AN APPLICATION OF A KNOWLEDGE BASED EXPERT MODELING PROCESS FOR SMALL TO MEDIUM SIZE TRANSIT SYSTEMS

National Urban Transit Institute

at the University of South Florida's Center for Urban Transportation Research

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16. Abstract

Many urban communities in the southeastern United States will continue to experience periods of increased growth in population and land use development in the next 10-20 years. With this, there will be corresponding increases and changes in demands on the existing urban transit systems based on many factors including ridership satisfaction. To remain viable, these transit systems have begun ridership satisfaction data collection efforts to aid both long and short term strategic planning (i.e., TALTRAN - Tallahassee, FL). The purpose of this project is to utilize the existing candidate models selected in FAMU-1 (1993-95) and replicate this assessment in a knowledge-base system to be used as a guide to system changes that will reflect the desires of the community.

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List of Abbreviations/Acronyms	
AHS	Automated Highway System
AI	Artificial Intelligence
ANNs	Artificial Neural Networks
ALRT	Advance Light Rail Tranist
ATIS	Advanced Traveler Information System
BP	Back Propagation
CATI	Computer-Aided Telephone Interview (Survey)
EARS	**E**xpert System for **A**ssessing **R**idership **S**atisfaction
FAMU	Florida A&M University
FHWA	Federal Highway Administration
FOIL	A computer learning program
GUI	Graphical User Interface
HASP	Human Associative Processor
HOVs	High Occupancy Vehicles
ITS	Intelligent Transportation System
IVHS	Intelligent Vehicle Highway System
LRS	Light Rail System
MIKE	Micro Interpreter for Knowledge Engineering
MOEs	Measures of Effectiveness
REGIME	Computer Model Used to Estimate Evaluation Criteria
ROUGH	A Commercial Learning System
TALTRAN	Tallahassee Transit System
VLSI	Very Large Scale Integration
FOCL	A computer learning program
VP-EXPERT	An Expert Computer Learning Shell

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AN APPLICATION OF A KNOWLEDGE BASED EXPERT MODEL PROCESS FOR SMALL TO MEDIUM SIZE TRANSIT SYSTEMS

ABSTRACT

Many urban communities in the southeastern United States will continue to experience periods of increased growth in population and land use development in the next 10-20 years. With this, there will be corresponding increases and changes in demands on the existing urban transit systems based on many factors including ridership satisfaction. To remain viable, these transit systems have begun ridership satisfaction data collection efforts to aid both long and short term strategic planning (i.e., TALTRAN - Tallahassee, FL). The purpose of this report is to utilize the existing candidate models selected in FAMU-1 (1993-95) and replicate this assessment in a knowledge-based system to be used as a guide to system changes that will reflect the desires of the community. The results of this project were the development of an expert system entitled Expert system for Assessing Ridership Satisfaction (EARS).

Executive Summary

Ridership satisfaction modeling has the potential to have a comparable impact as the jet engine had on aviation 45 years ago. Simulation, analysis, modeling and the necessary queries may be used to establish process/techniques for comparing and evaluating ridership satisfactions efforts.

An exhaustive search was conducted to access a wide range of all knowledge base model which may be applicable to reducing the cost of an assessment. Twenty three applications to transit/transportation were found in the review. They were grouped into four descriptive categories for ease of understanding. The descriptive categories were a) fuzzy logic and fuzzy sets, b) neural networks, c)artificial intelligence, d) intelligent transportation systems, e) other. There were many techniques noted in the search such as case-base reasoning, model-base reasoning, artificial neural network, computer vision, fuzzy logic and other knowledge-base systems.

The efforts of this research were to address the problems that many urban communities in the southeastern United States will be experiencing (periods of increased growth in population and land development) in the next 10-20 years. With this, there will be corresponding increases and changes in the demand on the existing urban transit systems based on many factors including ridership satisfaction. To remain viable, these transit systems have begun ridership satisfaction data collection efforts to aid both long and short term strategy planning. Additionally, this research evaluated existing models that considered ridership satisfaction for small to medium size transit systems and use this assessment as a guide to system changes that will reflect the desires of the community.

This project was developed as a follow-up to a previous study (Wright & Taylor 1995). In that study an urban model evaluation for small to medium size transit systems was performed. The result of that effort was a technical report that presented the analysis of the models in use. A logical follow-up to that research was to assess the selected models and similar activities utilizing computer technology. This project focuses on the applicability and use of computer technology in assessing changes associated with ridership satisfaction.

The past research identified primary problems and assessed the use that guided local strategies and decision making techniques for local areas. The selected models were useful to transit researchers, officials of transportation agencies, state and local transportation planners, transportation engineers and transit management personnel.

The researchers looked for various expert systems that may already be in existence. Simultaneously they considered the options of goal programming, fuzzy logic and developing an expert system. Due to the prohibited time and additional cost of such an endeavor it was determined that, if possible, an existing expert system could be modified and used.

