An Expert System Approach for the Selection of Land Use/Transport Planning Models

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Abstract:

The process of selecting a transport planning package that is well suited for the requirements of a particular planning agency is a complex task The selection of the best suited package ensures the minimal commitment of planning resources. The expert system described in this paper exploits heuristic strategies to assist transport practitioners in the process of choosing a transport planning package from six well-established program suites. The approach followed in the paper allows transport planners to obtain improved utility from the data already available and minimise the cost of collection of additional data solely for the input purposes of the transport planning package The methodology is also of importance to the developers of transport planning packages in the design of the input frameworks.

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Introduction

Expert system techniques which apply heuristic strategies provide an efficient tool to solve the family of transport problems that lack numerical expression and mathematical formulation. The attractiveness of the expert system methodology has been evident to researchers in the Department of Transport Engineering, School of Civil Engineering, the University of New South Wales where a knowledge-based system for road lighting, CARL, based on the Australian Public Road Lighting Standard, and its source code, has been successfully marketed in Australia and overseas countries such as New Zealand, Indonesia, South Korea, and South Africa. A prototype knowledge-based expert system to assist local government engineers and planners in the selection of traffic control devices for Local Area Traffic Management is currently being tested in the field. Research in progress is by far the most complex, being aimed at developing a system to assist planners select the best technology amongst transport planning packages. The only known parallel study of this problem is in the USA by Nabil, et al. (1990).

Local government authorities and planning agencies have a number of transport planning packages from which to select. Although prospective program purchasers instinctively demand much information related to the planning packages there is still confusion and apprehension as to how best to evaluate alternative planning suites. For example, the purchase price, modelling features, input – output characteristics, and user friendliness of the packages are considered by many prospective users in a checklist manner. Often the selection of a transport package is based on the experience of the transport planner toward a particular package. However, there are problems with this approach because of frequent staff turnover at planning agencies. Academics in continuing education programs conducted by Universities, and in seminar settings, are often requested for information about packages available, and about their opinions on relative merits.

This paper addresses the problems faced by users in the selection of a computer package for transport planning. The methodology adopted by the authors is based on identifying various attributes of the package and developing an information base which contains the developer-provided information and the experience of users of each of the computer packages. The process adopted in the development of an expert system is documented in this paper. In particular, it identifies important characteristics of the conceptual structure of the program as well as the methodology followed for the accumulation of the required knowledge.

The expert system package is named EXTRANS (EXpert system for TRANSport planning process). The expert system has been designed with two main objectives: to provide assistance in the selection of a planning package by matching requirements of the user with the program features, and to provide software enhancement tools to generate a transport planning suite for the specific needs of the user. However, the initial version of the EXTRANS package satisfies only the first objective. Further work is currently being carried out in relation to the second objective that will later be achieved through the EXTRANS to generate a suitable transport planning software for user.

The objective of the paper is to report on experiences in the development of the expert system for selecting transport planning packages. Although there are many packages in the literature, only six transport planning packages widely–used in Australia are considered. They are: QRS II (Quick Response System II); TRANSTEP; TRANPLAN; TRANSCEND; TRIPS; and EMME/2. The expert system attempts to look at the attributes of each planning package and then investigates how well these attributes match the requirements of a particular user. The software developer also can benefit from this methodology as it allows the developer to improve the design of program characteristics to suit the market.

Based on the objective of the paper, the following sections will cover aspects related to the program structure, the methodology adopted in the development of the expert system. The next section provides a brief overview of the applications of expert systems in transport engineering.

Overview of the expert systems applications in transport engineering

Expert system techniques, as distinct from conventional programming techniques, were initially put forward in the early 1960s. The medical profession is credited with one of the early successes in the area of expert systems for the development of a diagnostic system MYCIN in 1974 (Lugger and Stubblefield, 1989). Since then, there has been a marked increase in expert system softwares, as shown by Harmon and Sawyer (1990). As a result, expert systems applications are now available in many professional fields, such as Medicine, Business, various branches of Science and Engineering.

