and its Philosophical Underpinnings

Ethnography is a holistic methodology based on social constructionist approaches which seeks descriptions of total phenomena within their various contexts aimed at the generation of a description about their complex interrelationships (LeCompte and Preissle, 1993). The methodology examines the way people apply abstract cultural rules (tacit knowledge people use to generate and interpret social behaviour - Spradley, 1980) in concrete situations to make actions routine, explicable and unambiguous (Taylor and Bogilan, 1984).

Ethnography uses the assumption that knowledge structures which filter reality as we see it, are interpreted and socially constructed through the perceptions of many (Rosen, 1991), including those of the observer and those produced by the interaction between the observer and informants (Davies and Nielsen, 1992). This implies that there is no 'absolute truth' and it is not possible to be completely objective in knowledge description (Spradley and McCurdy, 1972; Patton, 1980).

The views above provides an implied basis for the researcher to work with and learn from the people in the culture under research (referred to as informants), as opposed to 'studying' the people as 'subjects' or 'respondents'. The knowledge 'produced' consists of a description the informant's behavioural system explained in their own terms, structural units, structural classes and within the context in which it was discovered (Davies and Nielsen, 1992). *Eemic*, is a popular term used to describe approaches of this nature (Sturtevant, 1972).

The Focus of the Ethnography Research

The ethnography used in this paper is referred to as an IS Ethnography (Rusli and Marshall, 1995) which originated from Health Sciences Ethnography as described by Muecke (1994). The ethnography is focused in nature and the results are expected to be used as valuable insights in applying Checkland's Soft Systems Methodology (SSM) in solving IS-related issues in this Indonesian-based organisation. A summary based on the attributes presented by Mueck (1994) is presented as Table 1.
There is a fallacy in the common belief that data is collected somewhat objectively, and prejudice is normally applied during later analysis and interpretation (Spradley and McCurdy, 1972). Selective observations and subjective judgments occur during the initial data collection where the researcher observes only the facts the researcher 'thinks' are important (selective observation) and interprets only what the researcher 'thinks' is relevant (selective interpretation) (Miles and Huberman, 1994; Spradley and McCurdy, 1972). In fact, more bias may affect data collection than it does analysis. Spradley and McCurdy (1972) for example claims that if social researchers with the same academic knowledge base are exposed to the same set of data, their interpretations based on this data will most probably be similar.

In interpretive-qualitative research techniques such as ethnography, the researcher's mind is the ultimate analysis tool (Lipson, 1994). At all times, some form of data analysis and interpretation always occurs (implicit analysis and implicit interpretation) (Rusli and Marshall, 1995). To reduce unintentional bias, an ethnographic researcher must be aware of his/her personal and cultural prejudices which may influence the data gathering process. In the attempt to reduce this potential problem, the writer went through a process of listing elements which he perceives to be possible influences which may cause bias in his judgments.

Analyses and interpretations described in this paper were those performed with intent and under the writer's awareness. In this research, analysis was conducted continually, starting from the initial data collection process. The Analysis and Interpretation stage was conducted almost concurrently with the two of the data collection stages which were the formal and post-formal stages (Rusli and Marshall, 1995).
The analysis and interpretation tasks were divided into two arbitrary levels. The first level involves analyses and interpretations performed during the formal data-collection period (Primary Analysis and Interpretation), and the second level involves analysis performed in the post-formal data collection period (Secondary Analysis and Interpretation). This is diagrammatically depicted in Figure 1.

![Diagram of data collection stages]

**Figure 1: Time Span of the Ethnography Data Collection and Analysis**

As seen from Figure 1, there was no 'conscious' data analysis performed during the pre-formal data-collection period. The aims of that this data-collection period were (1) to form trust, personal familiarities, and a feeling of social comfortableness between informants and the writer, and (2) to mold a working picture of the organisation in the writer's mind (Rusli and Marshall, 1995). At this data-collection stage, only limited amounts of data were collected, and they were analysed during later stages.

**Primary Analysis and Interpretation: During Formal Data-Collection Period**

Unlike some qualitative researchers who allocate a lot of time and energy into data collection, and then 'retire' from the field to 'analyse the data', the writer here tried to perform as much analysis and interpretation concurrently with data collection. Leaving the analysis after the data collection is over causes a number of difficulties. These potential problems are listed as follows (Miles and Huberman, 1994):

(a) It rules out the possibility of collecting new data to fill in gaps
(b) It rules out the possibility to test hypotheses which emerged during analysis
(c) It discourages rival-hypotheses which question a field-researcher's assumptions and biases
(d) It makes the analysis an overwhelming task that usually reduces of the quality of work

This stage is referred to as the Primary level for the reason that it was the stage where the core of the data was analysed. The writer discovered most of the collected cultural themes at this level. Initial interviews and early observations were lightly analysed to extract local terms and concepts. These concepts which were perceived to be important (due to frequent mention or
explicit stress by informants), were used as starting points to be pursued through further questioning (Confirmation Level Questions - Rusli and Marshall, 1995).

Although the writer tried to be constantly aware that the approach used is one of an emic nature, it is realised that to be a purist in research of this nature would be virtually impossible. All researchers are influenced to some extent by some 'cultural baggage'. Spradley and McCurdy (1972) believe that the approach should attempt to keep 'external' concepts at a minimum and base as much of the description on those discovered from the culture under research.

Some imported concepts were found necessary for the analysis. These meta-categories were used to classify the data collected initially, and was in no way there to limit arising local categories. Although compromising the idea of pure Interpretivism, the writer believes such meta-categories are concepts which are existent in most, if not all, cultures. Furthermore, Miles and Huberman (1994) believes that initial categories such as these are necessary to help researchers start their analysis. In the case where the writer found a concept to be irrelevant or appropriate, that concept was modified or deleted.

The meta-categories used in this research are listed in the following:

(a) **Local Definitions**
   This category includes how informants understand, define or perceive any understanding about various aspects of the culture under study

(b) **Views**
   The Views category includes thoughts, perceived problems, world views, feelings and attitudes of informants towards organisational elements

(c) **Process**
   This category includes explanations regarding procedures, sequences of events and changes over time, either regular or miscellaneous ones (Bogdan and Biklen, 1992)

(d) **Conditions**
   Conditions are expressed circumstances or elements which need to exist before a situation occurs. In searching for elements which fall under this category, the researcher looked for phrases which contained words such as 'because' (in the local language of informants) (Strauss, 1987)

(e) **Consequences**
   The Consequences category included those phrases / sentences which were results of certain actions. In searching for elements which fell under this category, the researcher looked for phrases which contained words such as 'as a result of' or 'was because of' (in the local language of informants) (Strauss, 1987)

(f) **Social structure**
   This category included all structures in the organisation (formal and perceived), e.g., cliques, coalitions, romances, friendships and enemies (Bogdan and Biklen, 1992)

The writer started out with the above meta-categories, and soon found that they could not hold the incoming information. A category (including the meta-category) which could not hold the
breadth of data or was found to contain blocks of information which had a common theme, was broken up into new sub-categories with appropriate headings. All the data related to a category were stored in its lowest level sub-category. An example of the hierarchy of categories is described in Figure 2.

The writer analysed the information based on a unit of data. The unit of data used in this research was either a phrase, a sentence or a paragraph which contained a single theme. Each unit of data was coded according to an appropriate category. Codes are tags or labels for assigning units of meaning to the descriptive or inferential information compiled during study and are efficient means of data-labeling and data-gathering which will speed up analysis (Miles and Huberman, 1992).

The process of coding was an analysis process in its own right. Miles and Huberman (1992) suggested that coding should be done early in the data collection process and not done at the end of the data collection. The initial coding of each unit of data, was considered by the writer as the first thorough run through the collected data.

During this Primary Analysis stage there were two sets of codes used. The first set of codes were used to represent a category (Category Code). The researcher used an alphanumeric string, formed semantically as close as possible (without making it too long) to the category it represented. The second set of code were used to represent the perceived social context of the unit of data collected (Social Context Code). As with the previous scheme, semantically similar alphanumeric strings were also used.
To keep track of all the codes used, the researcher kept two Table of Codes (one for the category codes and another for the social context code) which contained the meaning and description of each code. These tables were updated according to any addition or deletion of codes which were used. An example of the usage of codes are represented in Tables 1a and 1b. For the reader's better understandibility, the example of code usage was translated and the tables are presented in the English language. To keep local context preserved as much as possible, the coding was performed in the local language.

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Local Definitions</td>
<td>General definitions as perceived by the informants</td>
<td>CL1-DEF</td>
</tr>
<tr>
<td>Processes</td>
<td>General organisational processes as explained by the informants</td>
<td>CL1-PRO</td>
</tr>
<tr>
<td>Meeting Definitions</td>
<td>Definitions of what a meeting is as perceived by informants</td>
<td>CL2-MDE</td>
</tr>
</tbody>
</table>

*Table 1a: Table of Codes (Category)*

<table>
<thead>
<tr>
<th>Social Context Description</th>
<th>Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discussion with IS Section Manager (one-on-one), took place in the manager's office, conducted in a fairly formal mode (perceived informant acceptance: pretty low, only as a researcher)</td>
<td>SC-1MF</td>
</tr>
<tr>
<td>Discussion with IS Division Manager (one-on-one), took place in a public place while having lunch (perceived informant acceptance: high, as 'friend' researcher)</td>
<td>SC-2DI</td>
</tr>
</tbody>
</table>

*Table 1b: Table of Codes (Social Context)*

Each data collection session was given one or more social context code (according to the change in the mood, openness, or other contextual factors). On each unit of analysis was attached a category code, and if a unit of analysis did not have a 'suitable' category, the categories were changed accordingly. An example of the attachment of the codes to the data is diagramatically shown in Figure 3.

Informally, there are generally 3 types of managers in the organisation. (CL1-STR)

The first type is one from the old generation, who became a manager due to the time served in the organisation. (CL1-DEF)

A few managers from this generation are good decision makers and progressive in nature, while others are rather stagnant.

The second type is ..........
Based on the coding and further reading into the text, where time permitted during this formal data-collection period, summaries of events and interviews (Journal Entries and Contact Summaries), notes taken during interviews and in observations (field notes), notes of emerging thoughts and analysis (Researcher's Mind Pad) and other documentations (see Rusli, 1995) were consolidated into a form that which Miles and Huberman (1994) refers to as a write-up. The researcher found that during the preparation of write-ups, pieces of information which were not recorded in his written notes were revived. In accordance to purpose and the aims of this research, write-ups were prepared as the first version of the ethnographic report.

**Secondary Analysis and Interpretation: Reading the Text**

The start of the post-formal data-collection period was the end the researcher's 'stay' in the organisation to perform the data inquiry and analysis. Contacts were still made with informants (further questioning and clarification on thoughts) and new data were still collected, however the researcher did not come in the organisation on a regular basis (Rusli and Marshall, 1995).

Authors such as Lincoln and Guba (1985), Miles and Huberman (1994), and Thorne (1994) use the term secondary analysis to describe an analysis on text data collected by someone else. The writer uses the Secondary Analysis and Interpretation stage as 'a second look' at the material after leaving the organisation under study.

The writer aimed the Secondary Analysis and Interpretation for the following:

(a) **To make sure nothing is missed**
   The researcher had limited time to look at the data closely while he was in the organisation. This period allowed the writer to re-read the data and make sure that no themes were missed.

(b) **To modify (extend, delete, edit) the existing categories**
   The researcher had further time to examine existing categories to make sure that they were representative for the data. Where found unsuitable, those existing categories were modified accordingly.

(c) **To find links between categories and units of analysis**
   The whole data was revisited and observed as a whole to locate possible links between categories or different elements within them (units of analysis) which were overlooked or undiscovered previously.

(d) **To allow 'alternative' themes to arise**
   The researcher had coded and analysed most of the data during the previous period (Primary Analysis and Interpretation Stage). To allow for different paths of analysis, the writer tried to re-sort, and re-code the data in different ways which were perceived to be new insights to alternative conclusions.

(e) **To 'unattach' the writer from the context**
The writer had formed close links with many of the informants during the course of research. By leaving the research context to look at and think closely on the data, the writer hoped to be able to see 'elements' which was not seen earlier.

To accommodate the changes the writer used the same coding technique utilised from the previous stages. Within this stage, new themes were discovered and some of the existing data were recorded, and they were confirmed with the relevant informants from the organisation.

**Attaching Meaning: Interpretation Of Ideas**

Although this section was written separately, the actual conduct of the steps explained here was performed together with the two levels of analysis described earlier. In this stage, the writer tried to generate meaning by merging stories, or cases by looking at the analysed data. This process is often referred to as synthesizing (Morse, 1994).

The main activity in this step was to re-group categories which were perceived to have some connection with one another into a higher level group called clusters. Miles and Huberman (1994) explain this as the process of moving into higher levels of abstraction (*clustering*).

After the clustering process, each category within the cluster was revisited and re-read. Each item within the category of interest was sorted according to its social context code (described previously in the Primary Analysis and Interpretation Section). On the basis of this social context code, the writer was able to weight each item in the category in order to make a more meaningful interpretation of its importance and significance within the cluster. For example, it was noted whether the item referred to a highly informal social context (in which case it may generally have been relatively lightly weighted) or whether the item related to a more formal serious social occasion (in which case, it would generally have been weighted more heavily). While those weightings were a function of the social context of the item, they were also influenced by the nature of the cluster of interest. Thus for the 'Meeting' cluster, a heavier weighting was ascribed to more formal social contexts than to the less formal contexts. The weighting process was not merely a trial and error process but was carefully thought through, with judgments and decisions ultimately resting on the writer's insight and intuition. A sample of some of the categories which were grouped to form the 'Meeting' cluster is given in Figure 4.
"Meeting" Cluster

Category 1: Types of Organisation Members (CL-3-ANG)
- Director (formal position) (code: SC-2DF)
- Divisional Manager (formal position) (code: SC-2DF)
- 'Vocal' managers in meetings (code: SC-3MF, SC-4MI)
- New 'innovative' staff (Code: SC-6DF)
- Old 'dysfunctional' managers (Code: SC-6DF)

Category 2: Definitions of 'Meetings' (CL-2-DME)
- "More than two people meet to discuss a matter" (code: SC-2MF)
- "Gathering to discuss organisational problems" (code: SC-7SF)
- "Gathering to explain an organisation matter" (code: SC-OBF)

+ Other related Categories

Figure 4: Clustering, Transforming a Cluster into a Write-up and Transforming Write-ups into the Ethnography

The code attached to each item in a category (Figure 4) is the social context code. An example of some of the social context codes together with an indication of the type of weighting ascribed for the 'Meeting' cluster is given in Table 2.

<table>
<thead>
<tr>
<th>CODE</th>
<th>Description (detailed in Table of Social Context Code)</th>
<th>Implied Qualitative Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>SC-2MF</td>
<td>Source from Manager No. 2 during formal discussion at office (serious surroundings)</td>
<td>Important (manager's views, perception given in confidence)</td>
</tr>
<tr>
<td>SC-7SI</td>
<td>Source from Staff No. 7 during informal discussion over lunch with other staff members in public place</td>
<td>Fairly important but fairly general as information were described in public</td>
</tr>
<tr>
<td>SC-OBF</td>
<td>Source from researcher's personal observation</td>
<td>Important (researcher's perception of matter)</td>
</tr>
</tbody>
</table>

Table 2: Attaching Implied Weight on Social Context Code

Based on grouping categories of similar or relevant content, and subsequently weighting each item in those categories according to the impact it could have given its social context, the writer then proceeded to express the results in "write-ups" of a particularly activity. Although limited to a single activity of interest, the write-ups are similar in format to the ethnographic report which will be produced at the conclusion of this research.

As the secondary analysis and interpretation continues, so does the process of attaching meanings through clustering categories, allowing for additional write-ups of emerging themes. Meanings (clusters) and write-ups may also be modified as the writer gains new and deeper insights of the situation and hence, his perception changes.
Current Status And Subsequent Steps Of Research

In Rusli and Marshall (1995) the writer described the steps which have been taken in the data collection. The analysis and interpretation process was performed concurrently with this data collection stage (Primary Analysis and Interpretation), and as the introduction of new data had seemed to have stabilised, the formal data collection was terminated.

The Primary Analysis and Interpretation resulted with roughly around 45 categories, which were arranged and regrouped into organisation activities which were perceived to be important. Each of the important research activity, which is made of a cluster which contain related categories, are inscribed into write-ups. These individual write-ups will make the final ethnographic report.

Upon the completion of this paper, this research was at the Secondary Analysis and Interpretation stage. In this stage, the writer only had enough time to concentrate on one of the many cluster of activities which emerged as being important, that is The Meeting Process in the IS Division. A write-up on this cluster is currently under the preparation. Other clusters will be dealt with once this one has been completed to a satisfactory level.

A diagramatical summary of the steps taken in the course of the whole research is described in Figure 5.

![Diagram of Research Process]

*Figure 5: Writer’s Research Process*

From Figure 5 it can be seen that data collection does not end until the final ethnography is formed. However, the bulk of the data was collected in the initial part of the research, with the
amount declining towards the end of the research process (only confirming and adding to established themes) (Rusli and Marshall, 1995).

The final ethnography report could be used as a guide to other Information Systems researchers who are facing the, at times, perplexing issues surrounding the analysis and interpretation of ethnographic data. The whole research process and the results will be used as a learning process for the writer to apply Soft Systems Methodology (SSM) in the organisation's IS division.

Rejection Of Third-Party Analysers

There were numerous instances in the read of the recorded text (Secondary Analysis and Interpretation) where the researcher felt that external expert help in looking at the collected data may help to provide new insights. It was however realised, as the data was given in confidence, involving third parties to look at the data may not be approved by the informants. There are two main arguments of why an external text analyser might help in looking at the data (Thorne, 1994). First, there is a limit to which the primary researcher can generate knowledge from the available information. Second, due to differences in background and experience, different researchers may bring different insights from the available data.

Besides benefits, there are two potential problems associated with a third-party external analyser (Thorne, 1994). First, the third-party researcher will not have a complete background information on the context of research and thus might make interpretation errors. Second, there is a potential danger in exaggerating the effect of subjective bias in interpretive-qualitative research, either positively or negatively.

In addition to the two potential problems described above, the writer also felt that it would be unethical as an academic researcher to share confidential company information and personal staff views and attitudes with a third-party analyser, knowing that this will not be approved by the organisation members.

For the reasons described above, the services of third party analysers were never employed.