In selecting the most appropriate means of assessing ridership satisfaction, transit planners in small to medium size transit systems were interviewed as to their preference for the most effective method of evaluation customers' satisfaction. These transit planners were queried as to what methods they presently use, if any and what they would like to see as a tool for assisting them in the assessment. There was agreement that any method selected would have to be (1) user friendly, (2) accurate, and (3) cost effective. User friendly was described as a system that could be readily used by transit planners with little or no programming or mathematical expertise beyond statistical methods.

It was decided that although fuzzy logic would be very accurate by itself, it would not be readily adaptable by non mathematicians. And it was also determined that goal programming would not be appropriate for non linear programmers. It was decided that the choice is to use an existing user friendly "expert shell." There exists expert shell software that can be used in a personal computer (PC). The expert system is a means of using machine learning that can be used by a transit planner with little or no previous programming experience. These conclusions led the researchers to the search and development of an expert system for assessing ridership satisfaction (EARS).

Introduction

Ridership satisfaction is of primary importance to the transportation industry. Tom Peters and R. Waterman point out In Search of Excellence the importance of "staying close to the customer". Riders or potential riders are seeking methods of daily travel that will fit their personal needs and schedules. In small communities riders often will opt to use their cars as their primary form of transportation especially to and from work. Transit system costs are continually rising and the need for more riders is very crucial. Federal subsidies are decreasing and increased ridership is necessary for the survival of these systems. Local taxes and higher fares are not always publicly acceptable options especially if the existing ridership are not satisfied.

The riders or potential riders are more demanding in their expectations of local transportation systems. The transit system must be more responsive to customer needs in a timely manner. This includes making route changes, scheduling, ease of transfers, driver courtesy and safety.

The use of methods of responding to customer needs is of high priority. According to Albrecht and Zemke (1990) " the key success factor, where the service system is concern is the customer friendly system". Transit systems that are able to accurately and expeditiously make adjustments will most likely have higher ridership levels. This research is directed toward giving the transit planner another tool to keep track of their rider's needs.

With the increased governmental accountability of tax dollars expended, performance data for transit systems and evaluations of consumer satisfaction etc. Reliable data is necessary for the efficient operations of a transit system. The continued roll back in federal transportation dollars to the state and local transit agencies have made it imperative that transit systems operate in a highly efficient manner.

One way for transit systems to reach this level of efficiency is through the use of the latest electronic medians. ITS and personal computers, have opened the door for small to medium size transit systems to become more efficient. Prior to this, most electronic and computer equipment was too costly to purchase or use. Now there are many on the shelf programs that can be used for everything from vehicle maintenance, scheduling personnel, and route scheduling. The manager of tomorrow must not only be computer literate but must be innovated and forward thinking to maximize the use of these electronic tools.

Transit systems especially small to medium size systems can no longer afford to ignore the "wave of the future".

Further, experts frequently differ in their estimates of ridership satisfaction techniques associated with an assessment, but most agree it is necessary. There are those who believe that assessment techniques should address only the riders' attitudes who are presently using the system. While others believe that some assessments should actually utilize potential riders. However, all agree that the assessment should be cost effective and utilize techniques to reduce burdens on the populace while generating results that will be beneficial in the decision-making process (guide decision making). After reviewing the existing models, the researchers determined that the expert choice system would meet these criteria.

Review of Literature: Knowledge-Based Models

The research and literature related to this study include a number of sections. The objective of this review was to find the most appropriate model for use by small to medium size transit systems in evaluating customer satisfactions. The first section of this review summarizes the literature related to the Knowledge based models that are operational in various transportation modes. These knowledge base models are grouped into descriptive categories for ease of understanding. The next section gives a brief description and overview of how each of the above mentioned knowledge base models have been used in transportation related activities.

An extensive search for a wide range of knowledge-based models that are operational in various transportation modes was conducted. The objective of this search was to find the most appropriate model for use by small to medium size transit systems in evaluating customer satisfaction. The following exhaustive summary of knowledge-based models is grouped into descriptive categories for ease of understanding are as follows: A. Fuzzy Logic and Fuzzy Sets; B. Neural Networks; C. Artificial Intelligence; D. Intelligent Transportation Systems; E. Other. The "other" category consists of additional models reviewed that do not lend themselves to any of the previously general grouping.