Transport planning problems are often ill–structured from the point of view of the availability of complete set of numerical values and mathematical formulations. It has been claimed that such problems require a high degree of skill, judgement and experience in developing appropriate solutions (Conroy and Turnquist, 1990). For problems of the above nature, expert system programming techniques, which can handle heuristic formulations, are better suited than conventional programming techniques, which are effective for strictly procedural applications. Expert systems that form one branch of the field of artificial intelligence (AI) have become a useful technique for transport planners and engineers as the method already displays promising applications in all areas of transport engineering including planning, design, operations, maintenance and management (Courage and Hsu, 1990).

Although the potential applications of expert systems in transport engineering are high, there are still only a limited number of documented applications in transport planning. For example, a literature survey conducted by the authors identified about 30 documented expert systems in transport engineering, most of them are in the field of traffic engineering, operation and maintenance. Two possible reasons for the above lack of reported applications can be forwarded. The first is that the method is relatively young compared to other modelling techniques and therefore many of the applications are still in the developmental stages. The second reason is related to the apprehensions and reservations in the planning community about the new technique which has yet to demonstrate widespread acceptance. Notwithstanding the scepticism amongst some professionals, it is important to note that the expert system technique is scientifically sound.

Developing an expert system for selecting transport software packages has been previously attempted by Chang (1987), and Nabil, et al. (1990). Chang developed an expert system to select traffic analysis software to be suitable to the user's demand. The computer package has been developed on the INSIGHT 2+ expert system shell and allows the program user to select from 14 traffic engineering packages (Chang, 1987). On the other hand, Nabil, et al. (1990) developed an expert system, referred to as NETSSA, for selecting network–based transportation planning packages. NETSSA is based on the LISP computer language, operating on a VAX computer. Nine transport planning packages have been proposed for selecting. Ten categories of planning have been considered for the selecting process. The first four categories that have been considered as basic modeling analysis options are the four steps of the traditional transport planning model. The other six supporting analysis categories are related to the specifications of the transport planning package (Nabil, et al., 1990).

Some definitions related to expert systems

Definitions of some keywords are included in this section to assist in the comprehension of the expert system concepts being referred to in this paper. A number of different definitions of an expert system has been put forward by different teams of researchers (Waterman, 1985; Hunt, 1986; Wolfgram, et al, 1987; Giarratano and Riley, 1989; Luger and Stubblefield 1989; and Harmon and Sawyer, 1990). There is a general agreement that an *expert system* is computer software that: contains expert knowledge and expert inference;

applies heuristic strategies to solve specific classes of problems; and solves complex problems with the quality that approaches a human expert. Thus, an expert system is a term developed to convey the characteristic of the collection the knowledge of experts of a particular profession and the inclusion of the expert approach to solve problems in the software (Ortolano and Perman, 1990). It is observed that the terms *Expert System*, *Knowledge-Based System* and *Knowledge-Based Expert System* are often used synonymously (Giarratano and Riley, 1989), but the term *expert system* is preferred by the majority of researchers. The speciality of the expert system is limited to a particular subject area which is referred to as the *domain* or the *subject master* of the expert system.

The general methodology in the design of an expert system is to develop three interacting components. They are the *knowledge base*, which relates to the domain, the *inference engine*, and the *user interface* (Hunt, 1986; Wolfgram, et al., 1987; Smith, 1988; Giarratano and Riley, 1989; and Harmon and Sawyer, 1990). Before explaining the interaction between these components, these three terms are described below.

The *Knowledge Base* consists of facts and heuristic knowledge associated with the domain. There are a number of methods to represent knowledge in the knowledge–base (Wolfgram, et al., 1987; Hu, 1987; Lansdown, 1988; Roseman, et al., 1988; Martin and Oxman, 1988; and Sriram and Connor, 1989). The method commonly adopted is known as the rule–based method. A knowledge base developed according to the above method consists of number of rules. Each rule is an "If ... Then ... Else ... " construction that links statements together in order to facilitate inference. The expert system described in this paper adopts the rule–based construction.

The *Inference Engine* controls the operation of an expert system by processing the rules in the knowledge base as appropriate for the problem posed. The inference engine is often referred to as a controller or rule interpreter. This interpreter contains the computer instructions and procedures of problem solving–strategies required to simulate the decision–making process of the system by dealing with the information contained in the knowledge base. The basic concept of an expert system is to separate the knowledge base from the inference engine. This separation gives developers more freedom in programming and updating.