Research Evaluation

In the planning of the research, it was realised that the methodology was one of a pure interpretivist-emic approach. However during the course of conducting the research, the writer discovered a need to make a decision involving a trade off between research speed and methodology purity. This compromised view is supported by other ethnographic authors such as Spradley (1979; 1980), Werner and Schoepfle (1987) whom believe that it is virtually impossible to enter a research context without a minimal set of concepts.
From the research experience the writer found that in achieving academic rigour in field research, it was important to have a solid understanding of the philosophical underpinnings of the methodology and to have a good awareness of the personal biases of the researcher. Many times in the research required the researcher to make decisions which were specific to this context. Prescribed steps by other writers could only serve as a broad guideline, and the researcher had to return to those two basic element which form partly form the soul of the research design (see Introduction). The writer does not believe that this level of depth is understood by anyone and disagrees with the view of Spradley (1980) which states that ethnographic field research can be performed by anyone performing through following a set of fairly mechanistic steps.

There was an expectancy in the writer's mind that the data collection exercise would have been a clear-cut process. It is now fully realised by the writer that as the research deals with the tacit side of human nature (culture), any data collection, analysis or interpretation task is relatively complex, where following stages are highly contingent on previous ones.

The writer found the re-sorting and re-arranging steps in the Secondary Analysis and Interpretation stage to be a painstaking and tedious task, and later realised that this step could be helped a lot with the help of a computerised text analyser. The writer has had experience in using a text analysis software called Nudist® in a previous content analysis research project (Glasson and Rusli, 1994) and has now started to enter the text into the software system. The use of the software will allow ease of sorting the data (for alternative sorting and interpretation) and ease of linking the units of analysis. The writer perceives that the use of the software will speed up the Secondary Analysis and Interpretation stage.

This research specifically deals with the information systems / technology group within the organisation. Besides having the proficiency in local language, the writer felt that his background in the IS field was crucial need for the research. With this knowledge, the writer was able to be sensitive and critical about certain terms and concepts used by informants, which allowed analysis and interpretation at a deeper level.

**Conclusion**

This paper describes a certain part of the Ethnography research process: the analysis and interpretation steps. This does not suggest that the actual research was performed in distinct consecutive steps. Spradley (1979) identifies the common steps of all social science research which are selecting a problem, formulating hypotheses, collecting data, analysing data and writing up results. The steps of ethnography research differs from the common research sequence in a number of ways. Ethnography not only requires feedback to be passed cyclically between each step (steps not performed as discrete steps), the methodology also requires the research tasks of data collection, data analysis and data interpretation to go on at the same time (Spradley, 1979).
In this paper, the writer has described the steps which have been used to analyse and interpret most of the data. The tools and techniques used have been drawn from numerous ethnographic methodology descriptions both from the anthropological and sociological fields. Although the writer was faced by numerous methodological problems throughout the research, it was only due to ethical reason that the researcher did not obtain external help from third party qualitative analysers. At the moment the researcher is still concentrating on specific themes within the collected data, and the researcher believes that the remaining data will be processed in a similar manner.

As stated by Morse (1994), that the actual cognitive process inherent in analysis and the processes of synthesization would be unclear to all but the researcher, and this is made worse by papers where the qualitative analysis process are performed implicitly and results are presented without description of steps. Through this paper, the writer tries to share his analysis and interpretation steps to invite other qualitative researchers to critically comment the chosen research path.

The writer concludes this paper with a hope that further progressive writings appear and enrich the qualitative research field to push it as an acceptable alternative approach in human social research, particularly in the Information Systems research arena.

References


Acknowledgment

The writer would like to thank Judy McKay and Dr. Peter Marshall for their input and support in the writing of this paper.
Abstract
More and more the information age is becoming the information deluge. Executives at the helm of large companies are either swamped by vast volumes of information, or are quite out of touch with their organisation (Gray, 1994, p. 304). Both of these scenarios can be rectified with the assistance of a well-designed EIS, one which allows the executives to 'drill down' to the data level if required, one which has timely and current information, and one which is easy and pleasant to use. Numerous examples exist of these successful EIS, and it must be admitted that not a few failures are documented too (see for eg. Gray, 1994, p. 350-396).

That EIS are appropriate is illustrated by the following quote. "The art of the game [of business] is becoming a question of getting the tools in place that allow you to select out of the huge mass of information. And as the computer tools become more sophisticated, you can do that. Ultimately, that will drive all CEOs to use a computer." predicts Quantum Corp.'s chairman and CEO. (Investor's Business Daily 2/2/95 A6) In other words CEOs need information filtering, the service which is the focus of an EIS.

So how many EIS are there in New Zealand compared to eg. the United States? How effective has the IS profession been at convincing executives and CEOs that EIS are an essential business tool? In order to answer these questions two surveys were conducted in New Zealand, one in 1993 and a follow up in 1995, modelled on the surveys used by Hugh Watson in the United States (Watson, Rainer and Koh, 1991; Watson, Rainer, and Frolick, 1992). Because the New Zealand economy is much smaller than the United States economy it was possible to use the all of the companies registered on the New Zealand stock exchange as the sample. This article reports the results of the two New Zealand surveys and compares them to the results of the two United States surveys conducted by Hugh Watson. As is expected the results reflect the difference in size between the United States and New Zealand, but also give indications of the trends of EIS usage in New Zealand.

Introduction
It used to be the case that data was the important factor for consideration by computer users. In the 50s, 60s and 70s, the term Electronic Data Processing was used to denote the use of computers to process large quantities of data more quickly than previous manual methods. Usually this EDP activity would result in long printouts of numbers needing interpretation. However the current term, Information Processing or Information Systems, is used to distinguish current activities from those of the EDP departments of yesteryear. Large quantities of data are still being dealt with, but the computer systems of today are designed to transform data into information, and then present that information in a useable form. Data is still important, but information has replaced data as the important factor for consideration by computer users.
A text used in teaching first year Information Systems, Kroenke and Hatch (1993), provides several definitions of information:

- information is knowledge derived from data
- information is data placed within a context
- information is uncertainty reduction
- information is a difference that makes a difference (cited from G. Bateson)

In a section titled ‘What makes information valuable?’ Kroenke and Hatch (1993) also list four characteristics of good information, adding another dimension to the definitions already listed. They state that good information is:

- pertinent
- timely
- accurate
- able to reduce someone’s uncertainty

If we accept any of the definitions and characteristics we have some benchmarks against which we can measure the success of an information system. We can ask questions such as ‘Does this information reduce my uncertainty?’, and ‘Is this information relevant to me?’. Perhaps more to the point, we can ask the eventual users or beneficiaries of an information those same questions. Reports are legion of failed systems which did not meet user’s expectations, whatever the area the system was developed for (Watson, Rainer and Houdeshel, 1992, p 301).

In the case of an executive, especially the executive of a large organisation, the essence of any information system is to enhance their performance as an executive. One of the tools which an executive might use is an Executive Information System (EIS). Boone (1991, p. 242) lists the benefits of “executive computing” as allowing leaders to:

- Leverage Time
  - Improve responsiveness
  - Work independently of time and location
- Be Well-Informed
  - Stay up-to-date
  - Increase depth of knowledge
  - Adjust filters on information
  - Absorb information quickly
- Communicate
  - Be accessible
  - Improve the clarity and consistency of messages
  - Personalise communication with others
  - Improve listening abilities
  - Be more persuasive
- Coach
  - Build credibility as a leader
  - Track commitments
  - Balance the need to know with the need to delegate
  - Broaden peoples’ perspective’s
  - Teach critical-thinking abilities
- Shape Culture
Focus people on what is important
Measure performance on selected goals and objectives
Pick, promote and reward the right people
Flatten hierarchies and empower people

- Enhance Personal Thinking
  - Manage complexity
  - Think creatively
  - Balance logic and intuition
  - Improve clarity of thinking
  - Improve group thinking processes

A good EIS is able to enhance an executive’s performance in some or all of these areas. McNurlin and Sprague (1989, pp. 403-406) offer two possible purposes of EIS: a status access system, incorporating filtering processes for internal and external information; and a human communications support system designed to facilitate the person-to-person communications that executives use to run their business. Both of these purposes are valid and, if appropriate to the organisation, are also complementary.

Each of the four definitions of information is relevant to the areas listed by Boone, as are the characteristics of good information. This being the case the EIS should then tailor the information it provides to the desires of the executives for whom the EIS was developed for. Lending credence to this view is Burkan (1991, p. 43) who states “… the objective of an EIS is to target the organisation’s information flow to the specific needs of the executive”. It follows that, at a high level of abstraction, an EIS is a system for providing relevant information to executives - this is its purpose. In other words the irrelevant information should be filtered out.

EIS are appropriate if well constructed. Quantum Corp.’s chairman and CEO stated in (Investor’s Business Daily 2/2/95 A6): "The art of the game [of business] is becoming a question of getting the tools in place that allow you to select out of the huge mass of information. And as the computer tools become more sophisticated, you can do that. Ultimately, that will drive all CEOs to use a computer.". CEOs need information filtering, the service which is the focus of an EIS, in order to avoid being swamped with the potential deluge of information available to them.

So how many EIS are there in New Zealand compared to eg. the United States? How effective has the IS profession been at convincing executives and CEOs that EIS are an essential business tool? In order to answer these questions two surveys were conducted in New Zealand, one in 1993 and a follow up in 1995, modelled on the surveys used by Hugh Watson in the United States. Because the New Zealand economy is much smaller than the United States one it was possible to use the all of the companies registered on the New Zealand stock exchange as the sample. This article reports some of the results of the two New Zealand surveys and compares them to the results of the two United States surveys conducted by Hugh Watson. As is expected the results reflect the difference in size between the United States and New Zealand, but also give indications of the trends of EIS usage in New Zealand.
EIS Surveys

In the American Spring of 1988 a group of researchers mailed a survey on the topic of EIS to 286 firms in the United States. The responses to this survey formed the basis of a study on the key issues of EIS development and use. A total of 112 useable responses were received, a response rate of 39%. Of these 112 firms 50 had an EIS. In a follow-up study a revised survey was sent by the same group of researchers to 300 firms in 1991. This second survey produced 61 useable responses, a response rate of 20%. Of these 61 firms 51 had an EIS. A number of interesting differences between the two surveys exist, providing a valuable (although American in bias) picture of the evolving nature of commercial EISs. These surveys also give data on a wide range of key issues within the field of EIS. The results of these surveys have been presented in Watson, Rainer and Koh (1991) and Watson, Rainer, and Frolick (1992).

Fitzgerald (1992) reports on a survey conducted in the United Kingdom. The survey was sent to 500 companies of which 77 responded, a response rate of 15%. Of these 77 firms 36 had an EIS. The 36 positive responses came from ten different sectors of business, including six responses from the public sector. There were also four respondents in the less than £50 million category, a result on which Fitzgerald (1992, p. 5) comments: “This study indicates that [smaller companies] may be beginning to [obtain benefit from EISs]”. Some market research firms have also looked into the EIS environment (see for eg. Bird, 1991; Cronk, 1993).

The survey instrument was based on the one used by Professor Hugh Watson in surveying United States companies as reported in Watson, Rainer and Frolick (1992). Permission to use this survey and a copy of the survey instrument were obtained from Professor Watson. This survey instrument somewhat exceeded the scope of this project and a smaller survey was desirable for a high response rate. Careful analysis of the survey instrument was conducted to eliminate any unnecessary questions and to match the survey to the New Zealand business environment. Respondents were asked if they wished to receive a copy of summary results, an action which would enhance the return rate.

Because overseas surveyors found that EISs are still very rare in smaller organisations, it is unlikely that many EISs would be found in small New Zealand organisations. This being the case, the sample selected for this survey was the companies listed on the New Zealand Stock Exchange. This sample covers a broad spectrum of large business in a representative fashion. A list of the companies on the New Zealand Stock Exchange was obtained from the New Zealand Investment Yearbook 1993 (1993) and New Zealand Investment Yearbook 1994 (1994) respectively.

Results and Discussion

During June 1993, a survey modelled on that used by Hugh Watson was mailed to 114 companies registered on the New Zealand Stock Exchange. A total of 44 surveys were returned. Seven of the returned surveys were classed as unuseable, leaving 37 surveys for further analysis, a response rate of 32%. A follow up survey was sent to 125 companies registered on the New Zealand Stock Exchange in early March 1995. 46 were returned with 6 classed as unuseable, leaving 40 surveys for further analysis, a response rate of 32%.
These returned useable response rates compare favourably with the returned useable response rates of 39% and 20% reported by Watson, Rainer and Frolick (1992). However 44 surveys must be considered a small proportion of all New Zealand businesses, so extrapolation is problematical. Therefore any analysis must be considered merely an indication of EIS practices in the New Zealand business environment. The results will largely be shown by the use of tables and charts, using the premise that one picture is worth a thousand words.

Figure 1 Survey Respondents By Position

Table 1 Average Assets and Revenue of Respondent’s Companies

<table>
<thead>
<tr>
<th></th>
<th>1993</th>
<th>1995</th>
</tr>
</thead>
<tbody>
<tr>
<td>Assets At This Location</td>
<td>50-100 Million</td>
<td>10-50 Million</td>
</tr>
<tr>
<td>Revenue At This Location</td>
<td>10-50 Million</td>
<td>10-50 Million</td>
</tr>
</tbody>
</table>

Table 1 only shows NZ data. The 1991 US respondent’s companies had an average asset size in the $1,000 - 5,000 million range. This is considerably larger than the NZ companies, and the difference is noticeable in the rest of the NZ results when compared to either of the US survey results.

Table 2 presents some summary data for the two New Zealand surveys. No data is available as to why the 11 respondents who were planning an EIS in 1993 did not implement an EIS in the time between the two surveys. Because of the anonymity of the responses and the focus of the survey on trends rather than specific examples of EIS, I cannot say for certain that the 6 EIS in 1993 are not the same 6 EIS in 1995, but it is my opinion that they are not the same.

Table 2 Summary Data

<table>
<thead>
<tr>
<th></th>
<th>1993</th>
<th>1995</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of Useful Responses</td>
<td>37</td>
<td>40</td>
</tr>
<tr>
<td>Respondent’s with EIS</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Respondents Planning EIS</td>
<td>11</td>
<td>10</td>
</tr>
<tr>
<td>Respondents Failed EIS</td>
<td>0</td>
<td>2</td>
</tr>
</tbody>
</table>

Figure 2 shows that the average years of experience of the respondents in both surveys is comparable, with the only noticeable difference being in the category with the *. The difference is due to an outlier value from a respondent in 1993. The respondent had 10 years of EIS experience and was brought to New Zealand specifically to set up an EIS for a company.
Table 3 provides another good illustration of the difference in size or scale of the EIS involved in the US and NZ surveys. Size notwithstanding the proportions of expenditure are very similar, indicated by the percentage values eg, Software consistently rates as one of the most expensive categories in the Development of EIS in both countries, whereas for the Operation of EIS the highest proportion of money is spent on Personnel. The US figures are quite stable but the NZ figures are wildly variant due partly to the small numbers of respondents with EIS, partly to some non-reporting of costs.

Table 3  Average Costs of EIS (in $NZ)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Software</td>
<td>$256,000 35</td>
<td>$348,000 39</td>
<td>$40,000 67</td>
<td>$34,000 33</td>
</tr>
<tr>
<td>Hardware</td>
<td>$258,000 35</td>
<td>$306,000 34</td>
<td>$20,000 33</td>
<td>$15,000 15</td>
</tr>
<tr>
<td>Personnel</td>
<td>$180,000 25</td>
<td>$206,000 23</td>
<td>$0 0</td>
<td>$48,500 47</td>
</tr>
<tr>
<td>Training</td>
<td>$36,000 5</td>
<td>$38,000 4</td>
<td>$0 0</td>
<td>$5,000 5</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>$730,000 100</td>
<td>$898,000 100</td>
<td>$60,000 100</td>
<td>$102,500 100</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Operational Costs</th>
<th>1993 NZ</th>
<th>1995 NZ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Software</td>
<td>$92,000 22</td>
<td>$108,000 24</td>
</tr>
<tr>
<td>Hardware</td>
<td>$58,000 14</td>
<td>$64,000 14</td>
</tr>
<tr>
<td>Personnel</td>
<td>$234,000 56</td>
<td>$238,000 53</td>
</tr>
<tr>
<td>Training</td>
<td>$32,000 8</td>
<td>$36,000 8</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>$416,000 100</td>
<td>$446,000 100</td>
</tr>
</tbody>
</table>

The satisfaction of respondents with their EIS was obtained by attaching a scale of 1 (strongly disagree) to 5 (strongly agree) to 21 statements concerning the use and development of EIS in general. The results are shown in Table 4. Thus the higher the response the more satisfaction felt in relation to that statement. A large drop in the average satisfaction is quite noticeable, down from 4.4 to 3.5. This drop is present in all the 21 items in the satisfaction table. Perhaps the 1993 respondents were unduly optimistic and the 1995 respondents overly pessimistic about their EIS, perhaps other reasons exist for the decreased satisfaction. The data collected do not allow any conclusions to be reached concerning this. However the ramifications are clear that the IS profession has lost some ground with the users of EIS.
The IS profession has lost some ground with the users of EIS.

The lowest score in 1995 was for the provision of external access, a consistent theme across all three satisfaction ratings. The highest scores in 1995 were for the provision of internal data, and accurate and timely information. Taken together this shows that those with an EIS are happy with what information they get, but want more information available to them. The 1991 US lowest score was for a satisfactory response time, but both the NZ scores are quite high. This is perhaps indicative of the different size of the EIS, with the small NZ EIS providing less information more quickly than their US counterparts.