A. Fuzzy Logic & Fuzzy Sets

a) Fuzzy Fundamentals

b) Improved Freeway Incident Detection Using Fuzzy Set Theory

c) Fuzzy Logic and Embedded Control Motorola Background Information

B. Neural Networks

a) Applications of Artificial Neural Networks to Intelligent Vehicle-Highway Systems

b) Characteristics of Random Nets of Analog Neuron-like Elements

c) "Neural" Computation of Decisions in Optimization Problems

d) Electronic Implementation of Associate Memory Based on Neural Network Models

e) A Model of Human Associate Behavior Processor (HASP)

f) Neocognitron: A Neural Network Model for a Mechanism of Visual Pattern Recognition

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D. Intelligent Transportation Systems

a) Models of Commuters' Information Use and Route Choice: Initial Results Based on Southern California Commuter Route Choice Survey

b) Criteria and Methods for Evaluating Intelligent Transportation System Plan and Operational Tests

c) Regional Approach to Strategic Intelligent Vehicle Highway System (IVHS) Planning in Orange County

d) Urban Rail Corridor Control Through Machine Learning: An Intelligent Vehicle-Highway System Approach

E. Other Related Concepts

a) Advanced Public Transportation Systems: The State of the Art Update '92
b) Workbook for Estimating Demand for Rural Passenger Transportation
c) Synthesis of Practice Planning for Small and Medium-Sized Communities
d) Transit: An Innovation in Public Transportation

Fuzzy Logic & Fuzzy Sets

The first descriptive category reviewed was fuzzy logic and fuzzy sets. Fuzzy logic is a method of easily representing analog processes on a digital computer. These processes are concerned with continuous phenomena that are not easily broken down into discrete segments, and the concepts involved were difficult to model conventionally with mathematical or rule-based lines. Once the fuzzy model had been constructed, the process of simulation and proto cycling begins. In this adjunct to the methodology, the model was compared against known tests to validate the results. When the results were not as desired, changes were made either to the fuzzy set descriptions or to the mapping encoded in the rules. Tools were available to help project managers and system designers evaluate fuzzy set or rule level. These tools measure such factors as the statistical compatibility between the model and test-bed data and the stability of the model based on a loss of information. In general, a methodology will only be as good as the designer's understanding of the problem.

Changa and Wang (1993) reported that freeway incidents often occur unexpectedly and cause undesirable traffic congestion, mobility loss and environmental pollution with computerized traffic management systems in operation. Automatic incident detection, being one of the primary functions of computerized freeway traffic management systems, must be able to detect all freeway incidents instantly with minimum false alarms.

This study evaluated the applications of fuzzy set theory for improvements in existing incident detection algorithms. The potential system performance was compared with that of conventional systems using real world volume and occupancy data that were collected earlier. Further, this study explored the use of fuzzy logic to improve the operations of California Incident Detection.

The fuzzy rules represented by the linguistic in fuzzy set systems were much easier to understand and debug than the set rules that were commonly used in the non-fuzzy conventional approach. Fuzzy systems are also easier to maintain and adjust to various traffic control environments. Because different operating states can be used to represent degrees of severity of the freeway incidents, fuzzy rules can be grouped to simplify the operating states with similar behavior in the decision tree analysis. These simplified rules can further improve future operational efficiency and maintenance of fuzzy systems.

However, the performance of incident detection systems depended on how to generate suitable "threshold values" or "membership functions" in the fuzzy systems. Changa and Wang noted two problems that existed with the use of fuzzy reasoning: lack of methods to determine proper thresholds and lack of automatic learning functions or adaptability in the algorithm.

Neural Networks

Fuzzy logic was mentioned in the same breath as another technology, neural net computing. The two have some fundamental characteristics in common and should be viewed as complementary. In brief, neural nets are arrays of interconnected processing nodes, called neurons, loosely modeled on biological nerve cells. Each neuron receives one or more inputs, which multiply by so-called weighing factors and sum together to produce an output. Neurons were arranged in layers, with the first layer receiving primary inputs then passing its output to a second layer. Second layer neurons perform their own weighing and summation and so on until a final output was produced.

Of primary importance, the network was designed so that they were self modifying. If the final output was incorrect, the system adjusted the weights applied to each input to produce a new result; this was done in accordance with certain training algorithms. The training process was interactive: input data was run through the network repeatedly and each time the weights were tuned to improve the result. Eventually the desired output was achieved. In this way neural nets learn from experience.

Neural nets are said to be "data driven": presented with a mass of data, the net itself derived a solution to a problem. Neural nets were good at sorting through complex data and finding underlying patterns or rules. Their many practical applications include pattern recognition database search and retrieval and image processing.

Hya (1993) evaluated the potential applications of artificial neural networks (ANNs) to intelligent vehicle-highway systems (ITS) and the extent of use and the position of ANNs in future ITS implementations. Amari (1972) reported on the dynamic behavior of randomly connected analog neuron-like elements that processed pulse-frequency modulated signals that were investigated from the macroscopic point of view. The most interesting feature of random nets seems to be that the stability changes with the average threshold H or h which can be controlled by other networks. In this connection, random analog type nets have similar structures to those of digital type without any refractory period. This fact seems to show that the non-linear character of the output function is essential ،or the preceding characteristics of random nets, and the existence of the refractory period was responsible for them only through the non-linear character of the output function.