The *user interface* allows two–way communication between the expert system and its user. The user interface is more complex than the input and output facilities found in conventional computer programs because the user interface of an expert system has the additional function of providing explanations as required to examine the reasoning behind the advice given by the system. It has been now established in the industry that a user interface is a mandatory component in an expert system.

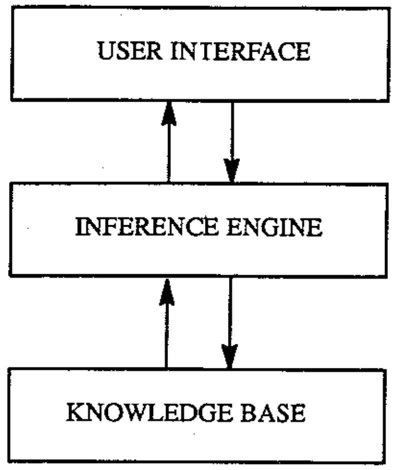

Figure 1. The Basic Components of Expert Systems

The interaction amongst these three components explained above are shown in a flow diagram form in figure 1. The user interaction is with the inference engine that mimics the functions of an expert by processing the appropriate rules stored in the rule base. To reduce the program developmental costs, a commercially available skeleton, known as an *expert system shell,* is used for the development of the expert system. The details of the program development are included in the next section.

Development process of the expert system

The expert system under development is specifically designed for selecting transport planning packages being used in Australia. The expert system has been developed utilizing the expert system shell CRYSTAL (a trademark of Intelligent Environments) for a microcomputer environment. The expert system will consider six transport planning packages, namely QRS II (Quick Response System II), TRANSTEP, TRANPLAN, TRANSCEND, TRIPS, and EMME/2 in the selection process. Its development consists of the following steps (Figure 2):

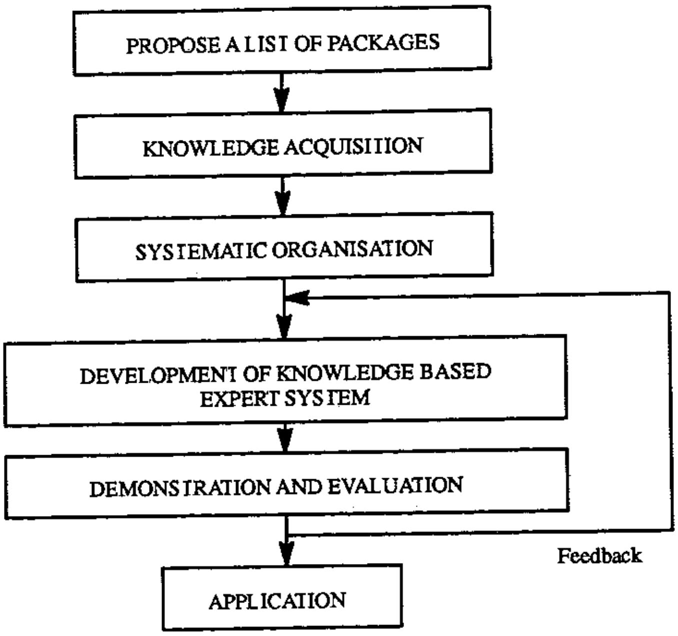

Figure 2. Development Process of Expert System for Selecting Transport Planning Packages

* Identify the list of candidate transport planning packages;
* Knowledge acquisition related to the selection process;
* Systematic organisation;
* Development of the knowledge–based expert system; and
* Demonstration and evaluation.

It is important to notice that feedback available from the demonstration and evaluation step is a significant aspect of the development of the expert system.

The first step is to *identify the list of candidate transport planning packages*. They were identified both from a literature survey and from personal contacts with various program developers and users. The six transport planning packages listed above were found to be the commonly applied transport planning packages in Australia. The step of consultation with users is required to develop the knowledge base.