Table 4  Respondent Satisfaction with EIS

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>The external data provided by our EIS are satisfactory.</td>
<td>2.8</td>
<td>4.0</td>
<td>2.8</td>
</tr>
<tr>
<td>The internal data provided by our EIS are satisfactory.</td>
<td>3.0</td>
<td>4.8</td>
<td>4.3</td>
</tr>
<tr>
<td>The capabilities provided by our EIS are satisfactory.</td>
<td>3.6</td>
<td>4.8</td>
<td>3.8</td>
</tr>
<tr>
<td>The information presentation methods of our EIS are satisfactory.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I think our EIS is very effective.</td>
<td>4.2</td>
<td>4.6</td>
<td>3.3</td>
</tr>
<tr>
<td>Our EIS provides accurate information.</td>
<td>4.0</td>
<td>4.8</td>
<td>4.3</td>
</tr>
<tr>
<td>Our EIS provides timely information.</td>
<td>4.4</td>
<td>4.4</td>
<td>4.3</td>
</tr>
<tr>
<td>Our EIS provides satisfactory access to external data.</td>
<td>2.4</td>
<td>3.0</td>
<td>2.0</td>
</tr>
<tr>
<td>Our EIS has a satisfactory user interface(s)</td>
<td>3.8</td>
<td>4.0</td>
<td>3.3</td>
</tr>
<tr>
<td>Our EIS is easy to use.</td>
<td>4.4</td>
<td>4.2</td>
<td>3.3</td>
</tr>
<tr>
<td>Our EIS needs minimal training to use.</td>
<td>2.8</td>
<td>4.0</td>
<td>3.5</td>
</tr>
<tr>
<td>Our EIS provides satisfactory response time.</td>
<td>1.9</td>
<td>4.4</td>
<td>4.0</td>
</tr>
<tr>
<td>Our EIS support staff satisfactorily supports our EIS.</td>
<td>3.0</td>
<td>4.2</td>
<td>3.8</td>
</tr>
<tr>
<td>The software we employed to develop our EIS meets our needs.</td>
<td>2.8</td>
<td>4.5</td>
<td>3.8</td>
</tr>
<tr>
<td>Our executive sponsor was in an appropriate or gainstional position to support the development of our EIS.</td>
<td>4.4</td>
<td>4.8</td>
<td>3.6</td>
</tr>
<tr>
<td>Our operating sponsor was in an appropriate or gainstional position to oversee the day-to-day details of developing our EIS.</td>
<td>4.2</td>
<td>4.6</td>
<td>3.5</td>
</tr>
<tr>
<td>Our EIS development team members held appropriate or gainstional positions to most effectively develop our EIS.</td>
<td>3.6</td>
<td>4.8</td>
<td>3.2</td>
</tr>
<tr>
<td>Our EIS development team members had the skills needed to develop our EIS most effectively.</td>
<td>3.4</td>
<td>4.6</td>
<td>3.2</td>
</tr>
<tr>
<td>Our EIS support team members held appropriate or gainstional positions to most effectively support our EIS.</td>
<td>4.2</td>
<td>4.8</td>
<td>3.4</td>
</tr>
<tr>
<td>Our EIS support team members have the skills needed to most effectively support our EIS.</td>
<td>4.6</td>
<td>4.8</td>
<td>3.8</td>
</tr>
<tr>
<td>The development methodology we used for our EIS was effective.</td>
<td>3.8</td>
<td>4.4</td>
<td>3.6</td>
</tr>
</tbody>
</table>

Average                          | 3.6     | 4.4     | 3.5     |
Conclusion

The need to filter information is becoming more pressing for executives, the people for whom EIS are developed. In fact, EIS are almost custom-made for filtering information. The technology problems that EIS have encountered are fading as technology improves (Watson et al, 1992, p iii), but for EIS to be useful they need first to be implemented and secondly used. This article has reviewed the results of EIS surveys used in the US and NZ.

The most striking thing to come out of this research is how few EIS there seem to be in New Zealand companies, despite the hype and glowing reports of success in past years. Only 6 of 39 respondents had an EIS - 15%. Yet according to three top executives of large American organisations major benefits are to be gained through the use of EIS (Wallis, 1989, in Watson et al, 1992, pp. 301-314). These benefits cover a range of areas:

• company performance data - good summarys and drill down capabilities for current information
• internal communications - for personal correspondance, reports and meeting scheduling
• environmental scanning - for updates on current events in the area of interest outside the company

Along with these general benefits come a raft of specific benefits such as reduced staff, flatter lines of control, improved competitiveness etc (Watson et al, 1992, p 299). Despite these benefits NZ companies do not have a high prevalence of EIS. An obvious question for further research is “Why?”.

Another issue raised by this research is the overall drop in satisfaction with established EIS. Several reasons could be behind this fall, such as increased expectations of users that aren’t being met by the EIS, worse EIS design and implementation, inadequate maintenance etc. Any of these reasons could be valid, but is speculative based on this research. The least satisfaction is gained from the access of the surveyed EIS users to external information. This is a clear signpost to an area which could be greatly improved.

Perhaps another reason is that NZ is a little behind the rest of the world, and has just come down from the euphoria experienced when EIS first started to hit the NZ marketplace.

If we are to believe Quantum Corp.’s CEO statement refers to EIS then much work remains to be done in NZ.

References

SECTION 4

ENVIRONMENTAL MANAGEMENT
THE USE OF QUALITATIVE SYSTEMS METHODOLOGIES IN ENVIRONMENTAL MANAGEMENT

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Introduction

Environmental management problems are, by their very nature, complex. They often involve many stakeholders with various values, levels of self interest, and economic involvement. Added to this is the technical problem of managing an ecosystem in this social environment. These problems are therefore, systemic in nature. This would imply using systemic techniques to assist in managing the situation. These forms of management approaches have been developed for use in organisations and yet seem to be lacking in portfolio of environmental managers. Very often quantitative methods are used which may be inappropriate. The reason for this is that before quantitative models can be produced, the system needs to be defined. As many stakeholders would disagree with the limitations of the system boundary drawn by the modeller (often a government department), the model produced is destined to be unsuitable (or incomplete) for effective management of the problem.

This paper investigates the use of a meta-methodology called Total Systems Intervention (Flood & Jackson, 1991) which attempts to match methodology to the type of problem situation encountered.

Total Systems Intervention

Flood and Jackson (1991) classify problems using two criteria: the complexity of the system, and the human situation it is in, ie is it cooperative or antagonistic. The problem situations are thus Simple or Complex, and Unitary, Pluralist, or Coercive (see table 1)

The problem at hand can be assumed to be anyone of these. The problem investigator can thus consider the problem from any perspective. Hence if an environmental problem is considered a simple-unitary problem, it will be treated in a vastly different way than if was considered complex-coercive.

I postulate that environmental management problems are almost entirely complex-coercive. Using the Integrated Catchment Management (ICM) problem as an example, the logic behind this will be illustrated. Table 2 lists the general characteristics of environmental problems and ICM in particular.

Table 1: Classification of problem types

<table>
<thead>
<tr>
<th></th>
<th>UNITARY</th>
<th>PLURALIST</th>
<th>COERCIVE</th>
</tr>
</thead>
<tbody>
<tr>
<td>SIMPLE</td>
<td>Simple-unitary</td>
<td>Simple-pluralist</td>
<td>Simple-coercive</td>
</tr>
<tr>
<td>COMPLEX</td>
<td>Complex-unitary</td>
<td>Complex-pluralist</td>
<td>Complex-coercive</td>
</tr>
</tbody>
</table>

Table 2: Characteristics of environmental problems and ICM in particular.

(for further explanation see Flood & Jackson, 1991)
Table 2: Characteristics of environmental problems

<table>
<thead>
<tr>
<th>Characteristics of environmental problems</th>
<th>Characteristics of ICM</th>
</tr>
</thead>
<tbody>
<tr>
<td>many and diffuse objectives</td>
<td>government agencies, economic groups individuals, community groups which are all involved in ICM tend to have different objectives</td>
</tr>
<tr>
<td>many sources of information</td>
<td>information comes from physical and biological scientists, farmers, social scientists, individuals, community groups, etc.</td>
</tr>
<tr>
<td>scope includes several sectors society and organisations with different interests and ideologies</td>
<td>catchment often includes those with different economic, social and philosophical views, as well as involving organisations such as government agencies, local government and community groups</td>
</tr>
<tr>
<td>long time horizons</td>
<td>ICM problems, eg salinisation, take long periods to solve especially in relation to economic demands</td>
</tr>
<tr>
<td>many policy options</td>
<td>ICM problems can be viewed from different perspectives which will influence policy options</td>
</tr>
<tr>
<td>many policy makers and constituents</td>
<td>many government agencies are involved as well as local government and government sponsored groups eg, Catchment Coordinating Groups</td>
</tr>
<tr>
<td>multidisciplinary</td>
<td>ICM involves complex technical and social problems which involves a many disciplines</td>
</tr>
<tr>
<td>non-monetary and monetary issues</td>
<td>in a catchment, economic and ecological issues are involved</td>
</tr>
<tr>
<td>degradation to environment difficult to reverse</td>
<td>degradation to such things as water quality difficult to reverse</td>
</tr>
<tr>
<td>property rights impinge on solutions</td>
<td>property owners in one part of the catchment can adversely affect others who have little redress, eg an upstream farmer who cuts down tree cover</td>
</tr>
<tr>
<td>problems can have considerable spatial extension</td>
<td>catchments can be large in area.</td>
</tr>
</tbody>
</table>

(Source: Stenberg (1980), Burton & Dukes (1990), Soderbaum (1991))

Again using ICM, this situation can be shown to be a complex using Flood and Jackson’s (1991) criteria - see table 3.
Table 3: Characteristics of ICM showing its complexity

<table>
<thead>
<tr>
<th>Characteristics of a &quot;complex&quot; system</th>
<th>Characteristics of ICM</th>
</tr>
</thead>
<tbody>
<tr>
<td>large number of elements</td>
<td>many individuals, organisations, species and physical factors involved</td>
</tr>
<tr>
<td>many interactions between elements</td>
<td>all above interact</td>
</tr>
<tr>
<td>attributes of elements probabilistic</td>
<td>attributes of people, organisations, ecosystem effects difficult to establish and changeable depending on circumstance</td>
</tr>
<tr>
<td>interactions between elements not highly organised</td>
<td>element (above) are not highly organised</td>
</tr>
<tr>
<td>system evolves over time</td>
<td>social, economic and ecological systems are dynamic</td>
</tr>
<tr>
<td>subsystems pursue their own goals</td>
<td>economic elements (eg farmers), government agencies, individuals, etc. pursue their own goals</td>
</tr>
<tr>
<td>system is affected by behavioural influences</td>
<td>ICM is affected by government policy, economic &quot;booms&quot; or &quot;busts&quot;, state of physical environment, etc</td>
</tr>
<tr>
<td>system is open to the environment</td>
<td>ICM is affected by legal, social, economic, biological changes</td>
</tr>
</tbody>
</table>

(source: Flood and Jackson, 1991)  
(Source: author)

In some circumstance it could be regarded as a pluralist situation and in others coercive situation - see tables 4 and 5.

Table 4: Characteristics of a pluralist situation

<table>
<thead>
<tr>
<th>Pluralist characteristics</th>
<th>Assumed ICM characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>basic compatibility of interest</td>
<td><em>overtly</em> compatible interests between CCGs, government agencies and communities</td>
</tr>
<tr>
<td>beliefs and values diverge somewhat</td>
<td>values and beliefs of scientists, farmers, public servants, etc. diverge</td>
</tr>
<tr>
<td>compromise is possible</td>
<td>CCGs seem to work on the principle of compromise</td>
</tr>
<tr>
<td>all participate in decision making</td>
<td>CCGs (hence the community) appear to participate in decision making</td>
</tr>
<tr>
<td>all act in accordance with agreed objectives</td>
<td>CCGs seem to have agreed objectives with government agencies</td>
</tr>
</tbody>
</table>

(Source: Flood and Jackson, 1991)  
(Source: Author)
Table 5: Characteristics of Coercive situations

<table>
<thead>
<tr>
<th>Coercive characteristics</th>
<th>Assumed ICM characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>no shared common interests</td>
<td>in some situations the interests of participants are not shared, e.g., developers/loggers versus conservationists</td>
</tr>
<tr>
<td>values and beliefs likely to conflict</td>
<td>see above</td>
</tr>
<tr>
<td>genuine compromise not possible</td>
<td>see above</td>
</tr>
<tr>
<td>some coerce others to accept decisions</td>
<td>political and economic influence can be used, e.g., in small rural communities influence can be brought to bear on individuals to conform</td>
</tr>
<tr>
<td>given the present systems, people cannot come to agreement over objectives</td>
<td>the conservationist/development debate can occur in a catchment</td>
</tr>
</tbody>
</table>

(Source: Flood and Jackson, 1991) (Source: Author)

Using Total Systems Intervention (TSI) as defined by Flood and Jackson (1991), techniques such as Soft System Methodology (SSM) - see Checkland and Scholes (1991), and Critical Systems Heuristics (CSH) - see Ulrich (1993), could be used. For a review of these techniques see Flood and Jackson (1991), Jackson (1991), or Ellis (1995).

Investigating environmental management problems using TSI

The techniques and their use with the ICM problem are more fully explained in Hutchinson (1995). However, the main philosophy is that methodologies/techniques are used as is thought appropriate by the system investigator. These reflective, qualitative techniques have two benefits:

they make the investigator critical of the approach being taken as well as assumptions being made, and

they define the problem so the definition encompasses all stakeholders’ views.

Only when the system boundary, assumptions, and desired outputs are defined, is it valid to attempt to build quantitative models of the desired management strategy.

Qualitative input can be used to produce conceptual models in SSM. For instance, in building models in SSM it is desirable to know the clients, actors, and owners involved in a system, as well as the desired processes in it, and the assumptions taken and constraints on it. Tables 6 and 7 show some of the qualitative data obtained by the author in a recent investigation into ICM (Hutchinson, 1995). Using this form of data, i.e., the perceived actors and clients of a system, definitions of the system can be produced. From these definitions, conceptual models of the desired system can be produced. The system now defined, “harder” / quantitative methods can be employed to model desired outcomes.
Table 6: Desired Clients of the ICM

<table>
<thead>
<tr>
<th>Those who should be the CLIENTS of ICM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Humans, non-humans, and flora</td>
</tr>
<tr>
<td>Environment</td>
</tr>
<tr>
<td>Rivers, hence the community</td>
</tr>
<tr>
<td>Physical factors, eg water quality, estuaries, coasts</td>
</tr>
<tr>
<td>Indigenous as well as migrant creatures</td>
</tr>
<tr>
<td>Future as well as present generations</td>
</tr>
<tr>
<td>Community not just the economy</td>
</tr>
<tr>
<td>All those with social, or economic interest in the area</td>
</tr>
<tr>
<td>All citizens</td>
</tr>
<tr>
<td>Local community who live and work in the catchment</td>
</tr>
<tr>
<td>Immediate land owners</td>
</tr>
<tr>
<td>Everyone whose interest is affected, inside or outside the catchment</td>
</tr>
<tr>
<td>State government</td>
</tr>
</tbody>
</table>

Table 7: Perceived Actors in the ICM system

<table>
<thead>
<tr>
<th>Those who should be the ACTORS in the ICM system</th>
</tr>
</thead>
<tbody>
<tr>
<td>Public servants / Government agencies</td>
</tr>
<tr>
<td>Public</td>
</tr>
<tr>
<td>Experts: physical / environmental /social scientists, academics, researchers</td>
</tr>
<tr>
<td>Catchment Coordinating Groups</td>
</tr>
<tr>
<td>Facilitation experts</td>
</tr>
<tr>
<td>Pressure / community groups</td>
</tr>
<tr>
<td>Local government</td>
</tr>
<tr>
<td>Private industry</td>
</tr>
<tr>
<td>Land owners</td>
</tr>
<tr>
<td>Minister of Water / Environment</td>
</tr>
<tr>
<td>Indigenous people</td>
</tr>
<tr>
<td>Stakeholders</td>
</tr>
</tbody>
</table>

**Conclusion**

This brief paper has attempted to illustrate the use of TSI and its associated methodologies to the complex area of environmental management. Systems methods have been used with success in business and government for solving complex organisational problems. There is no reason why they could not also be used in the environmental arena as well.

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GROUNDWATER DISCHARGE OF NUTRIENTS TO A SHELTERED MARINE SYSTEM: DATA UNCERTAINTY AND CONSTRAINTS ON MANAGEMENT

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Abstract

Cockburn Sound is a sheltered marine embayment near Perth, Western Australia which has suffered environmental degradation, largely as the result of the input of nutrients from industrial activity near the coast and past sewerage disposal. Inputs of nutrients from surface runoff have been mostly eliminated, but persistently high phytoplankton levels indicate that there is probably a continuing input of nutrients from groundwater discharge in excess of the assimilative capacity of the Sound. Analyses of nutrients in groundwater from 39 bores, together with estimates of the rate of groundwater flow from pump tests, suggest that about 330 tonnes of nitrogen and 2 tonnes of phosphorus are discharged each year by groundwater to this water body. This exceeds the estimated assimilative capacity in the Sound of about 300 tonnes per year of nitrogen.

Groundwater sampling uncertainties are estimated to cause an error of ±100 tonnes for nitrogen and ±1 tonne for phosphorus in the annual groundwater nutrient loads. In addition, there are very large uncertainties in the rate of groundwater flow, particularly in the case of dense contaminated groundwater. As it is impractical to obtain accurate estimates of nutrient discharges from groundwater, indirect water quality indicators of nutrient inputs need to be adopted.

The monitoring uncertainties cause major difficulties in environmental management of water bodies like Cockburn Sound. A cooperative involvement between government and the polluting industries is required.

Introduction

The management of the effects of human landuse on the environment is one of the greatest challenges faced by modern society. The degradation of ecosystems is often caused by the complex interaction of a number of variables which are hard to isolate and quantify, and management decisions are often made on the basis of limited data.

One of the most severe environmental problems in Western Australia is the degradation of estuaries and coastal marine environments, caused largely by the excessive input of nutrients from agricultural, industrial and urban landuse. In most estuaries, nutrients (especially nitrogen and phosphorus) are discharged by surface drainage. Provided that a large number of flow and water quality measurements are made on major drainages
Environmental Management

Discharging to estuaries, nutrient loads are relatively easy to quantify with a high degree of certainty.

However, the western coast of Australia has very few major rivers, and groundwater from regional groundwater flow systems is generally the most important source of nutrients discharged to coastal marine environments (Johannes, 1980; Hillman, 1981). Unlike surface drainage, the discharge of nutrients from groundwater is hard to quantify, and estimates of nutrient loads are invariably associated with large uncertainties.

This paper outlines the uncertainties in estimating nutrient fluxes to Cockburn Sound, a sheltered and degraded marine embayment near Perth, Western Australia. The magnitude and source of errors associated with nutrient discharge estimates are outlined, and the constraints that these uncertainties impose on possible management options for this water body are discussed.

Setting

Physical setting

Cockburn Sound is located to the south of Perth (Figure 1) and is important as a sheltered harbour for a number of industries, is an important fishery, and is widely used for public recreation. This water body has lost more than 80% of its seagrass, largely as a result of the input of nutrients from industrial activity and past sewerage disposal along the coast. The circulation of water within Cockburn Sound is restricted by Garden Island and the causeway linking the island to the mainland. Consequently, Cockburn Sound is poorly flushed, and is susceptible to environmental degradation caused by the input of contaminants.

In the 1970s, more than 1000 tonnes of nitrogen and phosphorus were discharged in waste water each year directly to Cockburn Sound, mainly in industrial and sewerage effluents (DCE, 1979). This caused severe blooms of phytoplankton and encouraged the growth of epiphytic algae on seagrass. The more critical of the nutrients is nitrogen. The surface inputs of nitrogen have been progressively removed, but the persistent appearance of phytoplankton blooms has indicated that there may be continuing inputs to Cockburn Sound by groundwater discharge at levels which may cause phytoplankton blooms.

