Expert Systems in Transportation

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Abstract

The purpose of this paper is to provide a brief overview of expert systems technology and its potential applications. The Organisation of Economic Co-operation and Development (OECD) held two workshops of expert systems, the First OECD Workshop on Knowledge-Based Expert Systems in Transportation held in ESPOO, Finland, in June 1990, to review current expert systems activities in the OECD countries, and the Second OECD Workshop on Knowledge-Based Expert Systems in Transportation held in Montreal, Canada in June 1992, to focus on the problems and potential of expert systems in highway transportation. Prior to the workshops, the OECD circulated two questionnaires (1990 and 1991) which provided knowledge on highway related expert systems existing and under development. This paper is largely excerpts from an overview of expert systems activities in OECD countries (1), presented at the second OECD workshop in Montreal.

1. Introduction

The feasibility of using expert systems has been proven for highway applications. This is clearly demonstrated by existing operational systems such as FRED (Freeway Realtime Expert System Demonstration), a component prototype real-time expert system for managing non-recurring congestion on urban freeways in Southern California, or ERASMUS, an expert system for pavement assessment and rehabilitation which is operational on thirty-five sites in France. Other developed systems such as FASTBRID, (Fatigue Assessment of STeel BRIDges), and the WZTS (Workzone Safety Training System) show that fully integrated decision aid / training systems are both possible and practical. With the large numbers of the current senior professionals approaching retirement age, expert systems can perform a useful role in the near future.

In 1989 the OECD, in recognition of the possible future role of expert systems in roadway engineering and operations, initiated a project to determine to what extent, and in whatareas expert systems can be utilized in road and road transport research, planning, engineering and management.

The OECD program resulted in two workshops, the first in Finland in June of 1990 where expert systems technology and potential for roadway applications were highlighted, and a guide for developing knowledge-based expert systems was presented, and the second in Canada in June of 1992 where the focus was on operational experience and perspectives. The sharing of information on expert systems developments and technology has been emphasized throughout the OECD program.

To support this activity two questionnaires on expert systems developments and their status were prepared and circulated by OECD. The first questionnaire resulted in a working knowledge of developments of Member countries and was instrumental in planning the first OECD Workshop. Findings from the second questionnaire are included in section 3, Observations, of this paper.

2. Current Applications in Highways

While applications in highway design, engineering and operations appear not to have gained the acceptance that expert systems have achieved in other fields, they are increasing in use. Recent surveys conducted by the OECD in Paris, resulted in information on ninety expert systems in various stages of operation anddevelopment. This survey represents only a portion of expert systems actually developed.

The systems included in the OECD survey are classified by function in four very broad groups as follows:

I. *Traffic Management and Control* -systems developed to advise or assist with traffic management and control operations, such as diagnostics of traffic problems from sensor data, incident detection, signage, and signalization;

II. *Traffic Impact and Safety* - systems for evaluating ways of reducing the impacts of traffic: noise control, safety workzone layout, accident investigation, etc;

III. *Highway Design and Planning* -systems designed to assist with roadway design, and to analyze roadway needs and problems, such as geometrics, landslide forecasting, and drainage; and

IV. *Highway Management* - systems to assist with roadway maintenance and operation and decisionmaking, including pavement maintenance, bridge deck repair, and bridge painting strategies.

The systems reported were also grouped according to the category of problem addressed. These categories are a) *diagnosis/monitoring*, b)*interpretation/classification*, c) *prediction/forecasting*, and d) *design/planning* were selected. Definitions used for these categories are *(2)*:

a) *diagnosis/monitoring* - The basic goal of diagnosis/ monitoring is to catalog a systems characteristics (deterioration, malfunction, etc.) into a specific cause or set of causes and from this develop solutions, i.e. what is wrong and what should be done about it. Monitoring can be considered to be real time diagnosis. They are similar in terms of the problems addressed and the complexities involved in developing the expert system.

b) *interpretation/classification* - This class of system, compares a situation with a set of known conditions and looks for matches. Expert systems which solve problems in this area are designed to model the pattern matching ability of someone who is an expert in identifying features or characteristics in the problem domain.

c) *prediction/forecasting* - The goal of this class of system is to forecast future conditions based on existing conditions and a knowledge of past conditions.

d) *design/planning* - The goal of this type of system is to derive aspecification of how something should be built (design) or a prescribed set of actions to meet a goal (planning). In most examples developed to date, this consists of providing detailed specifications for a generic design or plan.

Table 2.1 shows the systems reported grouped by category and function. This table depicts expert systems that are: operational and in active use, developed and under test and evaluation, or under development in 12 different OECD countries. All of the systems represented are either proven to be successful systems or are thought to have the potential to be useful operational systems when fully developed.

The heavy emphasis on Highway Management with diagnosis/monitoring systems on Highway Design and on Planning with design/planning systems is apparent. This does accurately reflect needs in the highway community where funding and staff are often inadequate and the problems cannot be ignored or deferred.

3. Observations

Several observations and conclusions can be drawn from the responses to the OECD questionnaires.

- The expert systems reported appear to be more developer driven than user demanded. Thisis to be expected in any relatively young technology. There is gradual acceptance of expert systems by the user work force as demonstrated by the increasing numbers of expert systems in use.