Hopfield and Tank (1985) found that highly-interconnected networks of nonlinear analog neurons were shown to be extremely effective in computing. The networks rapidly provided a collectively-computed solution (a digital output) to a problem on the basis of analog input information. Moopenn (1987) described an electronic embodiment of a neural network model in which the synaptic network takes the form of a binary connection matrix. In understanding brain functions, Hirai reported (1983) that one should always keep in mind that our brain consists of neural networks, and what the brain can perform depends on the structure of the networks. Our memory was characterized by its associative, distributed, and content addressable structure. To represent associative brain functions in terms of such structures, a model of an associative processor named HASP was proposed and its performance as associative memory was described.

Fukushima (1983) demonstrated in his research that the neocognitron recognized handwritten numerals of various styles of penmanship correctly, even if they are considerably distorted in shape. Although, the result was shown for the recognition of Arabic numerals, the neocognitron can be trained to recognize other sets of patterns, such as alphabets, geometrical shapes, and others.

Tank & Hopfield (1986) demonstrated how interconnected networks of simple analog processors can be used to solve decomposition decision problems and linear programming problems. Also, Tank & Hopfield demonstrated that for "simple" computational tasks and well-defined initial conditions, the networks can sometimes be guaranteed to find the global optimum solution. The major advantage of these architectures is their potential combination of speed and computational power.

Lippman (1987) reported that the greatest potential of neural nets remains in the high speed processing that could be provided through massively parallel VLSI implementations. Smith and Demetsky (1993) reported that much of the current activity in the area of intelligent transportation systems (ITS) focused on one simple objective: to collect more data. Clearly, improvements in sensor technology and communication systems allowed transportation agencies to more closely monitor the condition of the surface transportation system.

ITS technology allows for vastly improved data collection and data communication capability. However, a very real risk is that the world will become data rich and information poor. Thus, a critical effort in the development of ITS was to create real-time decision support software that relied on advanced technology, such as expert systems and models. A critical element of such support software that has been identified in this paper was a short-term traffic condition prediction model. This paper has demonstrated the potential of neural networks to accurately predict short-term traffic conditions in real time. Ang'eniol (1988) developed a study base on Kohonen's work on self-organizing feature maps, an algorithm for solving the classical traveling salesman's problem.

Artificial Intelligence

The third category of knowledge base expert modeling processes is artificial intelligence (AI). AI includes such techniques as computer vision, model-base reasoning and case base-reasoning. Other concepts such as expert systems, Artificial Neural network are Techniques that can fit into all five knowledge-base category. Mullholl and Oren (1994) presented the results of an evaluation of seven AI techniques, which may be applicable to the diagnosis of malfunctioning transit railcar systems and subsystems. The seven AI techniques were expert systems, case-based reasoning, model-based reasoning, artificial neural networks, computer vision, fuzzy logic, and knowledge-based systems. These techniques were chosen for evaluation because they have already shown potential for performing diagnosis in other industries and operations. With the exception of computer vision, all of the AI techniques were found to be appropriate for use in railcar systems diagnostics. A criterion based on maintenance operational requirements was developed to prioritize the AI techniques.

The concept of Automated Highway System (AHS) was a surface transportation system program that used modern electronics to instrument highways and vehicles to provide "hands-off" and "feet-off" vehicle operation Stevens (1993). Research to date shows that AHS had the potential to double or triple the nation's highway efficiency and to dramatically increase highway safety. The impact of AHS on the nation's highways was comparable to the impact the jet engine had on aviation 40 years ago. FHWA has established an AHS program that (a) identified and analyzed alternative AHS concepts and (b) demonstrated the potential feasibility of AHS in 1997.

Intelligent Transportation Systems

The fourth category of modeling process is noted as intelligence transportation systems. These systems made use of electronic data manipulation effort to decrease the manpower needed to process vast amounts of collective information. An example of this effort is the model of commuters information use in route choice etc..

A Computer Aided Telephone Interview (CATI) survey carried out as part of a research project at UC Davis was used by Abdel-Aty (1993). This survey was designed to gain a basic understanding of the drivers' route choice behavior, to collect detailed information about their commute routes and to explore how commuters use traffic information to decide on what route to travel to work.

Bivariate probit models were developed to determine the factors that influence information used and the propensity to use alternative routes. The models showed the significant influence of income, education, frequency of driving to work, and listening to traffic reports on the commuters' route choice. Negative binomial models were developed to assess a commuter's frequency in changing routes. Two models were developed: the first modeled the number of route changes per month on the basis of pre-trip traffic reports, and the second modeled the number of route changes per month on the basis of en route traffic reports.

At least two important directions for future research was suggested by the findings of this study. The first direction was methodological in nature. There was a need to develop a final procedure for estimating simultaneously with the commuter's choice to use information and the frequency of route changes. The second direction related to the need for information on the specific routes used by travelers. Such information was to include highway geometries, signal timings, and the temporal distribution of traffic.