Hydrogeology

Cockburn Sound receives groundwater discharge from the Jandakot Mound, a large groundwater flow system within superficial sediments that underlie much of the Perth Metropolitan Region (Figure 1). Near the coast, two aquifers occur: a sand aquifer (Safety Bay Sand) with a thickness of about 15 m which overlies a highly permeable limestone aquifer (Tamala Limestone) which is 15 to 30 m thick. They are generally separated by a 0.5 to 1 m thick silty or clayey shell unit which forms a confining bed that limits the interchange of water between the two aquifers.

Groundwater discharge from the two aquifers takes place where fresh groundwater is forced to ride over a wedge of denser, saline water (Figure 2). Discharge from the Safety Bay Sand generally takes place at the shoreline, while discharge from the Tamala Limestone probably occurs 100-250 metres off-shore where the confining bed is missing. In areas where the Safety Bay Sand is absent, discharge from the Tamala Limestone takes place near to the shore at the base of limestone cliffs.

The rate of discharge of ground-water into Cockburn Sound is highly seasonal, being highest in late spring and summer when tides are lowest, and low in winter when tides are...
high. There is also a strong fluctuation within each day, depending on the tidal range. Groundwater discharge is greatest at a time of the year when sea temperatures are high and favourable for the growth of phytoplankton.

**Nutrient Flux Estimates**

**Method of Calculation**

The total volume of groundwater discharging to Cockburn Sound was estimated using a flow-net analysis compiled by Davidson (1984) supplemented with discharge estimates derived from coastal pumping tests (Haselgrove, 1981). In June 1994, 39 bores in both the Safety Bay and Tamala Limestone aquifers were sampled in a joint industry-government sampling programme to provide synoptic chemical data (Appleyard, 1994). This allowed nutrient fluxes to be determined for each segment of coastline between bores using the expression:

\[ F = CQ \]

where

- \( F \) = mass-flux of nitrogen or phosphorus (mass per unit time per unit length of coast)
- \( C \) = concentration of nitrogen and phosphorus
- \( Q \) = groundwater discharge (volume per unit time per unit length of coast)

The total loads of nitrogen and phosphorus discharged to Cockburn Sound by groundwater were estimated by:

\[ M = \sum (F_1) \]

where

- \( M \) = load of nitrogen or phosphorus for each coastal segment
- \( l \) = length of coastal segment

A more complete breakdown of the approach used is presented in Appleyard (1994). The same methodology was also used by Mackie-Martin PPK (1992) to calculate the loads of nutrients discharged to Cockburn Sound by groundwater using historical data, and has been widely used elsewhere.

**Results**

The spatial variation in nitrogen fluxes from each aquifer (Figure 3) indicates that most of the nitrogen is discharged to Cockburn Sound from a limited number of industries, and that the discharge of this nutrient elsewhere is insignificant. The pattern of discharge is similar for both aquifers, but about 80% of the discharge probably takes place from the poorly monitored Tamala Limestone aquifer. The dominant nitrogen chemical species is ammonia, which can be rapidly taken up by marine plants. Phosphorus discharge is more uniformly distributed than nitrogen, but the fluxes are insignificant, and are generally two to four orders of magnitude lower than the nitrogen fluxes.

The total load of nutrients discharged annually by groundwater to Cockburn Sound is estimated to be about 330 tonnes of nitrogen and 2 tonnes of phosphorus. Preliminary results from modelling of sea-water circulation carried out by the Western Australian Department of Environmental Protection indicate that the assimilative capacity of nitrogen in Cockburn Sound may be as low as 300 tonnes per year. The current annual input of
nitrogen from groundwater may exceed the assimilative capacity of Cockburn Sound for this nutrient. Management of the groundwater input of nitrogen could therefore be a critical component of managing the environmental degradation of this water body.

Data Uncertainties

A preliminary estimate of the possible errors involved with the nitrogen and phosphorus loads was determined by kriging the spatial distribution of measured concentrations in groundwater (Appleyard, 1994). The estimated errors were about ± 100 tonnes for nitrogen and ± 1 tonne for phosphorus. These errors are related to the spacing between groundwater monitoring bores (up to 5 km).

There are also large sources of error in the estimation of the rate of movement of contaminated groundwater, mainly:

(i) *aquifer heterogeneity* - the permeability of the limestone aquifer in particular may vary by one or more orders of magnitude over short distances. Measurements of aquifer permeability made in pumping tests will probably not be regionally applicable, and may give rise to incorrect estimates of groundwater discharge.

(ii) *behaviour of contamination at a saltwater interface* - the largest groundwater sources of nitrogen near Cockburn Sound are relatively dense contamination plumes containing ammonium sulphate located at the base of the Tamala Limestone. The plumes would be retarded in their movement up the salt water interface during flow to the sea by their density. That is, estimates of nutrient load based on the rate of flow of fresh groundwater will give an over-estimate. The degree of retardation can not be accurately determined.

Combining the errors in determining contaminant distribution in the groundwater with the errors in determining the rate of movement, the total errors in the estimate of nitrogen load may be as high as ± 60% (200 tonnes per year), and are probably comparable to uncertainties determined for the discharge of nutrients by groundwater elsewhere (Giblin and Gaines, 1990).

A feature of groundwater is its slow rate of movement, which is typically 150 metres per year near Cockburn Sound. Although nutrient loads in surface drains can be quickly reduced by changes in landuse, reducing nutrient inputs to groundwater may take decades to have a significant effect on the receiving sea water. This makes it difficult to monitor the benefits of aquifer clean-up and contributes to uncertainty regarding required levels of contaminant reduction in the groundwater.

Implications for management

Management of environmental degradation in estuaries and nearshore marine environments in Western Australia is largely based on determining management limits for nutrient inputs based on estimated environmental assimilative capacities, and regulating landuse to ensure nutrient inputs do not exceed those limits. This approach requires that the nutrient inputs can be easily measured.

However, it is difficult to adopt this approach when there are large uncertainties in the magnitude of nutrient inputs to a water body, and in their spatial and time-variant behaviour. The current regulatory response to data uncertainty of using the 'Precautionary Principle' and adopting the highest possible nutrient loads may place unnecessary
constraints on landuse, and is probably impossible to enforce because of the uncertainty of the data. An alternative approach to monitoring marine water bodies like Cockburn Sound, is to accept that nutrient loads discharged from groundwater can only be measured very imprecisely, and to look for other indirect measures of groundwater inputs of nutrients (for example by using phytoplankton or chlorophyll levels in seawater).

Management of environmental degradation within marine water bodies like Cockburn Sound needs to be a partnership between government, the community and industry, as it is very difficult for government to adopt a traditional prescriptive pollution control role given the measurement uncertainties.

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MACKIE-MARTIN PPK, 1992, Groundwater inputs to the Southern Metropolitan Waters: Report prepared for the Western Australian E.P.A. as part of a Pollutant Input Inventory.
Figure 2. Groundwater discharge to Cockburn Sound
Figure 3. Estimated nitrogen fluxes to Cockburn Sound from groundwater
Figure 1. Location of Cockburn Sound
MODELLING, MANAGING AND MASSAGING ENVIRONMENTAL SYSTEMS WITH AEAM.

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Abstract
Adaptive Environmental Assessment and Management (AEAM) provides a means by which complex environmental systems are represented at a scale appropriate to the management of the system. AEAM involves structured workshops in which stakeholders define an agreed representation of the system. Algorithms representing system elements are developed by stakeholders, based upon best available knowledge. These algorithms are combined in a spatially representative model that allows exploration of alternative management actions. Improvements in the selection and acceptance of management actions can be made through the AEAM process by establishing a common understanding of the system amongst stakeholders and managers, selecting appropriate scales for representing and managing of system elements, and identifying indicators suitable for quantifying the results of management actions. An agreed, common understanding of the system and the probable outcomes of management actions engenders support for the actions because the benefits are understood by all affected parties. The identification of indicators of system response allows monitoring of the results of actions. These indicators must have established baseline values and must be able to provide reliable and sensitive indications of system response. The AEAM approach was used in the development of a water quality management strategy for the Goulburn-Broken River catchment. The model used in developing the strategy allowed comparison of the effects of alterations in township sewerage and stormwater disposal, land management practices, flow control and irrigation diversions. Managers of the system used the modelling results in the development of strategic plans for management of system nutrients and to identify critical gaps in the understanding of system interactions and behaviour.

Management of Natural Resources Systems
Natural resources management often involves the manipulation of complex system components and the assessment and comparison of alternative management actions on these components. Such assessment includes consideration of social, economic, ecological, chemical and physical systems, and also of the complex interrelationships that exist between these components.

There is often much known about the individual components of environmental systems. Aspects of some components, such as physical or chemical systems, are understood and modelled in fine detail.
Of the interactions and interdependencies between environmental system components, there is often much less knowledge and understanding. Many of the relationships between components are understood at a level that can best be described as "conceptual" or lying somewhere in the "rule of thumb" realm. The lack of knowledge of the links and relationships between different system areas is unsurprising as there has been, until recent times, little professional or societal support for integration of cross-disciplinary research and investigation.

In many areas of environmental management a move to a systems approach is occurring as researchers and managers are asked to deal with issues at a broad scale, including consideration of many individual components. The techniques of Adaptive Environmental Assessment and Management (AEAM) (Walters, 1974, 1986; Holling, 1978; ESSA, 1982) provide one approach to the representation of the interactions and interrelationships of complex system components.

**The AEAM Method**

AEAM has been developed over the past twenty or so years through a range of applications in North America, Europe and Australia. Applications include the management of spotted owl habitat areas, fisheries, alpine resort areas, ocean sewerage outfalls and river nutrients. Central to the method is the identification by system stakeholders of the possible management actions to be considered and the indicators of the system that will be used to assess the effects of a particular management action.

Through a series of workshops and specialist sub-group meetings a single, agreed model representation of system components and interactions is developed. This model is used to assess possible management actions.

Development of the algorithms for inclusion in the model provides a means for drawing out the best available understanding of the system components and, particularly, the effects of management actions on system indicators. When the model is completed, a series of gaming exercises allow an exploration of the sensitivity of components to different management approaches.

AEAM uses a structured workshop approach to identify management actions for the system, identify indicators to be used for the evaluation of different management actions, and develop and test the system model.

Key phases of AEAM methodology are as follows:

- Identify stakeholders within the system under consideration and identify a key person close to the issue who will be a champion of the approach.
- Use an initial workshop to identify possible management actions and indicators of system response. From this, identify key components of the system to be modelled.
- Use a series of workshops and specialist sub-group meetings to develop algorithms for the representation of key system components and combine algorithms into an interactive model.
- Use a gaming workshop to test the model and obtain feedback from stakeholders on the ability of the model to simulate observed system responses.
- Finalise model development and use a final workshop to present the model to managers and stakeholders.

The interactive model produced by the AEAM methodology is formulated by stakeholders and incorporates their expertise and understanding of the system. This is supported by integration and analysis of data that are available on various system components. Models can be written in any language that supports a flexible manipulation of input data and parameters, and a simple graphical output. Commonly used languages are Quick Basic™ and Visual Basic™, with simpler applications being modelled in a spreadsheet application such as Excel™.

The most commonly used model shell is based on aerially representative grid cells with characteristics such as elevation, land use, geology, and population. Cell linking can be used for the transportation of system variables, such as the transport of streamflow through elevation-based links. Models are typically run over a defined period of time to explore the effects of a management scenario under a range of seasonal, climatic or other time-varying influences.

Results of scenarios are compared by overlaying the graphical output from one scenario over the output from the previous scenario and gauging the relative change in the output. Generally no printed output is obtained from the model as the output is used primarily for estimating the relative effects of different scenarios.

The fundamentals of AEAM are stakeholder involvement, identification of possible management actions, identification of the indicators to be represented and used in the model, and the development of algorithms that represent system components and their links at an appropriate scale and level of understanding.

A number of examples of full and partial application of the AEAM methodology have occurred in catchment management in Australia. An example that illustrates the approach is the assessment and management of nutrients in the Goulburn-Broken River catchment in Victoria, and the impact of this catchment on nutrient loads in the River Murray.

Nutrient Management in the Goulburn-Broken River Catchment
The Goulburn-Broken River catchment is positioned in north central Victoria and drains generally northwards from headwaters in the alpine area, at elevations around 1700 m, to the confluence with the River Murray, at elevation 100 m (Figure 1). The catchment area is 23,700 km², with a population of 125,500. The two largest population centres are Shepparton and Seymour with 26,200 and 12,100 people, respectively. The Goulburn-Broken catchment is an area with mixed land use, including 2,500 km² of irrigated pasture, 13,200 km² of dryland grazing and 7,500 km² of forest.
The Goulburn River is one of the larger sources of irrigation water within Victoria, supplying to irrigation areas within the Goulburn-Broken catchment and also to the adjacent Campaspe and Loddon catchment. Lake Eildon, in the upper Goulburn, provides storage to meet irrigation supply and is one of the main controls of flow on the Goulburn. As a result of irrigation demands, the flow in the Goulburn River below Lake Eildon is dominated by high volumes in summer.

In 1994 an AEAM based project on the management of water quality in the Goulburn-Broken River catchment was undertaken. This followed Federal concerns over the contribution of the Goulburn-Broken system to nutrient loads in the River Murray, and local concerns over possible occurrences of blue-green algae outbreaks in the Goulburn and other streams. The AEAM methodology was selected for the development of a water quality strategy because of the ability of the approach to:

1. include stakeholders in model and strategy development,
2. include consideration of system components other then the physical system,
3. produce a single, agreed representation of the system (thereby reducing the potential for conflicts over simulation results), and
4. allow interactive and adaptive testing of management scenarios.

These four factors needed to be addressed because of the highly emotive nature of the water quality issue and the potential for conflict between various industry sectors and governing bodies over the causes of, and solutions to, high nutrient levels in catchment streams.

Identification of Management Actions and Indicators
AEAM is a workshop based approach, with an initial workshop being used for the identification of possible management actions and indicators. In addressing water quality in the Goulburn-Broken catchment, the first workshop included representatives of regional and state governments and water authorities, departments of agriculture and conservation, food processing industries, land and water livestock industries, irrigation bodies, forest and mining industries, alpine resort management, and researchers.
At this workshop the participants were first asked to identify possible management actions that could influence the nutrient concentrations and loads in the Goulburn and Broken Rivers. In identifying actions, participants were asked to consider as broad a range of actions as possible, with only limited consideration given to the practicality associated with particular actions. Over 150 possible management actions were found, ranging from household to legislative approaches.

Following the development of a list of possible actions, participants were asked to identify indicators within the system that could be used as measures by which the effects of management actions could be assessed. After considering all of the management actions, some of which were unable to be associated with indicators, approximately 120 indicators were identified. The actions and indicators were divided into four groups. Table 1 lists the groups and examples of actions and indicators within each group.

At the conclusion of the initial workshop four sub-groups were formed to undertake the algorithm development and modelling in each of the identified management action areas. The role of these sub-groups was to obtain the best available data or knowledge on the relationships between system components and identified indicators. In cases where these relationships were not able to be developed, an alternative approach was to develop algorithms relating the response of a system component to some of the basic indicators being modelled by one of the other sub-groups.

Hydrology | Water Quality
---|---
Change flow regime | Streamflow variables | Reduce fertiliser use | phosphorus levels
Change dam management | Streamflow variables | Change to tertiary sewage treatment | BOD

Ecology | Economic/Social
---|---
Control carp | Fish population | Re-use on-farm waste | Drainage volume
Control willow trees | Tree numbers/species | Manage fertilisers | Fertiliser sales

Table 1. Management Areas, Actions and Indicators

Algorithm Development and Modelling
The investigations and analysis by the four sub-groups took place along independent lines, with a degree of co-membership to facilitate communication between sub-groups. The closest links were formed between the hydrology and water quality sub-groups because of the nature of the issue under investigation.

Hydrological modelling was simplified through use of output from the REALM flow allocation model of the Goulburn-Broken system, run by HydroTechnology. Nineteen scenarios of river flow, irrigation release, water allocations and dam management were investigated and the results made available for inclusion in the AEAM model. Water
quality was modelled by allocation of phosphorus and nitrogen inputs from various land-use types and point sources into modelled sub-catchments. The loads for each sub-catchment were then routed through the system and were able to be monitored at sub-catchment outlets.

Modelling of ecological indicators was limited by the ability to relate indices of ecological condition to model variables. Three binary indicators were finally selected for examination, with the indicator state being set by the flow and nutrient levels shown in Figure 2. Figure 2 illustrates one of the model input screens and is used for setting the ecological index triggers. The ecological indices are turned "on" when the flow and total phosphorus values in the model are, respectively, below and above their trigger values.

<table>
<thead>
<tr>
<th>INDEX</th>
<th>Upper Flow trigger (ML/mo)</th>
<th>Lwr. Flow Trigger (ML/mo)</th>
<th>Total P trig. (mg/l)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Macroinv. diversity</td>
<td>240000</td>
<td>30000</td>
<td>0.05</td>
</tr>
<tr>
<td>Blue-Green Al. Risk</td>
<td>90000</td>
<td>90000</td>
<td>0.06</td>
</tr>
<tr>
<td>Filamentous Al. Risk</td>
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<td>30000</td>
<td>0.02</td>
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<th>INDEX</th>
<th>Upper Flow trigger (ML/mo)</th>
<th>Lwr. Flow Trigger (ML/mo)</th>
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<tr>
<td>Blue-Green Al. Risk</td>
<td>60000</td>
<td>60000</td>
<td>0.15</td>
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</tbody>
</table>

Figure 2. Ecological Index Trigger Input Screen

Similarly to the ecological sub-group, the social/economic sub-group was confounded by a lack of information on relationships between the modelled parameters - flow, phosphorus levels, and nitrogen levels - and changes or effects on sociological or economic parameters. Consequently, these aspects were not incorporated in the model, but were flagged for further investigation.

Following the data analysis and knowledge gathering of the sub-groups, model writing was undertaken by two members of the hydrology and water quality sub-groups. The model was based upon the shell used for a similar investigation of water quality on the Latrobe River (Grayson et al., 1994), and was modified to include the REALM flow inputs and the various hydrology, water quality and ecology algorithms. Final development and testing was undertaken at a gaming workshop to which all the participants to the initial workshop were invited.