- PC based expert systems are far more common than workstation or mainframe based systems. There are very few Macintosh based systems. The two reasons for this situation are obviously the primacy of PC's available to the intended end users and the availability of PC based development tools. There are however increasing numbers of examples of expert systems being developed on higher level workstations and then being ported to PC's. Of the systems reported, about 80 % were PC based with the balance divided between workstations and mainframes and (15 % and 5 % respectively).

- The integration of knowledge-based expert systems with algorithmic systems and data bases and other technologies is firmly entrenched as a practice. Many of the existing systems are hybrid systems where the knowledge-based expert system interacts with external programs and databases, or is only one component of a larger system.

From the OECD survey *(3)*, major expert systems conferences in Paris *(4)*,Espoo, Finland *(5)*, Avignon, France *(6)*, and Montreal *(7)*, and other sources, several additional observations can be made. These included:

- Currently available development tools are adequate for building knowledge-based expert systems in both basic and complex technical areas in highway engineering and operations.

- Fully integrated decision aid / training systems are both possible and practical by combining knowledge-based expert systems with interactive videodisc training systems and other conventional media.

- The time and cost of developing and implementing knowledge-based expert systems are high compared to the time and cost required for developing and implementing algorithmic systems of comparable magnitude. The time and cost are expected to decrease as development tools mature and procedures for the verification, validation and evaluation of knowledge-based expert systems are refined.

Observations more specific to the problems faced during the development, testing and application of expert systems include:

- Structured planning isrecommended for the successful development of a system. This should include the <u>problem / need</u> to be addressed and the system benefits, organizational risk factors, technical risk factors, and user risk factors.

- Management support in the institution sponsoring the development of the knowledge-based expert system is necessary. This support must include the commitment of both staff and financial resources needed to successfully develop and implement the system. Full knowledge and understanding of the costs, benefits and risks involved is essential.

- The end user is pivotal to the development of knowledge-based expert systems and must be involved from the planning through the field evaluation stages. The end user provides definition of the skill level of the user community, information on how problems are addressed in practice vs the prescribed solutions, advice on how the system must function (interact with the user) to be accepted by the user community, and a cadre of supporters to test and promote the system once it is completed.

- Knowledge elicitation from the experts is vital throughout the duration of the entire knowledge-based expert system development. It is vital both in terms of building the system and for maintaining interest and continuity throughout the project.

- Maintainability must be considered in all phases of the system development. Since the maintenance will probable not be performed by the developers, the system structure must be clear and straightforward. Logical and understandable names should be used for objects and knowledge structures within the system. Clear and complete system documentation is required for effective maintenance.

- The selection of the development tool for a knowledge-based expert system project should be performed by a qualified knowledge engineer or expert systems developer. This is critical because there are significant differences between the development tools that are not explained in available literature and an application should be keyed to the specific knowledge handling and operational characteristics of a development tool.

4. Future Directions

Several of the expert systems currently under development should further demonstrate the value of expert systems and the variety of problems thatcan be addressed using them. For example a small expert system is under development to diagnose signals from an inductive loop detector tester which when completed will demonstrate the practicality if imbedding an expert system in testing hardware. Other current applications range from bridge rail retrofit design systems to pavement management systems to freeway incident management systems. There are numerous potential applications in the IVHS program.

One of the technical factors slowing the development and fielding of expert systems is the difficulty in testing these systems. There is little agreement among experts on how to accomplish the verification (is the system built right?), validation (is it the right system?), and evaluation (is the system valuable?) of expert systems. [Green and Keys] *(8)* identify the vicious circle where "nobody requires expert system validation and verification, so nobody does it. Since nobody knows how to do it, nobody requires it." One of the causes for this lack of agreement, and thus lack of accepted methodology, is the "combinatorial explosion" of possible solutions resulting from the execution of an expert system. The six step solution proposed by [Geissman and

Schultz] *(9)* offers an approach to the validation and verification of expert systems, but it does not really address the complexity of the solution state space and offer processes to design field tests. Fundamental research on these issues has been conducted through NASA *(10)* and the USAF *(11)*,and applied research is being initiated by FHWA.

New series of tools including expert systems as one component are in the planning phases. One example of such a hybrid system is a voice actuated tool to assist with freeway or highway incident management. The system will provide an environment where interaction between the system and the user will approach natural language dialogue between two individuals with knowledge of incident management. The system will both advise the user and build the required record of the incident during the dialogue.

Two areas of opportunity that are not receiving adequate attention are expert systems as training aids and intelligent data bases. The potential for such systems is great interest is increasing, especially in intelligent data bases. An intelligent data base is defined as having the built in capability to reason about and draw conclusions about its contents. This will usually be accomplished using an artificial neural network or expert system with appropriate inferencing capabilities. A limited family of commercial databases are currently available with built in intelligence.

For a variety of reasons, not all of which are technical, expert systems have not achieved their potential in highway engineering and operations. However the outlook for expert systems is quite optimistic.

References

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(6) AVIGNON91, Eleventh International Conference on Expert Systems and their Applications, Avignon, France, May 1991.

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TABLE 2.1 - REPORTED EXPERT SYSTEMS

CATEGORY FUNCTION	a) diagnosis/ monitoring	b) interpretation/ classification	c) prediction/ forecasting	d) design/ planning
I. Traffic Monitoring and Control	7	6		4
II. Traffic Impact and Safety	4	9	3	3
III. Highway Design and Analysis	2	5		16
IV. Highway Management	24	8		5