Brand (1993) developed a criteria and method for evaluating intelligence transportation system plan and operational Tests. This evaluation process used in the preparation of Intelligent Transportation System (ITS) plans sensitive to the differences between ITS and conventional transportation improvements. A relatively complete set of evaluation criteria for ITS improvements was presented and structured to clarify the confusion between the supply and demand impacts of ITS. This separation between "efficiency" and " output" measures means that one must distinguish between ITS technology supply and efficiency benefits. The criteria and default values highlighted where research and operational tests can provide improved values and information that will most quickly advance the state of the art of ITS evaluation.

Further, ITS plans and operational tests were developed and evaluated in a way that was sensitive to the differences between ITS and conventional transportation improvements. They were developed by recognizing the separate supply (efficiency) and demand (increased output) impacts of ITS and avoided dramatically underestimating the benefits of the new technology. The methodology and criteria presented in this paper provided the required structure and default values to evaluate ITS improvements for inclusion in transportation system plans. The criteria and default values provided also highlight where research and operational tests provided improved values and information that most quickly advance the state of the art of ITS evaluation.

Harinoviski (1993) developed a framework under which advanced technologies were deployed to improve the operation of Orange County, California highway and public transportation systems. The most significant challenge of the study was to reconcile an overall high-level transportation vision with the needs, concerns, responsibilities and financial limitations of all the local and regional agencies. The process used to develop a regional strategic plan was described and a review of the required areas of emphasis in developing such a plan was discussed.

Although the program emphasis was oriented more to the near term, the architecture developed in the study was highly appropriate for support of efforts toward in-vehicle navigation devices and automated vehicle control and efforts that are integral to the overall direction of the program. Thus, the nature of this regional strategic plan has been to emphasize the practicality of implementation as a key criterion.

Khasnabis (1993) noted that traffic c control along an urban rail corridor with closely spaced stations can be considered a sequence of decision-making stages. A train on an urban rail corridor that connects two terminal points with a number of intermediate stations can follow various regimes of moving and stopping, which identify individual driving scenarios. The learning algorithm was based on the theory of rough sets. The feasibility of machine learning in automated knowledge acquisition to develop decision rules for complex engineering problems (i.e., urban rail corridor control) was demonstrated.

The objective of this paper was to explore the concept of knowledge acquisition through inductive learning to establish decision rules for an urban area. The study demonstrated the feasibility of using machine learning in automated knowledge acquisition about complex engineering problems such as urban rail traffic control.

The rules developed were based on three separate evaluation criteria: passenger comfort, travel time, and energy consumption. Additionally, a set of rules was developed with all the three attributes combined. Machine learning in rail traffic control was new, complex and interdisciplinary research, and more work was needed to determine a better understanding of the problem and to prepare a program that would lead from research to practical application of results.

Other Related Concepts

The final grouping was the other category of knowledge-base expert modeling techniques. Labell (1992) documented a limited investigation on the extent and adoption of advanced technology in providing public transportation services in North America. The report was an update to a similar report published previously (May 1991). The report was not an exhaustive search of every city or transit authority, which have tested, planned, or implemented an advanced technology concept. Rather the focus was on some of the most innovative and comprehensive implementations categorized broadly during four different types of an operational test: Market Development, Customer Interface, Vehicle Operations and Communications, and High Occupancy Vehicle Facility Operations. The goal of market development projects was to increase the utilization of high occupancy vehicle modes. Providing travelers, especially regular commuters, with traffic and transportation service information prior to embarking on their trips would allow travelers to make the most informed choices of modes and routes. The Workbook for Estimating Demand for Rural Passenger Transportation by SG Associates, Inc. (1995) provided demand estimation methodology which treated separately two distinct types of passenger transportation demands. These types are program-related demand-trips that would not occur but for the existence of specific social service program activities and non-program-related demand that include all other trips. Program-related demand was estimated as a function of program enrollment.

The methodologies contained in the final report and in this workbook enabled agencies to prepare consistent estimates of the demand for passenger transportation services in rural areas. The methods proved useful not only to local agencies involved in the operation of services but also to the state agencies engaged in the administration of funding programs and the preparation of state transportation plans.

The synthesis of practice for small and medium-sized urban areas presented twenty-six (26) case studies in four distinct topical areas of a) assessing growth effect, b) assessing data collection and management information system, c) assessing public transportation services, d) assessing programming financial and communication with decision makers.

The objective of the synthesis report was to provide transportation practitioners, who are responsible for delivering transportation services and planning with case study examples of effective planning approaches toward solving local transportation problems. This synthesis report did not imply endorsement of any particular technique, but only attempted to stimulate thinking about a particular approach.

Nisar and Khan (1992) presented analysis results based on actual service and cost information. The report provides further insights in the comparative assessment of bus transit-way and LRT-based systems for medium-sized urban areas in terms of level of service, cost efficiency, and cost effectiveness criteria achievements levels. These achievements' levels were transformed into relative values on a scale from zero to one and then weighed by the importance of criteria.