The Gaming Workshop

The aim of the gaming workshop is to present the model to stakeholders and managers, and to allow them to investigate operation of the system and the response of the system to simple manipulations of input variables. The gaming workshop can also be used for fine tuning of the model algorithms if the system response is at variance with observed responses. For the Goulburn-Broken investigation the limited time available for the
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gaming workshop allowed consideration of only a small number of management scenarios associated with the most commonly suggested scenarios. Grayson and Doolan (1995) list some of the scenarios and provide a copy of the model for further system investigation.

As an example, one of the scenarios investigated the impacts of irrigation on the loads of total phosphorus (TP), in Tonnes per month (T/mo), being exported from the Goulburn-Broken catchment. To examine this a simulation run was performed with the system settings adjusted to the default (i.e. existing) conditions. The output graphs that were selected for viewing were the TP for a site on the Goulburn River upstream of the irrigation areas, another site at the catchment outlet, and the annual accumulated TP exported from the catchment. The model cells representing the irrigation land use type were then all changed to dryland agriculture and the simulation run again (Scenario A) with overlaid output graphs. The simulation used 15 years of flow data from REALM runs, over the period 1974 to 1989, for the simulations. This period contains some of the highest flows and one of the drier periods on record.

The model output is reproduced in Figures 3, 4 and 5.

![Figure 3](image1.png)

**Figure 3.** Total Phosphorus, Goulburn River upstream of Seymour

![Figure 4](image2.png)

**Figure 4.** Total Phosphorus, All Goulburn-Broken River

![Figure 5](image3.png)

**Figure 5.** Annual Accumulation of Total Phosphorus, All Goulburn-Broken River

Figure 3 represents the TP load upstream of the irrigated areas. Consequently, the exact overlaying of the Scenario A and Default results indicates that changing land-use further downstream has no effect on upstream loads, as expected. In Figure 4 it can be seen that the land-use change has had a significant effect on the TP loads for the whole catchment and that this effect is not focussed on either the high or low flow periods. The difference in
annual loads is illustrated in Figure 5 and can be estimated at between 30 and 40% of the catchment load.

The value to managers of the information presented in Figures 3, 4 and 5 lies not only in what is able to be told about changing irrigation land to dryland agriculture, but also in the comparison of the results of this scenario with those from other management scenarios. Through exploration of a wide range of management scenarios managers and stakeholders not only obtain an understanding of the impacts of individual changes, but also the relative effects of competing management options.

Conclusions
The AEAM approach provides a method for the assessment and management of complex natural resources systems. The value of this methodology lies in the ability to provide an agreed representation of the system with a high level of stakeholder input, thereby engendering stakeholder "ownership" of the management assessment process and providing a path for conflict resolution.

The complexity of modelling in the AEAM approach is sometimes at a lower level than is often encountered in modelling of single system components. The scale of modelling is selected to be appropriate to the scale of the problem under consideration and to the level of understanding of the interactions of system components, thereby providing a management tool that allows generally simple but holistic examination of environmental management decisions.

Grayson and Doolan (1995; in press) provide notes and further information on the facilitation of AEAM workshops and the modelling of systems using the AEAM approach.

References
SECTION 5

APPLICATION OF SYSTEMS METHODOLOGIES
A SYSTEMIC INTERPRETATION OF THE BUILDING PROCUREMENT SYSTEM

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Abstract

The building industry is one of the largest single sectors of gross domestic production and directly includes a large proportion of the labour force in providing and maintaining buildings and facilities (A.B.S. 1994). Despite the common focus by this group on building production and maintenance, the industry is not recognised for operating as a cohesive unit but is alternatively renowned for its fragmentation (Kalay et al. 1995).

The industry's fragmented characterisation generally refers to a client's difficulty in interacting and identifying with the procurement system—the processes required to turn a client decision to acquire a building or facility into a reality. In practice procurement involves creating a temporary organisation from a disparate selection of specialists to subsequently fulfil client objectives for a typically unique project (Cherns et al. 1984; Mohsini 1992; Bennett 1990). It is the relative quality and success in integrating the procurement system's components that is a primary determinant in the success of a given project and also a factor in perceiving industry fragmentation (Miller 1967). This paper examines the concept of industry fragmentation, identifies some of its causes and their implications, and subsequently discusses how some of the negative aspects of fragmentation can be combated through methods of integration.

Introduction to the Building Industry

A discussion on the application of systemic thinking to the notion of construction industry fragmentation requires an appreciation of the construction industry and how it can be perceived as fragmented. This allows a more detailed study of the processes of building procurement which subsequently provide the foundation for discussing the form and methods employed by the industry to integrate its fragmented components.

What is the construction industry?

The 'building' or more generally, the 'construction industry' is a phrase used to refer to a conglomeration of industries directly and indirectly related to the production of buildings and fixed physical facilities (Mohsini 1992). It has several distinct components which may be grouped according to their relation to the project site (i.e. off or on-site production) or by market sector. Individual sectors can be further differentiated into smaller sub-sectors which producers specialise for the level's demands, though in practice specialists rarely focus on just one sub-sector but rather expand their scope to overlap others in order to reduce their dependence on any one market sector. For example, a contractor may have
recognised expertise in procuring educational facilities however, to reduce dependence on that particular market, the contractor will also seek and obtain work in some of the other non-residential building markets such as: hotels, shops, factories, offices, health, and entertainment facilities (A.B.S. 1995). Though the diversification rarely goes beyond two or three sub-sectors, by having a degree of diversification and specialisation that includes working on more than one project at a time (Walker 1989), a self perpetuating form of market stimulation results through further specialisation and competition for work within and between sub-markets (Langford 1991). The main industries affiliated with construction may be grouped according to their relationship to the project site—either direct or indirect—and are listed as follows:

Fixed physical facilities i.e. structures (sectors as defined by the A.B.S. (1994)):
- residential (dwellings or houses for long term residential purposes),
- non-residential (commercial & social infrastructure),
- engineering (civil and major plant for the other engineering disciplines).

Materials and products:
- materials manufacture and supply,
- product manufacture and supply.

These five industry sectors, though useful in indicating the diversity of the construction industry’s products, are limited in explaining the nature of the processes of the procurement of new and the refurbishment of existing buildings—the primary focus of this paper. In general, two main sources of resources have been inferred so far: the providers of buildings (producers), and those who instigate their creation (clients). These two categories of resources provide the componentry from which procurement is achieved however, they require relationships to structure their association. In other words, a means of effectively bringing together or integrating their individual and collective abilities (possible outputs) and desires (required inputs) is required. Given this basic starting point, an alternative view of the construction industry can be achieved by differentiating between those components oriented to task based operations and those to management and coordination (Walker 1984).

Miller (1967) illustrates this process of creating a new system for work (Figure 1) using an industrial model where physical and human resources are combined to form a client operating system. The principle of combining complementary resources provides a useful analogy for explaining the structure of the building procurement system except that in building procurement, the plant system includes all resources associated with a given task/operation based group—both physical, human, and their individual management. To complement the task based resources, the organisational structure, associated monitoring
systems and affiliated management staff are initiated by the client to act on its behalf to procure the building. Miller ironically defined this as the organisation building system. The product of the combined operation and management systems in the building case is called the procurement system.

**What is industry fragmentation in the building industry?**

In assessing the claim that there is industry fragmentation one must consider what is seen as fragmented, and subsequently, who sees the industry as being fragmented? In general, fragmentation is more readily identifiable at the industry and project levels, for after analysis, certain patterns emerge that distinguish not only differences in each industry’s product, but also the processes they employ. A comparison between engineering and non-residential construction (as defined above) readily illustrate such differences. As a consequence of the relatively low variety of unit production per project, engineering construction has developed the application of specialised machinery which has led to a situation where process and product are integral to each other. Alternatively, non-residential construction has the greatest variety per unit of turnover (though it varies between sub-markets such as schools to high-rise office towers). In addition, non-residential construction as compared to engineering generally employs a greater volume of specialists per-project requiring coordination. Further more, in conjunction with the growing complexity of individual projects, the non-residential sector is witnessing expanding market size and scope coupled with variable market requirements, subsequently catalysing continued proliferation of specialists (Bennett 1990; Pries 1995).

The importance of providing an effective organisation which integrates and coordinates the resources for procurement has increased with the corresponding growth in specialisation, especially as seen in the non-residential sector (Bennett 1990). Drucker (1955, p 128) describes this situation as an increase in the ‘burden of diversity’. This phenomena is seen in the greater specialisation of procurement componentry ‘shifting the burden’ of producing complex buildings from the shoulders of individual producers to those responsible for assembly. It is this attribute of differentiation accompanied by assembly or more correctly, integration, that is largely responsible for the construction industries’ fragmented characterisation (Mohsini 1992). As far as the client is concerned, the initial perception of the construction industry is of a fragmented form—specialists quite distinctly detached from each other. It is only after the formation of the procurement system that it is possible for the client to identify an organisation or system that has responded to their needs. Further more, the procurement system only exists for the duration of the project (which in the majority of building projects, is a matter of months rather than years) and accordingly, the holistic organisation which a client and specialist has caused to exist is only temporary. This therefore limits the ability for either the specialists or the client to associate and/or identify with the temporary organisation and subsequently assesses its performance as a whole.

It is difficult to perceive the construction industry as a whole, given the increasing complexity and diversity of its projects, and the further development and differentiation of market sectors, sub-sectors, and differentiation between specialist groups. However, despite the importance of perception in discussing industry fragmentation, critical problems characterise the creation and management of the procurement system that are caused by the industries fragmented structure. This paper subsequently focuses on the procurement
Building Processes

The introduction presented some basic attributes of the building industry: its segregation into the division of material and product manufacture and supply, for the sectors of residential, non-residential, and engineering construction; differences between a sectors’ product and processes; the role of integrating specialists to construct the procurement system; and the temporary existence of the procurement system. From a summation of these and other factors, in particular the temporary nature of the procurement organisation and the relative difficulty of integrating the specialists in the procurement system, it can be seen that the building industry is perceived by clients as being fragmented. The following section provides a more detailed outline and discussion of the attributes of building procurement, and identifies sources for negative criticism of the industries fragmented structure.

The building life span

A building or facility can be considered as existing for a set span of time which can be broken into distinguishable phases within the general classifications of building procurement and use (Figure 2). The phases of procurement refer to the segregated stages of production responsible for a new building or facility, these are subsequently succeeded by the cyclic use system that is focussed on realising the intended client benefit of the building product through its use for the duration of the buildings operable life span. Given this scope, the two system categories develop various task systems (sub-systems) that specialise in effectively combining human and physical resources required to perform the tasks required (Miller 1967). For example, a traditional procurement model is broken up into the distinct series of transformations of design, documentation and construction. The transformations (processes) are largely reciprocally interdependent where the outputs of each part become the inputs for the others (Walker 1989), with concurrent operation usually avoided unless time constraints elicit such operation such as in fast-track development.

In practice, building procurement and use systems differ significantly in their formation and structure largely because of their modus operandi—a building’s procurement or its use—however, the most critical factor influencing industry fragmentation is the life span of the two systems. The aim of building use is to facilitate the achievement of client objectives for the duration of their involvement in a given building or facility, a time frame that can reach several decades. Similarly, procurement is designed to facilitate the objectives of the client, however this system achieves them through the production of the building—a finite task often measured in months. Consequently, building use has the opportunity to develop a relatively permanent system that will last for the duration of the buildings’ existence where-as the procurement system has a short life that is only active for
building production. The differing life spans subsequently provide grounds for a variety of attributes that contribute to the differentiation and design of the two systems. Given the longevity of the use system the demand for an organisation structure to manage the present but also plan for the future needs of the client and the building's use is heightened (Duffy 1993). This demand is reflected in the development of facility management, a specialist profession designed to coordinate the current and future use phase of a building facility.

On the other hand, the procurement system does not have the life span to rely nor use long-term feedback mechanisms but must use the short feedback systems that monitor the more immediate issues such as monthly, weekly and day-to-day progress. Further more, given the one-off nature of building projects and the limited repetition possible given the short and temporary nature of the procurement system, the components are compelled to rely on pre-existing knowledge and techniques in order to act in the new project, a situation which acts to limit innovation. It is this system of procurement, that the paper primarily addresses.

**Building procurement system**

The procurement process involves stages which differ significantly not only in objectives, but also in their component elements. Thus given the differentiated structure of procurement, multiple systems are required. In particular, for a new building the procurement process can be separated into three phases (Walker 1984):

I. project conception—results in the client's decision to acquire real property to achieve objectives;
II. project inception—results in the client deciding upon the form that the real property to achieve the client's objectives will take; and
III. project realisation—encompasses the design and construction of a building.

The three phases identified above (as illustrated in Figure 2) are sequentially related and include numerous specialists to varying degrees that are based upon two forms of involvement: task based operation, and/or management—monitoring and coordination (Raftery 1994). The majority of materials and labour (resources) used in procurement systems are for fulfilling the constituent tasks required for building (operation) (A.B.S. 1993). However, the management sector has an equally important role in designing and managing the procurement organisation. The management sector must resolve industry fragmentation by attracting an appropriate selection of specialists and creating an integrated organisation for building procurement. Coupled with the increasing complexity
of buildings, we have seen, and will continue to see the development of specialists such as project managers, construction managers, and project architects, that focus on designing and managing the procurement systems.

The duration of specialist involvement in the procurement system varies. Some specialists such as architects, quantity surveyors and engineers may be involved throughout all three phases of procurement, other participants are involved sparsely and spasmodically, such as for one clearly identifiable task such as an acoustics specialist, geotechnical engineer, or crane driver. The resulting system for each phase is therefore a combination of specialists that are related through their participation in building procurement. However, the number and duration of the associations made by specialists varies significantly therefore limiting any permanent characterisation of individual specialists to the system, but not the tasks that they may perform. Further more, each project, apart from being different in objective, will usually have a different labour force of operatives and managers thus ensuring differences in the management and interpersonal behaviour on each project simply because people are different (Raftery 1994). This variation between projects is illustrated by Raftery in Figure 3.

The role of the client is in general not a single attribute issue but depends on a number of closely interrelated attributes (Kometa 1994). The difficulty in incorporating the needs of the client is similar to the difficulty in assimilating and integrating the varying attributes of the specialists to create the procurement organisation as the client cannot be considered as unitary. Therefore decisions made by a client cannot be considered in isolation of the events that precede such a decision e.g. the decision to build (Cherns 1984; Walker 1984). Thus the procurement system may involve various groups within the client organisation whose interests differ and may be in conflict, and whose observed behaviour cannot adequately be explained without reference to the past. Therefore, the process of creating a procurement system can be considered as creating a “new, though temporary, organisation... a temporary multiorganisation” (Cherns et al., p 180) that integrates the needs of a client with the abilities of the construction industry and its specialists.

Integration & Differentation in Procurement

The construction industry is clearly made up of many sub-industries, many specialists, and is driven by clients that vary in their demands both as a collective group and as individuals. Given such possible diversity for building procurement, the design of each temporary procurement system is heavily dependent on the differentiation employed to break up the tasks for procuring a complex project and the corresponding methods for integrating such elements to enable the procurement system to run effectively and efficiently. Therefore, a large part of the success of the procurement system depends on those responsible for the systems design and management—the integrators—and how successful they are in defining the internal and external boundaries of a system, managing their relationships, and employing the current tools of management. This final section provides an insight into the differentiation exhibited in the procurement system and subsequently how integration is achieved.
Differentiation and integration in practice

A principal attribute of the building procurement system is that the complex task of producing a building or facility is achieved through the employment of many varied components, but how are these components differentiated from each other? Differentiation in the building industry primarily occurs on the basis of difference in cognitive and emotional orientation among contributors to a project who offer specialist skills (Lawrence 1986; Walker 1989). In practice this can be seen as creating boundaries based on criteria such as: discontinuity in production, such as delay between design and documentation; differentiation of technology e.g. plumbers and electricians, engineers and architects; territory, such as differences between sub-contractors and principal contractor; time orientation; or a combination of these factors (Miller 1967; Walker 1984,1989). The resulting differentiation may be further reinforced by the affiliation by professionals to professional associations and their related learned societies, referred to as exhibiting sentience to respective sentient groups (Miller 1967, p. xiiiin). Thus the common example of affiliation to task based professions such as an architect to architecture is just one example of differentiation and is likely to be coupled with a specialists affiliation to other bounded groups or ‘role-sets’ (Merton 1968). Role-sets not only represent differences in orientation but also in formality of structure both within a particular specialist’s organisation and when as a part of the procurement system (Lawrence 1986).

The various cognitive and emotional orientations employed in differentiating a system, establishes internal boundaries between system componentry (Lawrence 1986). These boundaries have a variety of effects on a given organisation or system and largely determine ‘the scope and direction of any subsequent efforts to improve the system (Cavaleri 1993, p 21)’. Given that the definition of a system implies a significant degree of association in the form of relationships between its component elements that subsequently differentiate it from its environment (Klir 1991), the act of creating and maintaining such relationships can be referred to as integration. More specifically, integration in practice is directed at facilitating the quality of the collaboration between the resources that are required by the demands of the procurement system (Cleland 1983; Lawrence 1986). Just as differentiation occurs throughout all levels of an organisation, integration must also apply; from the task specific level to more conceptual tasks such as determining project feasibility. The other and equally important need is for integration between the output of the tasks, each output must be compatible with each other and in relation to the project objectives. The integrative mechanisms will therefore depend on the particular project and its environment, but will range from integration through informal personal effort to more formal and rigorous feedback mechanisms at key decision points (Walker 1989).