Knowledge acquisition related to the selection process consists of two stages. In the first stage, preliminary knowledge acquisition has been carried out. The tasks performed include a literature review and familiarisation with the six transport planning packages in order to determine the characteristics of each package. In the second stage, knowledge in applying the transport planning packages is required and this has involved: learning by applying each transport package; participation of Transport Planning Software Short Courses; and conducting a questionnaire survey to investigate the hierarchy of priorities and implications related to input data availability as perceived by practicing transport planners.

Some features of transport packages are summarised in table 1. This table provides information related to the characteristics of the six transport planning packages such as hardware requirement, software limitations and price.

Systematic organisation is related to developing the structure of the expert system software. It has been decided to create an object oriented data–base, using C++ programming language, to list, and sort, information relevant to each transport packages. Details about the structure of the expert system is included later in this paper.

Table 1. Features of Transport Planning Packages

General Information	Transport Planning Package					
	QRS II	EMME/2	TRANPLAN	TRANSCEND	TRANSTEP	TRIPS
Language Used	PASCAL	FORTRAN	FORTRAN	FORTRAN	FORTRAN	FORTRAN
Computer supported: PC Work Station Mainframe	 Yes No No	 Yes Yes Yes	 Yes Yes Yes	 Yes No No	 Yes No No	 Yes Yes Yes
Price	US$ 195 – US$ 585 *	US$ 9000 – US$ 60000 *	US$ 7920 #	n/a	AUS$12000 @	US$ 3750 – US$ 5625 !
Limitation of Zones	900	1600	3000	n/a	300	2000
Limitation of Nodes	n/a	10000	16000	n/a	2000	9999
Limitation of Links	20000	32000	32000	n/a	3500	20000
Handling Public Transport	Yes	Yes	Yes	No	Yes	Yes

Legend:
(*) Depending on the option of package capacity or computer environment
(#) Basic price of TRANPLAN, excluding supported softwares
(@) Updating cost AUS$ 100 00
(!) Depending on the version for basic highways or for the protected mode

The *development of knowledge base* is to represent the acquired knowledge collected from literature review of transport packages and the expert knowledge from package users obtained through surveys. The challenge at this step is to translate the expert experience into a computer processable list. Rule–based method has been adopted in this project. Therefore, the selection process experience is represented in the form of a list of "IF ..... (condition) ..... THEN ..... (conclusion) ....." statements. Rule–based representation allows the inference engine to efficiently process the facts and decision rules. For example, the rule for seeking the description of a transport package is:

```
IF
        TRANSPORT PACKAGE = EMME/2
THEN
        GET EMME/2 PACKAGE INFORMATION
```

The advisory expert system contains rules, such as the one given below, to recommend to a client a transport package based on transport data available:

```
IF
        THE AVAILABLE DATA = POPULATION
   AND  REGIONAL TRIP GENERATION RATE
   AND  AVERAGE TRIP LENGTH ACCEPTABLE FOR JOB
   AND  PROPORTION OF TRIP PURPOSES
   AND  INCOME CATEGORIES
THEN
        TRANSTEP PACKAGE IS PROPOSED
```

The final step of *demonstration and evaluation* involves applying and testing the expert system. To date, the program has been demonstrated only in a laboratory setting. A prototype of the expert system is now available for extensive testing of the package. The next section summarises details related to the computer codes of the expert system.

Expert system software

Computer codes of two different types were required during the development of the expert system. Program codes were written in the CRYSTAL shell. The shell controls the processing of the facts and rules forwarded to the expert system and also controls the user interface. As the knowledge base was developed in a object oriented manner to enable later marriages with other similar packages, the C++ programming language (a trademark of the Borland International, Inc.) was used for the construction of the database.

The expert system shell CRYSTAL supports the inference engine and user interface. The problem solving strategies of forward chaining and backward chaining have been applied. In the forward chaining strategy, the system will search for transport packages matching with the input data, starting from the initial state of input data. In the backward chaining strategy, the expert system will search backwards, from the selected transport package: the system will retrieve all the characteristics of the package through the getting package information rule.