Research Design

The researchers of the previous research noted that goal programming was perhaps the optimum model for evaluating customer satisfaction. However, a closer evaluation or goal programming revealed the imitation requiring only a mathematician or equal to alter the program. As a result of this limitation, the researchers sought to find or develop a model that would be more user friendly and easily adapted or changed as needed by the user (e.g., transit planner). The planners, especially in small to medium size transit systems, most often will have limited programming nor high level mathematical expertise.

The researchers looked for various expert systems that may already be in existence. Simultaneously they considered the options of goal programming, fuzzy logic and developing an expert system. Due to the prohibited time and additional cost of such an endeavor it was determined that, if possible, an existing expert system could be modified and used.

After reviewing the various decision making models in existence the researchers determined that many of those models were appropriate. The researcher however, concluded that most useful models include either: (1) goal programming models, (2) fuzzy logic, or (3) an existing expert shell. These three models appear to have the most compelling attributes to accomplish the task at hand: assessing ridership satisfaction.

In selecting the most appropriate means of assessing ridership satisfaction, transit planners in small to medium size transit systems were interviewed as to their preference for the most effective method of evaluation customers' satisfaction. These transit planners were queried as to what methods they presently use, if any and what they would like to see as a tool for assisting them in the assessment. There was agreement that any method selected would have to be (1) user friendly, (2) accurate, and (3) cost effective. User friendly was described as a system that could be readily used by transit planners with little or no programming or mathematical expertise beyond statistical methods.

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Development of an Expert System for Assessing Ridership Satisfaction (EARS)

Expert Systems

An expert system is a set of computer programs that solve problems in a specialized domain that usually requires human expertise (Patterson, 1990). Expert systems differ from conventional computer systems in several ways:

- Expert systems use knowledge rather than data to control the solution process. The knowledge usually is heuristic rather than step-by-step procedures.

- The knowledge is encoded separately from the program that uses the knowledge. This allows the possibility to represent the knowledge in a more natural fashion which also makes it easy to modify the expert system to improve its performance.

- Expert systems can explain how a particular conclusion was reached, helping a user understand and assess the system's performance for knowledge. Expert systems use symbolic representations for knowledge that closely resemble natural language.
- An expert system can reason about its own knowledge; that is, an expert system knows the limits of its knowledge.

Expert systems have been built to solve a range of problems. Applications can be found in mathematics, medicine, engineering, chemistry, geology, computer science, and education. Example applications are as follows:

- Scheduling of customer orders and various manufacturing tasks
- Planning experiments in biology and molecular genetics
- Diagnosing of complex electronic systems
- Forecasting crop damage

Developing a process for EARS

In developing EARS, we used the typical software life-cycle for expert system development. The development phase contained several stages: (See Figure 1)

1. Problem analysis
2. Problem formalization
3. Knowledge acquisition
4. Knowledge representation
5. Prototype development
6. Full system development
7. System evaluation and documentation