Integration management

It is clear that differentiation and integration must complement each other if the procurement system is to function effectively. Therefore, it is logical that the required differentiation and integration of procurement is a function of complexity because as the complexity of a building increases so does the need for further internal differentiation thus creating internal boundaries that require associated integration. For example, the differentiation of building procurement into Walker’s (1984) three systems of: conception, inception and realisation, is not only a reflection of the process of procurement, but also a
function of a given projects complexity. As the systems complexity increases, several more orders of differentiation may be required to ensure a manageable task system. The determination of these boundaries occurs on the basis of associating the necessary resources through which a particular and subsequently dominant import-conversion-export process is accomplished e.g. documentation and construction in the realisation system. At the other and more common end of the scale, the extent of differentiation on smaller and medium sized projects is often not recognised despite that fact that the scope is generally sufficient to require positive action to integrate the contributors rather than just proceeding with the expectation that integration will happen (Walker 1989). In general differentiation enables increased performance in specialist fields however, a complementary effort must be associated to integrate specialists to ensure the system required for procuring client objectives can perform effectively (Mohsini 1992). Therefore, the role of integration in procurement can be seen as managing the internal boundaries (differentiated elements) of the system; a field of management referred by Miller (1967) as boundary control. Miller recommends four kinds of control. They are derived from the criteria initially used to differentiate the system:

- regulation of task-system boundaries (regulation of the system as a client operating system, and regulation of the constituent systems of activity) e.g. two sub-contractors working on a single building element
- regulation of sentient-group boundaries (the boundaries of the groupings to which people belong either directly through their roles in systems of activity, or indirectly through their role-sets) e.g. the interface between architect and building contractor
- regulation of organisational boundaries e.g. quantity surveyor and architect
- regulation of the relation between task, sentient, and organisational boundaries e.g. the role of the project manager

The management of sub-contractors or out-sourced components, is the most prevalent example in the procurement system where integration is required. The traditional methods of procurement rely on independent professional firms, contractors and sub-contractors selected in competition that are then expected to form the temporary procurement organisation and subsequently operate together successfully. This widespread form of sub-contracting is useful as it transfers the responsibility of managing sentient and task boundaries, however there are essential maintenance activities required to keep the procurement system going which generally cannot be left in the hands of out-sourced components (Miller 1967). For example, the core responsibility of procurement is generally attributed to one entity, customarily the principal contractor as overseen by a project manager. Such responsibilities are seen in the form of monitoring the time, quality and cost performance of projects and obtaining commitment by the task-systems to such objectives. This core task is further complicated by the short life of the system and the subsequent difficulty in incorporating feedback to redesign the system. Procurement system managers often have inadequate expert knowledge to manage specialists and the monetary and time cost of re-work caused by most errors, highlights the problem often caused by inadequate integration.

The role of management movements in building construction

The management of the procurement system, in particular the phase of construction, has generally developed “in an evolutionary way based on developments in practice which appear to be largely unaffected by mainstream management theories (Betts 1994, p. 551).”
Such a characterisation of the management movements, raises questions about their potential usefulness in practice despite the acceptance of their espoused principles. For example, there has been only limited success of Quality Assurance as applied in the building case and this illustrates issues that are similarly reflected by the role demanded of integrators in the procurement process (Seymour 1990; Pheng 1993). Despite the quality movement in construction having been rationalised to represent both determinable and indeterminable elements (Pheng 1993), it has found difficulty in facilitating the indeterminable elements in practice. This has led to its application largely being focussed on procedural systems for determinable elements. Consequently, because of the quality assurance movement’s difficulty in recognising the broader (indeterminable) cultural issues of an organisation it has been criticised as taking too mechanical a view of the quality problem (Seymour 1990). Molander and Sisavic (1994) go so far as advocating that for successful application of the quality movements, they should be considered as social movements and as adopting a role as social movement leaders, a position well advanced from their current form. They detail some of the implications of not taking the broader social perspective and are joined by Molander (1994) in advocating the need to reflect the prevalent boundaries or role-sets attributed to organisations and their components. Therefore in terms of integration, quality assurance reflects a case of not fully identifying and recognising all the significant boundaries that characterise the components of the procurement system, and because of this limitation, is unable to comprehensively address all the variables and constants responsible for the quality of a given product. This example is a lesson for the current and future integrators of building procurement: integrators must identify and reflect all the elements of the prevalent role-sets of a given system in order to achieve reliable management of the process.

Conclusion

The construction industry consists of a host of industry sectors and individual producers that join together to form temporary procurement systems for the fulfilment of client organisations’ objectives. The procurement systems’ life span is typically short, therefore the specialists that constitute the industry identify with other groups (reinforced by sentience) rather than the client based procurement system. This form of differentiation, coupled with other forms based on task, territory, time or a combination of these, must be subsequently identified and appreciated in the development of strategies of integration in the formation and management of the building procurement system. The demand for integration is further reinforced given the increasing complexity of projects coupled with a reduction in project duration, correspondingly increasing the demand for further specialisation. Therefore, given an inevitable increase in differentiation, and subsequent specialisation and industry fragmentation, for any management strategy to be effective, it must not become part of the industry’s evolutionary development and practice integration. Alternatively, as Molander argued, it will only achieve limited success.

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Application of Systems Methodologies


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Application of Systems Methodologies

USING THE SYSTEMS APPROACH TO EDUCATE IN A VOLATILE ENVIRONMENT

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Abstract

The article discusses the approach used in designing, and the experiences gained from conducting, a graduate Information Systems auditing course at the Australian National University. The Systems Approach of Churchman [1968] was adopted to integrate the course's subsystems (topics, instructions, grading) with the environment and available resources in a holistic manner. General Systems Theory provides hallmarks which were used to identify the range of topics for the course. Recognition is given to the pervasive effect of diverse and complex Information Technology on auditing. To broaden access to audit information and to compare itself to audit developments elsewhere it is recommended that the course makes increasing use of the electronic audit resources available on the fast growing Internet.

Introduction

Organisations depend on auditors for evaluating and improving the integrity of their Information Systems (IS). A specialist group of IS auditors has emerged to deal with systems that have become technologically complex and diverse. IS auditing expertise provides high rewards as shown by the attractive career advertisements in professional accounting and auditing journals. This in turn has increased the demand for specialised courses. There exists, however, no agreed approach on how IS audit education should be conducted. The challenge for educators is how best to deal with a volatile Information Technology (IT) and business environment.

The aim of this article is to present the approach used in designing, and the experiences gained from conducting, a graduate IS auditing course by the writer at The Australian National University (ANU). Use was made of the Systems Approach of Churchman [1968] to integrate the course's objectives, subsystems (topics, instructions, grading) with the environment and available resources in a holistic manner.
Course Objectives

The course objectives aimed to provide students with appropriate knowledge and skills in IS auditing and to provide a suitable teaching and learning environment. They together with the performance measures are stated below.

Objectives
• To provide students with theoretical knowledge in the auditing of business systems in which IT plays a major role.
• To provide students with applied skills in the auditing of business systems in which IT plays a major role.
• To provide a teaching and learning environment appropriate to a graduate course.

Performance Measures
• Meeting the university's grading outcomes for a graduate course.
• Acceptance of graduates in the market place as reflected in job offers.
• Satisfaction of students as expressed in unit evaluation forms.

Environment

The course was influenced by environments internal and external to the university.

External Environment
The external environment is determined by two professional activities, namely IT/IS and Auditing. As discussed earlier, the technological environment is rapidly changing and IT now plays an integral part of organisational activities. Hence, it was accepted that the impact of IT/IS on audit is all pervasive. The auditing environment in Australia is influenced most strongly by The Institute of Chartered Accountants (ICA) and the IS Audit and Control Association (ISACA, formerly the EDP Auditors Association). Among the former are those who carry out statutory corporate audits. The strongest interest in IS auditing, however, comes from the latter because it is the only internationally recognised specialist IS audit body. It is estimated that in Australia there are about twelve thousand members of the ICA and one thousand practising IS auditors.

Internal Environment
The IS Auditing course was part of the graduate programme in the Department of Commerce at The Australian National University. The course is of an independent nature, offering topics not found or topics not covered in depth in the undergraduate auditing course. The university is located in Australia's capital city Canberra and is ranked among the top six of the thirty-five Australian universities. Academic staff within the department come from three disciplines, namely Accounting (including generic Auditing), Finance and Information Systems. Many of the staff have strong interests to carry out interdisciplinary research.
Resources

There were three types of resources under the control of the course: the course leader (the writer), outside speakers and teaching resources. I regarded myself as suitably qualified to conduct the course since I possess both auditing and IT/IS qualifications, actively research in the area and belong to both the ICA and ISACA. Based on Foster's [1987] finding that the knowledge gap between staff and students hindered teaching outside speakers were used to complement and to supplement my own efforts. These speakers consisted of departmental faculty who taught auditing and information systems, an overseas academic visitor to the department with an interest in computer crime, and a computing professional from industry.

The teaching resources took the form of texts, readings and a computer laboratory. Extensive use of readings was made since it was found that IS auditing texts either were technologically out of date or lacked sufficient depth for an advanced graduate course. A computer laboratory provided the Audit Command Language (ACL) software which was used to carry out a computer audit case study.

Subsystems

Subsystems should be developed for the purpose of meeting the objectives of the whole system through making use of the available resources and interacting with the environment. The three subsystems for the IS Auditing course were topics, instructions, and grading and are depicted in Figure 1. Subsystems are decomposed into components in Figure 2.
Each of the subsystems was designed following the Systems Approach by identifying its objectives, activities and performance measures. They are discussed below.
Topics

Objectives
- To provide an appropriate range of topics.
- To provide an appropriate coverage of topics.
- To meet professional standards of the ICA and the ISACA.
- To encourage and instil the desire for research in students.

Activities
The most difficult task of an IS audit course is to determine the range of topics (i.e. which topics to include) and the coverage of these topics (i.e. how much class time to spend on them). General Systems Theory (GST) provides hallmarks which were used to identify the range of topics for the course. These hallmarks have previously been used to develop a training course for computer security professionals [see Yngstrom, 1992]. The postulates were listed and, by deduction, the implications for IS auditing were derived (Table 1).

Table 1

<table>
<thead>
<tr>
<th>General Systems Theory and IS Auditing</th>
<th>Implications for IS Auditing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Postulates</td>
<td></td>
</tr>
<tr>
<td>There exists an interrelationship and</td>
<td>Focus on all components of IS-</td>
</tr>
<tr>
<td>interdependence of objects and their</td>
<td>information technology, people,</td>
</tr>
<tr>
<td>attributes.</td>
<td>procedures, etc.</td>
</tr>
<tr>
<td>All systems have a gestalt - a</td>
<td>Understand the environment in which IS operates.</td>
</tr>
<tr>
<td>wholeness.</td>
<td></td>
</tr>
<tr>
<td>All systems are goal seeking.</td>
<td>Security goals need to align with organisational goals, strategies and objectives.</td>
</tr>
<tr>
<td>All systems are open.</td>
<td>System inflows and outflows need to be controlled.</td>
</tr>
<tr>
<td>All systems transform inputs into</td>
<td>Processes that transform inputs into outputs need to be controlled.</td>
</tr>
<tr>
<td>output.</td>
<td></td>
</tr>
<tr>
<td>Systems have a degree of structural</td>
<td>Disorder needs to be resisted or neutralised.</td>
</tr>
<tr>
<td>order or disorder (entropy).</td>
<td></td>
</tr>
<tr>
<td>All systems need to be managed to</td>
<td>There is a requirement for security planning, management and control.</td>
</tr>
<tr>
<td>reach their goals.</td>
<td>Consider the degree of structure (complexity) within IS.</td>
</tr>
<tr>
<td>There exists a natural hierarchy</td>
<td></td>
</tr>
<tr>
<td>within systems - systems contain</td>
<td></td>
</tr>
<tr>
<td>subsystems.</td>
<td></td>
</tr>
<tr>
<td>In complex systems specialised units</td>
<td>Focus on security requirements of specialised (technologically advanced) components of IS.</td>
</tr>
<tr>
<td>perform specialised functions.</td>
<td></td>
</tr>
<tr>
<td>Open systems can reach their goals</td>
<td>Have concern for more than just simple cause-and-effect of natural systems.</td>
</tr>
<tr>
<td>in many different ways (equifinality).</td>
<td></td>
</tr>
</tbody>
</table>

The IS auditing implications were interpreted to become topics in the course. This was done in two ways. First, topics were derived directly from Table 1 and resulted in the
following: IT/IS and auditing; audit of computer programs and data; fundamental internal control; advanced internal control; and the impact of new IT developments on audit. Second, consideration was given to the requirements and influences of the external environment, namely IT/IS and auditing. Under GST it is the natural tendency of objects to fall into a state of disorder (or entropy). A living system can forestall the movement towards entropy by accepting inputs into the system from the external environment. This provided the following topics for the course: computer assisted audit techniques (CAATs); the use of ACL; professional standards; issues in IS security; and computer crime and abuse. Another topic, research opportunities in IS auditing, was included to complete the system objective for teaching and learning (see earlier section). The complete list of topics, delivered over twelve weeks, is contained in Table 2.

Performance Measures
- Acceptance of the course by the ICA and ISACA.
- Satisfaction of the students as expressed in unit evaluation forms.
- Continuing interest of students in the topics throughout the semester.

Instruction

Objectives
- To provide "good" teaching.
- To critically discuss the readings provided.
- To acquire practical skills in computer auditing.
- To acquire the ability to review the security of an organisation's IS.

Activities
Under good teaching, students take over the responsibility of learning and look to the lecturer for stimulation and guidance [Entwistle and Tait, 1990]. For this reason, a diversity of instruction modes were employed for the course and are shown in Table 2. Texts were used in three areas: theory, professional guidelines and the use of ACL. As can be expected in a graduate course, extensive use was made of readings. They came from professional and academic journals, conference proceedings and faculty research papers. Journals with a relevant skill orientation include: The EDP Auditor Journal (now IS Audit & Control Journal), EDPACS, Computers & Security, Information & Management; those with an academic orientation are: MIS Quarterly, and Information Systems Research.

Students used a computer laboratory, first to acquire the skills of ACL and second, to complete an audit case study. The case came from Davis et al. [1990] and required the evaluation of the controls of, and the completion of substantive audit tests on, a payroll system and its data. Students were also required to conduct an industry project. This had been arranged for them and consisted of a review of the IS security in a real life organisation and the submission of a report. The importance of a cooperative effort between academics and industry in IS auditing education was stressed by Bailey [referenced in Singleton and Flesher, 1994].

Outside speakers were used in three different ways. First, a debate took place between an audit and an IS faculty member in front of the class on how they viewed the integration of audit with IT/IS. A number of views were expressed and reflect the current pros and cons...
for the integration of IS, general auditing and IS auditing [see Kneer et al., 1994] and cross-training [see Owen, 1994]. The visiting academic provided research findings on computer crime and a representative from a local computer firm outlined the dependency of business on IT and disaster recovery services available to them.

Table 2
Topics and Mode of Instruction

<table>
<thead>
<tr>
<th>#</th>
<th>Topic</th>
<th>Mode of Instruction</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>IT/IS and Auditing</td>
<td>Text, Readings, Outside Speakers</td>
</tr>
<tr>
<td>2</td>
<td>Computer Assisted Audit Techniques</td>
<td>Text, Readings, Cases &amp; Problems</td>
</tr>
<tr>
<td>3</td>
<td>The Use of ACL</td>
<td>Text, Computer Laboratory</td>
</tr>
<tr>
<td>4</td>
<td>Issues in IS Security</td>
<td>Readings</td>
</tr>
<tr>
<td>5</td>
<td>Auditing Computer Programs and Data</td>
<td>Text</td>
</tr>
<tr>
<td>6</td>
<td>Internal Controls: General, Applications,</td>
<td>Text, Readings</td>
</tr>
<tr>
<td></td>
<td>Physical</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Internal Controls: Advanced IT</td>
<td>Readings, Cases &amp; Problems</td>
</tr>
<tr>
<td>8</td>
<td>Information Systems Development</td>
<td>Readings</td>
</tr>
<tr>
<td>9</td>
<td>Computer Crime and Abuse</td>
<td>Readings, Outside Speaker</td>
</tr>
<tr>
<td>10</td>
<td>Professional Standards and Privacy</td>
<td>Text, Readings</td>
</tr>
<tr>
<td>11</td>
<td>Research Opportunities</td>
<td>Readings</td>
</tr>
<tr>
<td>12</td>
<td>The Impact of IT Developments</td>
<td>Readings, Outside Speaker</td>
</tr>
</tbody>
</table>

Performance Measures
- Satisfactory completion of the audit case study and industry project.
- Active participation of students in class discussions.
- Satisfaction of students as expressed in unit evaluation forms.

Grading

Objectives
- To achieve student performance that satisfy the expectations of the ICA and ISACA.
- To achieve levels of knowledge and skills attractive to potential employers.
- To achieve a balance between examination and continuous assessments.

Activities
In devising a grading scheme it was endeavoured to satisfies the student's intrinsic, competitive and vocational motivation, rather than instilling a fear of failure [Entwistle and Tait, 1990]. Emphasis was therefore placed on continuous assessment in the form of the audit case study and the industry project. The approach also satisfied the good teaching principle of providing freedom of learning and orientation to personal meaning [Ramsden and Entwistle, 1981] and the practical requirements of the two professional bodies. The internal university environment required the completion of a final examination. This
consisted of solving problems and answering questions requiring some degree of reproducing knowledge gained.

Performance Measures

- Satisfactory completion of the audit case study and the industry project.
- Acceptance by organisations of the industry project reports.
- Meeting the university expectations for overall course performance.

Course Outcomes and Recommendations

The following were key course outcomes. First, the course received a positive response from the environment, both external and internal. The ISACA was strongly supportive to the extent that it offered an annual student prize. Two ICA firms, both big six international accounting firms, made job offers in their IT Quality Assurance sections to graduating students. All students completed the course with grades satisfying the university's expectations. The academic department was particularly pleased with the course since it successfully integrated auditing and information systems disciplines. Second, the organisations receiving the students' industry project reports reviewing their IS stated that the reports provided valuable assessments of the security of their information systems. Third, the students' evaluations of the course provided very strong endorsement of the design and conduct of the course. Students particularly valued the practical work they completed in the form of the audit case study and industry project. One student volunteered that it was the best course she had attended at the university.

Under the systems approach, the outcomes of meeting the system objectives can only be judged by observing what the system does over a period of time. The course therefore needs to evolve and be finetuned "because no one can claim to have set down the correct overall objectives, or a correct definition of the environment, or a fully precise definition of resources, or the ultimate definition of components." [Churchman 1968, p. 45]. To broaden access to audit information and to compare itself to audit developments elsewhere it is recommended that the course makes increasing use of the electronic audit resources available on the fast growing Internet.

References


PARTICIPATIVE APPROACHES TO THE SYSTEMIC ANALYSIS AND DESIGN OF WORK: THE USE OF WORK MAPPING AND SIMULATION TECHNIQUES IN THE AUSTRALIAN TAXATION OFFICE

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Abstract

Meaningful participation in the design, development, and implementation of computer systems has been limited by the "language" used by business systems analysts to describe aspects of work, and by the use of formal tools for the analysis and design of work. The Australian Taxation Office has developed a work mapping technique that enables managers and staff to participate in the systemic analysis of work and to identify the potential impact of technology and other changes to work and the work environment.

Background

The Australian Taxation Office (ATO) is an organisation undergoing massive change. Seven years ago the ATO embarked on a ten-year programme addressing the major redevelopment of all its business computer systems; in 1993, it initiated a fundamental organisational restructure, and in 1994, the ATO entered into an Agency Agreement with the Community and Public Sector Union (CPSU) for workplace reform and productivity improvement.