The prototype expert system is available in two versions, referred to as *developer version* and *user version*. The developer version allows enhancement of the expert system by inclusion of modifications to the knowledge base. These modifications typically represent further experience related to the selection procedure. The developer version can also be used as a research tool to evaluate different forms of representing the rules in the knowledge base. The user version allows access only to the knowledge base through the user interface. The knowledge base of the user version has been fixed for the precaution to maintain the reliability and integrity of the expert system. Knowledge base changes can be applied only by professional developers with the consultations of the users of the transport planning packages.

The top section of figure 3 shows the method involved in dealing with the developer version of the expert system. The user interface, inference engine and knowledge base components, shown within the shaded area, represents the expert system. The program to be released to the users is shown in the lower part of the diagram. The user version allows interaction only through the user interface for consultation for the purpose of selecting a planning computer package.

Structure of the knowledge base

There are three areas of interest that the expert system user will encounter during the program selection process. The three sections are related to the description of transport planning packages; the index of knowledge base; and the recommendation of transport planning package(s). Figure 4 shows the framework for these three different areas presented during the application of the expert system. Typically, the program user will be given four options when the program is started. These options include the option to terminate the program or access one of the above three sections. Notice that the user can move from one section to another section as desired. These sections are described below.

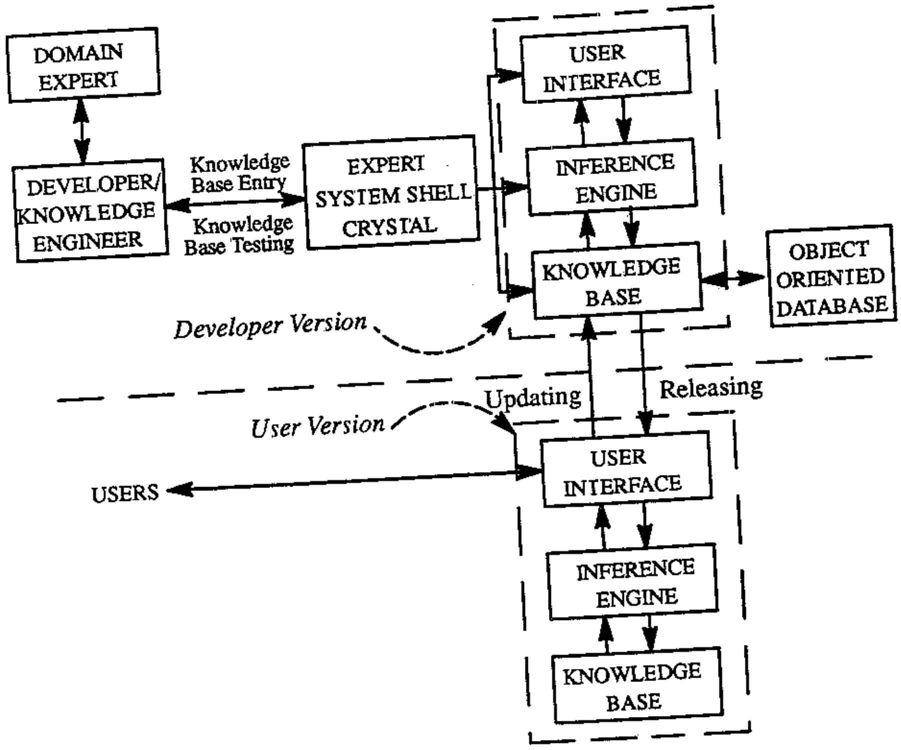

Figure 3. Two Version of the Expert System for Selecting Transport Planning Packages

Description of transport planning packages

In this section of the program, a brief description of each transport planning package is displayed. The expert system adopts a structure that allows the program user to retrieve characteristics of the transport planning package simply by menu selection. The description includes the name of transport package, developer's name and address, latest available version, person(s) or organisation(s) for contacting, approximate price (1991 prices), computer environment required, level of transport planning application, limitations, modules used for each step of transport planning, and input data required. These information are retrieved from the object oriented database. For example, table 1 shows the computer language adopted by the developers, computer hardware requirements and approximate price of the packages. The table also shows the limitations related to numbers