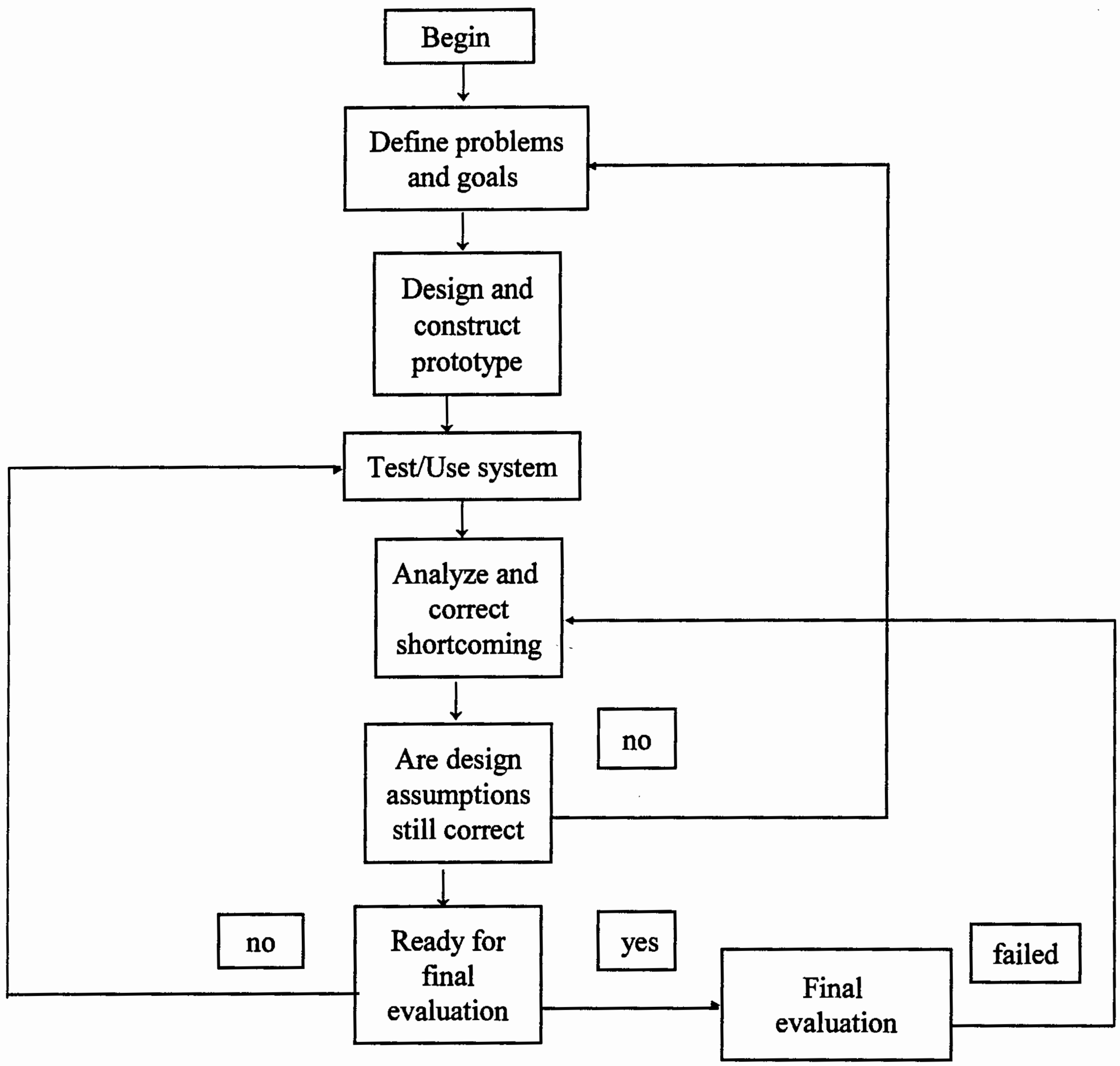

Figure 1: Typical Software Life Cycle

Problem Analysis

The problem analysis stage involves determining whether the problem is appropriate for expert system development. During this stage we evaluated the need for EARS using the following criteria:

A) Does the needs justify the cost and effort?

It was determined that considerable savings could be made because one program would be able to do the work of many experts. Over the long run, the initial cost of development would be recovered through these saving.

B) Human expertise is not available in all situations

What happens when the expert planner retires, takes another job, or is no longer available to continue plans with the transit system? This could mean a slight disruption in the planning activities of the organization. We determined that when human expertise is not available, EARS could help the current decision-makers function in a fashion close to the level available with the human expert.

C) The problem domain well structured

Transit planning is well studied; the terms in the field are well defined, and there exist some clear conceptual models for the field. Some well structured domain places boundaries on the amount of information needed to model the domain with an expert system.

D) Experts exist

Experts are available that can provide the knowledge that will be placed in the expert system.

Problem Formalization

During problem formalization the basic structure of the expert system is designed. The kind of problem the system will solve often determines the structure of the system. Following is a partial list of the types of problems that have been solved with expert systems.

Interpretation - forming high-level conclusions or descriptions from raw data.

Diagnosis- determining the cause of a malfunction.

Prediction- projecting probable consequences.

Design- determining a configuration of system components that meets certain performance goals.

Planning- devising a sequence of actions that will achieve a set of goals.

Assessing ridership satisfaction is an Interpretation problem. The expert system EARS will have to form a conclusion about ridership satisfaction based on limited data and using the experience drawn from human experts. The user will use the conclusion drawn from EARS, an architecture suitable for solving Interpretation problems (See Figure 2).