The Problem

The ATO employs 18,000 staff located in 26 offices across Australia. Although committed to the philosophy of industrial democracy and participative management practices, the organisation struggled with developing activities that provided management and staff with opportunities for meaningful participation in major change programmes, particularly in organisational change and in computer systems development. As a business systems analyst employed by the ATO, I became involved in early 1993, in the search for an approach to meaningful participation in computer systems development.
The Issues

Examination revealed a range of issues relating to meaningful participation which included:

- access by staff to practical tools for the analysis and design of work;
- the skills of business systems analysts (understanding, perception, analytical skills, experience etc);
- the use of language as a communication between line managers and staff and computer systems analysts;
- the context of change versus the abstract concepts of work.

To me the question was not so much one of "how to encourage participation?", but rather "what language will we use?" and "what analytical tool will we use?".

Work Mapping

Working with two other ATO business systems analysts, Phil Fisher and John Smithwick, I developed a technique that we called "Work Mapping" which had the following features:

- staff develop systemic models of work in their own language;
- participants are encouraged to use creativity and imagination;
- simulation techniques are used to enhance and validate the models;
- participants identify issues and problems in the workplace that impact on productivity, and locate the issues/problems in the models;
- participants use the models as a basis for understanding the potential impact of proposed changes.

During 1993 we successfully trialled and evaluated these techniques in a range of computer systems development initiatives and productivity improvement programmes.

Skilling

Managers and staff were introduced to these techniques in a three-day workshop using an experiential learning model and in which they were encouraged to participate in a collaborative learning environment. In the context of developing models of their own work in their own language, participants were introduced to concepts of systemic and holistic analysis, and to the use of office theatre and simulation techniques as tools of analysis. By using this approach to analysis in developing a "common language" line management and staff were able to contribute to the discourse on the nature of work and on the potential impact of change.

Action Research

Work Mapping techniques were developed using an action research approach. Throughout 1994, in a number of applications in the ATO, I further refined and developed the concepts and modelling techniques and addressed a range of associated issues including:

- skilling facilitators to conduct workshops
• facilitators versus analysts
• making explicit the process of analysis
• making explicit the systemic nature of work and the components of work
• validation of the models and the addressing of issues/problems with work identified in the modelling process (including costing, sizing, priority, classification)
• analysis versus design in the modelling process
• the discipline of analysis
• change management processes to support work mapping activities
• work impact analysis
• participative approaches to the design of systemic work environments.
• jointly agreed guidelines for the use of work mapping between the ATO and the Communication and Public Sector Union (CPSU)

A Very Short Case Study: Ato Imaging Project

In 1994, the Australian Taxation Office commissioned an internal project to investigate the potential application of imaging and optical character recognition technology. I became involved in the project when I was approached by the project team and asked whether the work mapping techniques could be applied to the participative development of a preliminary staff impact statement associated with the trialling of particular imaging technology. The "Imaging Project" had established small working parties comprising 4 to 6 staff located in three ATO Branch Offices (Bankstown NSW, Cannington WA, and Dandenong Vic.) to undertake a participative analysis of selected forms processing and to develop staff impact statements that addressed the potential changes to current work with the application of imaging technology. My role was to train the Branch Office working parties to use work mapping techniques and to provide a consultancy service during the analysis of work and the development of the staff impact statement.

I believed that this project offered unique challenges and opportunities for the further development of work mapping techniques and I set about modifying the techniques to meet the specific contextual needs of the project. One of the challenges was that these members of the working parties were relatively junior staff who had no previous experience as business systems analysts nor had they any experience in conducting participative change processes.

I re-designed the work mapping technique to enable work maps to be developed in stages, with staff building layers of complexity into their models of work depending upon the purpose and scope of the analysis.

This modification also involved designing the tool so that a member of a working party could work with individuals or small groups of staff to collaboratively develop analytical models of the work. In doing so the work mapping sessions needed to be flexible so that they could be conducted for different durations at different times (eg one hour per day, two hours per week) depending on the availability of staff to participate.

Work mapping could now be used as a participative tool where:
there was a work mapping analyst working with one participant at a time (eg 1 to 2 hours per day or week), to gradually develop work maps;

there was a work mapping analyst working with a small number (2 to 4) of participants (eg 1 to 2 hours per day or week);

there was a work mapping analyst conducting a 2 to 3 day workshop for 10 to 15 participants;

and the models of work could be developed using layers of complexity depending on the focus and scope of the analysis.

I conducted a five-day training workshop for the members of the three Branch Office working parties and other members of the project team in Sydney in October 1994. During this training workshop I addressed a range of practical skills and techniques including:

- participation and collaboration;
- the systemic analysis of work, including the components of work and the process of analysis;
- change management, including the process of change and collaborative decision making,
- use of simulations in analysis,
- presentation and facilitation,
- documentation management; and
- personal management of change and stress.

The working parties returned to their respective Branch Offices and over the next five weeks conducted a systemic analysis of specific aspects of their work, during which they actively engaged management and staff from the relevant work areas in the development of work maps.

We met again in Melbourne in early December where I conducted a two-day workshop in which the working parties and the project team reviewed and compared the three different series of work maps. They were also introduced to information about imaging technology and given an opportunity to discuss the possible features of this technology with two subject-expert consultants. I then demonstrated a practical technique for assessing the impact of the proposed technology by using the work maps and yellow "post-it" stickers, which the working parties practised before returning to their respective Branch Offices to conduct further participative analysis. This involved managers and staff using the work maps as a focus for discussing and assessing the potential impact of the technology on their current work. A final two-day workshop was held in Melbourne in January 1995, when the working parties presented their work impact statements and then developed a consolidated staff impact statement which was formally presented to the project team. This completed the working parties involvement in this stage of the project.
Staff who four months ago were relatively inexperienced in the analysis of work had, by using work mapping techniques, participatively developed and validated sophisticated systemic models of their work and had used these models to identify and assess a range of potential changes to the work and the work environment. This placed them in a very well informed position to actively recommend specific conditions that would need to be met in the change management programme associated with the possible introduction of this technology.

Conclusion

Work mapping techniques have been used to overcome the language barriers between business systems analysts developing computer systems and the managers and staff who may be impacted by the changes to their work and their working environment. The techniques have enabled managers and staff to have meaningful participation in the development of computer business systems and to identify the potential impact of changes in their workplaces. In addition, in using work mapping techniques, managers and staff have been introduced to the process of analysis and to the systemic nature and components of work, which has led to the identification of a wide range of productivity improvements. By developing contextual models of work in their own "language", managers and staff now have a practical tool with which to enter into the discourse on the nature of work, and on the possibilities for collaborative design of systemic work environments.

Diagrams:
1. An example of developing a work map in stages: Work Mapping Levels.
2. Work Mapping - Common Symbols
3. Work Mapping - The Hand Tool
WORK MAPPING LEVELS

LEVEL 1
BROAD WORK FLOWS
STRATEGIES
LEGISLATION
BUSINESS OBJECTIVES
POLICY (BUSINESS AND ADMINISTRATION)
BUSINESS EVENTS

LEVEL 2
DETAILED WORK FLOWS
COMPUTER SYSTEMS
DECISIONS
BROAD TIME FRAMES

LEVEL 3
INFORMATION SOURCES
INFORMATION RECORDS
PEOPLE
CLIENT CONTACT
THINKING

LEVEL 4
WORK CONTROL
MANAGEMENT PRACTICES
BUSINESS PROCESS INFORMATION

LEVEL 5
WORK PRACTICES
RESOURCES
RELATIONSHIPS WITH OTHER AREAS

LEVEL 6
EEO ASPECTS OF CURRENT WORK
OH & S ASPECTS OF CURRENT WORK
WORK ENVIRONMENT

LEVEL 7
REGIONAL DIFFERENCES
WORK MAPPING

COMMON SYMBOLS

- TASKS
- WRITE A FEW WORDS TO IDENTIFY THE TASK
- WORK FLOWS
- PEOPLE
- COMPUTER SYSTEM
- DECISIONS
- MAKE A DECISION

TOOLS OF PARTICIPATIVE ANALYSIS
WORK MAPPING

THE HAND TOOL

WHAT HAPPENS?

HOW DOES IT HAPPEN?

WHY DOES IT HAPPEN?

WHEN DOES IT HAPPEN?

WHO DOES IT?

Tools of Participative Analysis

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THE APPLICATION OF SYSTEMS ANALYSIS TO THE OPERATION OF WATER SUPPLY HEADWORKS SYSTEMS

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Abstract

Urban water supply authorities in Australia are moving from a 'construction' phase to a 'management' phase. For most capital cities, the cheapest sources of water supply have been developed and any major new dams are now unattractive due to a general shortage of capital funds. Most of the recent emphasis of Australian water supply authorities has been on managing the existing system so as to achieve maximum efficiency. The application of systems analysis techniques to the planning and operation of water supply headworks systems has demonstrated significant reductions in operating costs can be achieved with little reduction in system reliability. In this paper the application of systems analysis techniques to the operation of water supply headworks systems are reviewed. Benefits that can be obtained through the application of these techniques are demonstrated with reference to savings in operating costs that have been achieved in the operation of the Adelaide water supply headworks system.

Introduction

Most major cities in Australia have a headworks system consisting of a complex network of reservoirs, pipelines, channels and pumping stations. The operation of these complex systems is based largely on experience, supplemented in some cases by the use of computer simulation models. Work in Australia by Perera and Codner (1985) on the Melbourne system and Crawley and Dandy (1993) on the Adelaide system have demonstrated that potential increases in efficiency in the operation of these systems can be achieved with the application of system analysis techniques.

Water authorities are now seeking to utilise their existing water supply infrastructure to achieve maximum reliability at minimum cost. To achieve these objectives, systems analysis techniques have been applied to the planning and operation of these water supply headworks systems. Work undertaken by the EWS department in South Australia has demonstrated that significant reductions in operating costs can be achieved with little reduction in system reliability.

In this paper the application of systems analysis techniques to the planning and operation of water supply headworks systems are reviewed. Benefits that can be obtained through the application of these techniques are demonstrated with reference to savings in operating costs that have been achieved in the operation of the Adelaide water supply headworks system.
A Review of the Application of Systems Analysis to the Planning and Operation of Water Supply Headworks Systems

The headworks of a water supply system can be defined to include the water sources, the bulk water pumping and transmission components, the bulk water storages, and the bulk water treatment plants. Operational decisions associated with these components in a water supply headworks system require the consideration of large numbers of possible combinations, and historically these decisions have been made on the basis of experience.

Many models have been developed since the late 1960's applying systems analysis techniques to the planning and operation of reservoir systems. These models were reviewed by Yeh (1985), and classified according to the various methods and algorithms on which they were based. These include linear programming, dynamic programming, nonlinear programming and simulation. Each of these four broad groups of techniques contain a variety of methods having certain advantages and disadvantages. Detailed descriptions of these methods is contained in the paper by Yeh (1985).

When selecting an appropriate modelling technique for the planning and operation of a water supply headworks system, the following considerations should be taken into account. What modelling techniques are currently available? Is the modelling technique applicable to the actual operation of the system? What level of accuracy is required of the modelling technique in its representation of the actual operation of the system? What level of precision is required of the results? How flexible is the modelling technique for consideration of operating rules changes?

When applying systems analysis techniques to real operational situations, applicability and ease of use must be considered. One of the significant conclusions drawn from the ASCE National Workshop on Reservoir Systems Operation (Toebes and Sheppard, 1979) was that although considerable research effort was being expended on systems analysis, the successful application of these techniques to real reservoir operation of systems was limited. The reluctance of reservoir operators to use systems analysis techniques in day to day scheduling and planning were identified as:

- Reservoir operators were not directly involved in the development of the models and hence were hesitant in their application to the real system.
- The majority of published research dealt with simplified reservoir systems and was difficult to adapt to real systems.
- Institutional constraints make user-research interaction difficult.

In the remainder of this paper, the application of systems analysis to the planning and operation of the metropolitan Adelaide water supply headworks system will be described. This application of systems analysis to a real-world system has highlighted the potential benefits that can be obtained through the successful application of systems analysis to water supply headworks systems.
The Adelaide Water Supply Headworks System

The metropolitan Adelaide water supply system caters for a population of approximately one million people and seeks to maintain a reliable supply of water at minimum cost. South Australia is the driest state in the driest continent in the world. Water is a precious commodity in South Australia and to maintain a water supply of suitable quality is a challenging task. Within the state, limited areas exist where sufficient runoff enables reservoirs to be economically constructed and operated. These locations are also of prime agricultural and horticultural value. There are few remaining reservoir sites that would increase the available water supply to metropolitan Adelaide. At the same time, the available water supply from the existing reservoirs is insufficient in the majority of years to maintain supply to the metropolitan area. This fact has long been recognised by the EWS and so a number of major pipe networks have been constructed to supplement the available catchment runoff with water from the River Murray, some 80 km. east of the city.

A schematic of the metropolitan headworks system is shown in Figure 1. Water may be pumped from the River Murray (represented by the three source symbols on the right-hand side of the figure) via three pipelines to nine of the 10 reservoirs, the exception being Myponga Reservoir. The capacities of the reservoirs provide a total system storage of 202 GL. and the average annual yield for the system from the local catchments is 130 GL. The system can be conveniently divided into a northern and southern sub-system, which operate largely independently of one another. Water consumption in metropolitan Adelaide averages 185 GL. annually and has remained steady over the last few years due to low population growth and demand management measures. Water pumped from the River Murray varies between 10% and 90% of the total supply in any particular year with an average of 42%, at an average annual pumping cost of $7M. Pumping is planned on a water-year basis, commencing at the beginning of July and ending at the end of June in the following year. This program is revised on a monthly (or at times, weekly) basis, in response to changes in inflows and demands. Historically, the preparation of this pumping program relied on operator experience with the system, although use was made of a computer spreadsheet to analyse the consequences of various policies.
In the following section the application of systems analysis to the operation and planning of the Adelaide water supply headworks system is described. An optimisation model has been developed with the objective of minimising pumping cost subject to maintaining storage levels in the system at or above specified target levels.

System Analysis Techniques Applied to the Adelaide Water Supply Headworks System

As shown in Figure 1, the Adelaide headworks system comprises 10 major storages and three major supply pipelines. This may be divided into a northern system (with seven storages and two supply pipelines) and a southern system (with three storages and one supply pipeline). It was considered that dynamic programming was not a suitable technique for this system because of problems associated with dimensionality. An important output of the application of systems analysis is the desirable set of reservoir storage levels at various times throughout the system. The use of dynamic programming would involve the "lumping" together of reservoirs and, therefore, the loss of information important for system operation. Deterministic linear programming was selected as a suitable technique to identify optimum operating policies for the Adelaide headworks system for the following reasons:

- It does not have problems with dimensionality.
- Commercial linear programming packages are available, which run quickly and can handle large problems.
- The principal non-linearity in the system (the pumping cost curves) can be handled easily using separable programming because the cost curves are convex.
The model developed for the Adelaide system is somewhat unusual in that it can be used both as an operational model and as a planning model. As an operational model, it can be used to assist in the selection of optimal pumped, transferred, and stored volumes on a month-by-month basis. As a planning tool, it can be used to examine the selection of target storage levels and inflow forecast levels or the increased yield from new reservoirs or pipelines.

As a planning model, it has been used to compare the historical operation of the system with the operation of the system if the model had been placed as the operator controlling the system. This comparison was used to highlight the potential savings available through the application of the model as an operational model in the future.

The general equations used to model a multiple reservoir system using linear programming have been outlined by Crawley and Dandy (1993) and are not included in this paper. The objective of the model is to determine optimal sequences of pumping and transfers for the system so as to minimise pumping costs while maintaining a satisfactory level of system reliability. The reliability of the system is determined through a series of minimum target storages for each reservoir for each of the time periods under consideration. The model takes into account the non-linear nature of the pumping cost curve, the capacities of the pumping and pipeline network, the reservoir capacities, the transfer and spill capacities of each reservoir and the evaporation characteristics of each reservoir in determining the optimal operating policy.

The following data are used as input in formulating the linear programming model. Catchment inflow volumes, system demands, pump-cost curves, storage versus evaporation curves and penalty and benefit coefficients. A detailed description of these input data has been given by Crawley and Dandy (1993).

**Southern System - Historical and Model Comparison**

A comparison was made between the historical operation and the model performance in both perfect and forecast modes for the southern system. The model was run using a monthly time step for the period July 1975 to June 1987 (12 water years in all). The comparative costs are shown in Table 1. Operation of the system after June 1987 has involved use of the developed optimisation model and therefore cannot be used to compare the historical operation with the model performance.

The results presented in Table 1 indicate that savings in operating costs of 8% could have been obtained if the model had been used as an operational tool by the pumping engineers. Given perfect forecasting ability, the maximum achievable reduction in pumping costs is 20%. An adjustment has been made to take into account the value of water in storage at the end of the period. This water is valued at the lowest-cost pumping rate on the Murray Bridge-Onkaparinga Pipeline ($55,900/GL).
<table>
<thead>
<tr>
<th>Operating Period (July-June Water Year)</th>
<th>Pumping Electricity Costs ($M)</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Historical</td>
<td>Model (forecast mode)</td>
<td>Model (perfect forecasts)</td>
</tr>
<tr>
<td>1975-76</td>
<td>0.041</td>
<td>0.031</td>
<td>0.000</td>
</tr>
<tr>
<td>1976-77</td>
<td>4.104</td>
<td>3.349</td>
<td>3.185</td>
</tr>
<tr>
<td>1977-78</td>
<td>4.442</td>
<td>4.448</td>
<td>4.368</td>
</tr>
<tr>
<td>1978-79</td>
<td>1.024</td>
<td>0.729</td>
<td>0.762</td>
</tr>
<tr>
<td>1979-80</td>
<td>0.557</td>
<td>0.719</td>
<td>0.000</td>
</tr>
<tr>
<td>1980-81</td>
<td>1.775</td>
<td>1.934</td>
<td>1.890</td>
</tr>
<tr>
<td>1981-82</td>
<td>0.247</td>
<td>0.157</td>
<td>0.064</td>
</tr>
<tr>
<td>1982-83</td>
<td>5.340</td>
<td>4.204</td>
<td>4.113</td>
</tr>
<tr>
<td>1983-84</td>
<td>0.606</td>
<td>0.815</td>
<td>0.222</td>
</tr>
<tr>
<td>1984-85</td>
<td>0.453</td>
<td>1.067</td>
<td>0.419</td>
</tr>
<tr>
<td>1985-86</td>
<td>1.786</td>
<td>1.987</td>
<td>2.017</td>
</tr>
<tr>
<td>1986-87</td>
<td>0.015</td>
<td>0.325</td>
<td>0.000</td>
</tr>
<tr>
<td>Total</td>
<td>20.390</td>
<td>19.765</td>
<td>17.040</td>
</tr>
<tr>
<td>End Storage (GL)</td>
<td>47.475</td>
<td>56.353</td>
<td>64.061</td>
</tr>
<tr>
<td>Adjustment</td>
<td>0.927</td>
<td>0.420</td>
<td>-</td>
</tr>
<tr>
<td>Total Cost</td>
<td>21.317</td>
<td>20.185</td>
<td>17.040</td>
</tr>
<tr>
<td>Average Annual Cost</td>
<td>1.776</td>
<td>1.682</td>
<td>1.420</td>
</tr>
</tbody>
</table>

Table 1: Southern System - Historical and Model Comparison

There are several water years where the model in both forecast and perfect modes involves greater pumping cost than historical operation of the system. This is because the model has held rigorously to the target storages within the reservoirs, whereas historically, the reservoirs have been allowed to fall below these values. Benefits for maintaining these target storages are reaped in the dry year 1982-83. The model in forecast mode appears to improve on the model with perfect forecasts in the 1978-79 and 1985-86 water years. This is a function of differences in the end-of-year storage.