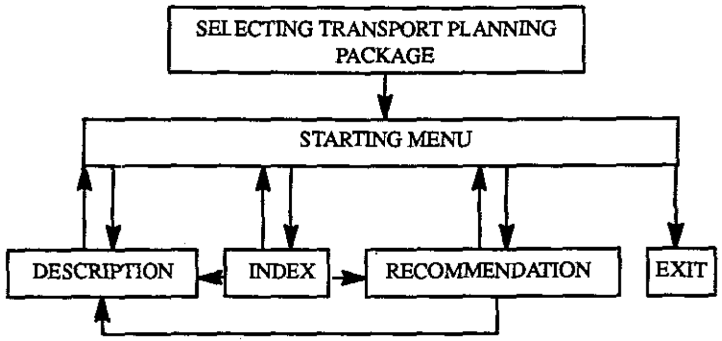

Figure 4. The Structure of the Knowledge Base

of zones, nodes and links related to each computer package extracted from the knowledge base. In addition, table 2 shows the type of analytical model incorporated in each computer package for trip generation. Further information related to the analytical models adopted in trip distribution, modal split and traffic assignment are also included in the expert system.

Index

In this section of the program, the user is allowed to investigate the content stored of the knowledge base. It is also possible to display a summary of characteristics of the planning packages using a keyword search method.

Table 2. Modes Used in Trip Generation of Transport Packages

MODEL	Transport Planning Package					
	QRS II	EMME/2	TRANPLAN	TRANSTEP	TRANSCEND	TRIPS
REGRESSION MODEL	Yes	–	Yes	No	No	Yes
CATEGORY ANALYSIS	No	–	Yes	No	Yes	Yes
OTHER	–	Yes #	–	Yes *	–	–

Legend: (#) Matrix manipulation which allows user to choose trip generation models
(*) Using opportunity model to combine trip generation and trip distribution into one step

Recommendation of transport planning packages

The program choice procedure is sensitive to the selection criteria of the user. It is observed that the selection criteria is usually based on the user preference related to a particular attribute. Often the ability to use existing transport database is seen as important in the package selection process. Therefore, the selection criteria allowed in the model is presented as three options. They are:

- Selection based on ability to use available transport data;
- Selection based on user preferences related to a particular attribute; and
- Selection based on a combination of the previous two options.

The questions posed by the expert system will be based on the selection criteria nominated by the program user. The expert system allows the program user to request for explanations at all stages of the consultation.

An attempt is made to include as much explanations and precautionary notes as necessary to ensure the users provide accurate responses. The correctness of the user response is important because it contributes to the outcome recommendation from the expert system. The task of processing the user responses in accordance with the rules in the knowledge base is carried out by the inference engine.

The expert system provides a list of packages suitable for the particular user in the order of suitability. None of the planning packages are recommended when the user's responses do not permit a logical selection. In a future version of the expert system, it is planned to include a method to suggest an order of transport packages by ranking the matching of the user's responses to the selection criteria. When a transport planning package is recommended, a menu selection allows the user to (1) enter the description section to obtain details of the proposed package, (2) enter the explanation facility to investigate the recommendation, (3) restart the recommendations section, or (4) exit the expert system. These programming options and linkages were shown before in figure 4

Conclusions

This paper has presented an expert system that can simulate the transport planning program selection procedure of an human expert. The expert system is able to suit the user preferences against the characteristics of the planning packages A specific strength of the expert system is its ability to recommend a planning package to match the type of planning data available to a planning agency. This allows the agency, such as a local government, to avoid extra expenses for collection of data to apply the planning package; a valuable feature given that some transport planning packages are data hungry.

The knowledge base of the system has been developed from formal and informal training in the packages as well as from a survey of experts. The knowledge base is represented as a collection of rules. The knowledge acquisition and the translation of such knowledge to a rule–based system have been two of the main tasks of this project.

A commercially available expert system shell has been used for the software development of the expert system. The knowledge base, however, has been developed using a programming language because it was decided to develop the knowledge base in an object oriented form. Additions and changes of expert knowledge to the knowledge base can be incorporated with ease using the expert system shell and the programming language. However, the expert system user interface presents menu commands that program user can use readily to activate the program selection process.

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