The major differences in the model and the historical operation of the southern system can be summarised in the following manner.

- The model tends to make more use of Myponga water resulting in lower storage levels in this reservoir.
- Pumping on the Murray Bridge-Onkaparinga Pipeline for the model commences earlier in the water year than the historical operation of the system. Pumping is also
maintained by the model, wherever possible, in the middle section of the pump-cost curve.

The model maintains more water in storage in Mount Bold than Happy Valley Reservoir to minimise evaporation losses.

Northern System - Historical and Model Comparison

A comparison was made between the historical operation and the model performance in both perfect and forecast modes for the period July 1979 to June 1987 (8 water years) for the northern system. The comparative costs are shown in Table 2.

The results indicate that a saving in operating costs of 10% could have been obtained if the model had been used as an operational tool by the pumping engineers. The maximum achievable reduction in pumping costs given perfect forecasting ability was 20%. An adjustment due to the variation in end-of-period storage within the reservoir for the three system runs is made based on the base rate for pumping on the Mannum-Adelaide Pipeline ($60,400/GL).

<table>
<thead>
<tr>
<th>Operating Period (July-June Water Year)</th>
<th>Pumping Electricity Costs ($M)</th>
<th>Model (forecast mode)</th>
<th>Model (perfect forecasts)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Historical</td>
<td>Model</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1979-80</td>
<td>4.197</td>
<td>4.037</td>
<td>2.635</td>
</tr>
<tr>
<td>1980-81</td>
<td>4.556</td>
<td>4.143</td>
<td>3.913</td>
</tr>
<tr>
<td>1981-82</td>
<td>2.456</td>
<td>2.652</td>
<td>2.356</td>
</tr>
<tr>
<td>1982-83</td>
<td>7.977</td>
<td>5.934</td>
<td>5.642</td>
</tr>
<tr>
<td>1983-84</td>
<td>3.179</td>
<td>3.081</td>
<td>2.272</td>
</tr>
<tr>
<td>1984-85</td>
<td>4.158</td>
<td>3.810</td>
<td>3.894</td>
</tr>
<tr>
<td>1985-86</td>
<td>5.239</td>
<td>4.741</td>
<td>4.931</td>
</tr>
<tr>
<td>1986-87</td>
<td>2.678</td>
<td>3.357</td>
<td>2.120</td>
</tr>
<tr>
<td>Total</td>
<td>34.800</td>
<td>31.655</td>
<td>27.763</td>
</tr>
<tr>
<td>End Storage (GL)</td>
<td>70.319</td>
<td>75.353</td>
<td>74.319</td>
</tr>
<tr>
<td>Adjustment</td>
<td>0.316</td>
<td>-</td>
<td>0.871</td>
</tr>
<tr>
<td>Total Cost</td>
<td>35.116</td>
<td>31.185</td>
<td>27.834</td>
</tr>
<tr>
<td>Average Annual Cost</td>
<td>4.390</td>
<td>3.682</td>
<td>3.479</td>
</tr>
</tbody>
</table>

Table 2: Northern System - Historical and Model Comparison

There are two water years (1981-82 and 1986-87) where the model involves more pumping cost than historical operation of the system. In both years, the end-of-year storages are held at higher levels in the model runs. In the 1981-82 water year the benefits from these higher
storages are reaped in the following dry year 1982-83. In the 1986-87 water year, the same benefits have not been reaped, as the 1987-88 water year was not a particularly wet or dry year. The model in forecast mode appears to improve on the model with perfect forecasts in the 1984-85 and 1985-86 water years. This again is a function of the end-of-year storage. The major savings are made by the forecast and perfect models during the dry water year 1982-83; however, small savings are also made during average water years.

The major improvements in the operation of the northern system can be summarised in the following manner.

Pumping via the Mannum-Adelaide Pipeline is maintained at a more uniform rate throughout the year, thereby reducing the volume of water pumped at the upper end of the pumping cost curve.

Pumping out of Millbrook Reservoir and back into the Mannum-Adelaide Pipeline, is kept to a minimum since this water is predominantly double-pumped.

During most months, the branch from the Mannum-Adelaide Pipeline to the Warren Reservoir is used to capacity, since this water is cheaper than the water pumped via the Swan-Reach-Stockwell Pipeline. A consequent reduction in the pumping via the Swan Reach-Stockwell Pipeline is made when compared with the historical operation.

Evaporation losses are reduced by maintaining higher storages in South Para and Kangaroo Creek Reservoirs while reducing storages in Warren and Millbrook Reservoirs, respectively.

Conclusions

Systems analysis techniques have been successfully applied to aid in the identification of optimum operating policies for the Adelaide headworks system. A linear programming model has been developed, with the objective function aimed at minimising the operating costs while ensuring system reliability by maintaining minimum-target storage levels in the reservoirs. Application of the systems analysis techniques to the Adelaide water supply headworks system has shown potential for savings in pumping costs of between 5% and 10% with minimal reduction in system reliability. In dollar terms, this amounts to savings on average of between $400,000 and $600,000 per year. The models described in this paper have been adopted by the EWS Department, and are being used to assist in the optimal operation of the Adelaide headworks system.

References


SIMULATION MODEL FOR EMERGENCY EVACUATION IN BUILDINGS USING SYSTEM DYNAMICS APPROACH

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Department of Building & Construction
City University of Hong Kong

Abstract
Safe evacuation of occupants in a building in case of emergency should be a major concern for architects, building designers, building control officers, building managers, insurers, as well as the occupants themselves. Although various codes of practices for building design, which control the safety use of the building, are enforced for individual components of buildings, such as staircases geometry, they may not offer an adequate measure for securing successful evacuation. Therefore, a model that can simulate the evacuation pattern of the occupants can facilitate the assessment of the effectiveness of the exit routes in a building. The purpose of this paper is to develop a system dynamic model to analyse the interrelationship amongst the variables affecting people movement in a building under emergency situation, and the computer software, ITHINK, is used to simulate the model.

Introduction
Evacuation in a building is the movement of its occupants to some designated safe area in an emergency situation such as fire, leakage of gases, bomb threat, and threat of earthquake or other violent situations. Safe evacuation of occupants should be a major concern for architects, building control officers, designers, building managers, insurers, as well as the occupants themselves.

Although various codes of practices for building design, which control the safety of the building occupants, are enforced for individual components of buildings, such as staircases or lobbies geometry, they may not offer an adequate measures for securing successful evacuation. For example, individual components conform to the codes of practices, but as a collected whole, they may lack the coordination necessary for the inducement of smooth escape during evacuation. A simulation model may thus assist the designer to view the whole building as a total system as well as the effectiveness of evacuation plans.

Overview Of Previous Research
Despite the importance of building evacuation, previous studies of modelling of such evacuation problems are scarce. In the past, the physical environment was seen merely as a factor that constrained the movements of occupants and lead to studies that concentrated on flow capacities and sizes of different elements. Chalmet et al. and others have developed a network model to predict the course of action of evacuees which can explain their physical movement in one way. However, these models make no attempts to describe the behaviour of the evacuees.
Recent studies have revealed that the environment also poses psychological restrictions to the users. These studies on psychological problems are descriptive rather than quantitative. Therefore, it may be necessary to have a simulation model which can manipulate the physical movement as well as psychological reaction of the evacuees.

Scope And Approach

This paper presents an alternative approach to modelling and simulating evacuation process. The approach is based on the system dynamics methodology. The basic systems dynamics methodology is discussed. This is followed by an illustrative application of the modelling method, within the unprotected zone of a building. Influence diagrams are used to develop the link between the real system and the mathematical model. Details of the simulation results produced with the mathematical model are given along with a sensitivity analysis. Finally, the practicality of the presented method for use in design and analysis are briefly discussed.

The System Dynamics Methodology

The approach of System Dynamics used in this paper is centred on the ideas of Forrester. From a System Dynamics perspective all systems can be represented in terms of levels (state variables), rate variables and auxiliary variables.

A level is an accumulation, or an integration, over time of flows or change that come into and go out of the level. In addition to accumulating tangible flows, a level can be an integration of information over time.

The second variable type is a rate, a flow, decision, action or behaviour that changes over time as a function of the influences acting upon it.

All tangible variables are either levels or rates, i.e. they are either accumulations of previous flows or are presently flowing. But there is one more type of information variable, which is called an auxiliary. Auxiliary variables are combinations of information inputs into concepts. The concepts are used as inputs to rate decisions. Auxiliary concepts can refer both to any tangible as well as to any information variable. Auxiliary concepts are used in models to clarify and simplify the representation of rate variables.

System Dynamics is essentially for continuous deterministic models but can be adapted to discrete and stochastic cases. The System Dynamics approach has approved popular for the treatment of non-technical systems such as many business and social systems, but appears not to have been used in formulating evacuation process of a building. This paper presents a formal methodology for applying the System Dynamics approach to evacuation simulation.
Modelling Evacuation Using System Dynamics

It is considered that a building is subdivided into 3 different zones namely, unprotected zones (usually refers to as the rooms), partially protected zones (usually refers to the protected corridor(s)) and fully protected zone (usually refers to the protected staircase(s)). The modelling process is demonstrated for the first stage in the evacuation process (i.e. within an unprotected zone). The evacuation process may be considered to have 3 phases: occupants in the zone started to evacuate (starting); occupants moving towards the exits of the zone (moving); occupants leaving the unprotected zone through the exits (exiting) (with possible queue at the exits). A schematic diagram of the process is shown at Figure 1.

![Figure 1: Schematic Diagram for Evacuation in an Unprotected Zone](image)

Influence Diagrams

The schematic diagram is then converted to an influence diagram in Figure 2. The convention adopted in this paper is that dashed arrows are used to represent information flows and solid arrows are used to represent physical flows; arrows are used to represent, not the flows themselves, but the consequences of influences arising from these flows; the levels are boxed.

The possible levels are: pre-movement, responded, move and queue. In between the levels is their associated rate which will change the levels. In the influence diagram, rates sometimes represent the start and finish of an activity which are discrete event. For example, "start move" and "enter queue" are two such rates.
The model can be used for the determination of system output over time. It is also possible to determine evacuation pattern and to find the bottlenecks of different exits so that management can plan and control the evacuation process. From influence diagram assumptions, the change of the levels depends on their associated rates. Hence, the level equations are:

\[
\begin{align*}
\text{pre-movement} (t + \Delta t) &= \text{pre-movement} (t) + (- \text{response rate}) \times \Delta t \quad (1) \\
\text{responded} (t + \Delta t) &= \text{level} (t) + (\text{response rate} - \text{start move}) \times \Delta t \quad (2) \\
\text{move} (t + \Delta t) &= \text{move} (t) + (\text{start move} - \text{enter queue}) \times \Delta t \quad (3) \\
\text{queue} (t + \Delta t) &= \text{queue} (t) + (\text{enter queue} - \text{pass exit}) \times \Delta t \quad (4)
\end{align*}
\]

Accordingly, the level equations have the following standard form:

\[
\text{level} (t + \Delta t) = \text{level} (t) + (\text{inflow rates} - \text{outflow rates}) \times \Delta t \quad (5)
\]

It only remains to define the rate equations.

\[
\text{Warning System} \quad \Downarrow
\]

- \quad \begin{align*}
\text{Pre-movement} & \quad \Uparrow \quad \text{Response Rate} \\
\text{Total Occupants} & \quad \Downarrow \quad \text{Density} \\
\text{Room Shape} & \quad \Downarrow \quad \text{Move Time} \\
\text{Flow Rate} & \quad \Downarrow \quad \text{Door Width} \\
\text{Enter Queue} & \quad \Downarrow
\end{align*}

\[
\text{Figure 2: Influence Diagram}
\]

The Response Rate

Research studies in most countries have shown that the occupants in a building do not respond quickly to the information initially available in a fire and evacuate immediately, especially when the initial information is given by fire alarms. Table 1 summaries an experiment carried out by Building Research Establish (UK) to indicate the approximate
time of response and the percentage of occupants decided to evacuate in relation to different types of warning system.

Indeed, the behavioural reaction of the individuals is complicated. A series of decision making process will be taken to determine their action. The possibility that an individual will decide to evacuate depends on the level of warning received. When time is passed, the level of warning will increase and so is the possibility of starting to evacuate. Therefore, in order to simplify the computation, it is assumed that the percentage of occupants starting to evacuate is an exponential function with time. It is therefore assumed that the probability density function for a time \( t \) at which an occupant starts to evacuate can be expressed as \( f(t) = k e^{-kt} \), for \( t > 0 \); and \( k \) is the parameter with respect to different type of warning system. Then, for \( t \) is continuous, the cumulative distribution function \( F \) can be expressed as:

\[
F(t) = k e^{-kt} dt = 1 - e^{-kt} \quad (6)
\]

Thus, the response rate (which accounts the psychological reactions of the occupants) can be expressed as:

\[
\text{Start response} = [1 - \text{EXP}(-k\times\text{time})] \quad (7)
\]

The average number of occupants responded per second with respect to different warning system may be referred to Table 1.

<table>
<thead>
<tr>
<th>Type of Warning System</th>
<th>3D</th>
<th>2D</th>
<th>LCD</th>
<th>T</th>
<th>S</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Response Time (Seconds)</td>
<td>44</td>
<td>48</td>
<td>42</td>
<td>48</td>
<td>37</td>
<td>34</td>
</tr>
<tr>
<td>% of occupants selected to evacuate</td>
<td>65</td>
<td>45</td>
<td>44</td>
<td>28</td>
<td>45</td>
<td>10</td>
</tr>
<tr>
<td>assumed k value</td>
<td>-0.024</td>
<td>-0.012</td>
<td>-0.014</td>
<td>-0.0068</td>
<td>-0.016</td>
<td>-0.0031</td>
</tr>
</tbody>
</table>

Abbreviations: 3D - 3D graphic; 2D - 2D graphic; LCD - Bresens Text; T - Anna's Text; S - Anna's Speech; F - Firebell

Table 1: Response to Different Type of Warning System

The Moving Time

The moving time, \( T \), within an unprotected zone normally affected by the room shape (also the location of the furniture), the density of the evacuees, etc. It can be expressed as:

\[
T = f (\text{room shape, speed}) \quad (7)
\]

where speed = walking speed of the evacuees which can be taken as \( 1.4(1-0.266D)^{16} \), and \( D \) is the density of the evacuees.
Rate of Passing Exit

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>flow rate (p/min/m)</td>
<td>105</td>
<td>90</td>
<td>105</td>
</tr>
</tbody>
</table>

Table 2: Flow rate of occupants passing through exit door(s)

While the evacuees arrive at the exit, the rate of passing through the exit will depend on the width of the exit which can be taken as an average of the research results as listed at Table 2 (i.e. 100 person/minute/minute width is taken), and the queue size. i.e.

\[ \text{passing rate} = f (\text{queue size, flow rate, door width}) \] (8)

**Example**

In accordance with the rates considered above, an evacuation model within an unprotected zone can be illustrated by the following example:

*First, it is assumed that the zone is of size 5m*20m, the number of occupants is 100, the exit width of the zone is 0.9m, walking speed of the occupants is taken as 1.4*(1-0.266*D), the flow rate passing the exit is taken as 100 p/min/m.*

<table>
<thead>
<tr>
<th>Warning System</th>
<th>3D</th>
<th>2D</th>
<th>LCD</th>
<th>T</th>
<th>S</th>
<th>F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Evacuation Time (sec.)</td>
<td>87</td>
<td>125</td>
<td>112</td>
<td>176</td>
<td>98</td>
<td>350</td>
</tr>
</tbody>
</table>

Table 3: Average Evacuation Time of Different Warning Systems

In this paper, the computer software package, ITHINK 19, is used to simulate the model. The simulation results for different warning systems are tabulated at Table 3 above.

The evacuation time can be regarded as the time required by the occupants in an unprotected zone to enter a relatively safer zone. Such time can be used to compare with the Available Safe Egress Time (ASET)19 which is the time interval between detection and the onset of hazardous conditions. In general, it is considered as safe for the occupants if ASET > the required evacuation time.

**Sensitivity Analysis**

The question of "what if" will arise naturally after the model has been constructed and the initial calculations have been completed. It may be necessary to check the effect of changing one or more variables in the model.

The door width is one of the major constraints of the system (queuing before passing the exit). The simulation results of different door width are shown in Figure 3 below.
Moreover, other variables, such as response rate, the density of the occupants, speed of the evacuees, the psychological reaction rate to different type of exit, may also influence the system. Other sensitivity analysis may also be carried out to examine the effect of these variables.

The system model can also be easily adopted to different design of a building, for example, the number of exit can be altered, by amending the influence diagram as shown at Figure 2 above. Finally, the system model of a building can be developed by aggregating the elementary model (for each zone) developed above.

Conclusion

This paper presents an alternative method of modelling and simulating evacuation process in a building. The building is subdivided into finite zones so that the flow of the evacuees can be treated as in a network. System dynamics' framework of levels and flows are then adopted to model the flow process. This model is general and can be modified and applied to different layout of a building.

In addition, system dynamics simulation capacities make it powerful tool to test alternatives and "what if" questions. This is especially useful in the analysis of the evacuation process as many options of the layout of a building can be tested. Moreover, system dynamics provides a flexible structure to set up, modify, and understand complex problems. Therefore, for a building with complex layout, system dynamics approach may be a simpler method to model to evacuation pattern for the building.
Reference

9 Bryan, J. L., (1977), "Smoke as a determinant human behaviour in fire situation", Department of Fire Protection Eng., University of Maryland, College Park, MD.
14 protected means the zone is enclosed by fire resisting construction (i.e. the walls, floors or ceiling enclosing the zone should have adequate fire resisting properties.