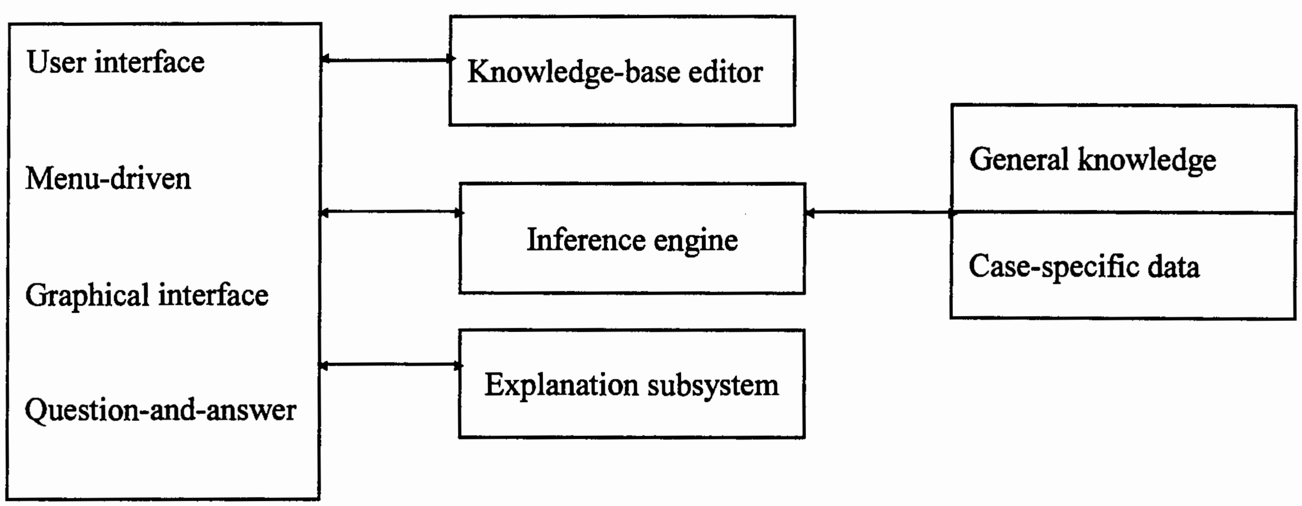

Figure 2: EARS Architecture

Developing this type of architecture from "scratch" today is not necessary. All one has to do is find an expert system shell and then give the shell details of the problem domain: we used this approach for developing EARS. The first task, of course, was to select an appropriate shell. The task of selecting a shell is not trivial, considering the number of shells on the market. We narrowed the possibilities by first considering only those shells that were in the public domain, inexpensive or free. Please note that today, expert system technology has advanced to a point where many low-cost shells rival some commercial shells in quality and performance. Our goal allows for upgrading to a commercial shell in the future, if necessary.

We considered several shells before and machine learning programs written in Common Lisp. The machine learning program extends Quinlan's FOIL program by containing compatible explanation-based learning components. FOCL learns Horn Clause programs from examples and (optionally) background knowledge. The expert system includes a backward-chaining rule interpreter and a graphical interface to the rule and fact base.

BABYLON is a development environment for expert systems. It includes frames, constraints, a prolong-like logic formalism, and a description language for diagnostic applications. It is set up in Common Lisp and has been ported to a wide range of hardware platforms.

MOBAL is a system for developing operational models of application domains in a firs. order logic representation. It integrates a manual knowledge acquisition and inspection environment, an inference engine, machine learning methods for automated knowledge acquisition, and a knowledge revision tool. By using MOBAL's knowledge acquisition environment, the possibility to incrementally develop a model of your domain in terms of logical facts and rules. You can inspect the knowledge you have entered in text or graphics windows, augment the knowledge. or change it at any time. The built-in inference engine can immediately execute the rules you have entered to show you the consequences of your inputs or answer queries about the current knowledge. MOBAL also builds a dynamic sort taxonomy from your inputs. If you wish, you can use several machine learning methods to automatically discover additional rules based on the facts that you entered or to from new concepts. If there are contradictions in the knowledge base due to incorrect rules or facts, there is a knowledge revision tool to help you locate the problem and fix it. MIKE (Micro Interpreter for Knowledge Engineering) is a full-featured, free, portable software environment designed for teaching purposes at the UK's Open University. It includes forward and backward chaining rules with user-definable conflict resolution strategies and a frame representation language with inheritance and "demons" (code triggered by frame access or change), plus user-suitable inheritance strategies. Automatic "how" explanations (proof histories) are provided for rule execution, as are user-specified "why" explanations. Coarse-grained and fine-grained rule tracing facilities are provided, along with a novel "rule graph" display which concisely shows the history of rule execution. MIKE, which forms the kernel of an Open University course on Knowledge Engineering, is written in a conservative and portable subset of Edinburgh-syntax Prolong, and is distributed as non-copy-protected source code.

All of these may have been sufficient for implementing EARS: each contains most of the desirable properties of expert system shells. The main drawback, to these shells, however, is that they appear to be designed for someone familiar with computer programming, with the inner details of expert system. VP-Expert, on the other hand, does a good job of shielding the developer from these unnecessary details. This shell offered all of the features we felt were necessary for achieving the goals of EARS.

1) GUI (Graphical User Interface)
2) Forward and backward chaining
3) Confidence factors
4) Support for databases and spreadsheets

The next section provides an overview of the VP-Expert, giving a description of each of the features listed above.

Knowledge Acquisition

The next step in the development of EARS was the knowledge acquisition phase, also known as knowledge engineering. In this stage a knowledge engineer gathers from the experts the information that will be placed into the expert system, the knowledge that will give the system intelligence. This knowledge is placed into the knowledge base and will interact with other components of the expert system as described in the diagram in section

The **Interview** is the technique most often used to acquire knowledge during the knowledge engineering phase. The goal is to elicit knowledge from the expert and examine the expert's thought processes. For developing EARS knowledge base, we used a panel of three experts on transit planning and ridership satisfaction. During the interview the experts were asked to explain the most important information they use in assessing ridership satisfaction. Five key areas were gleaned from the initial interviews: Safety, Effectiveness, Comfort, Customer-Oriented, and Dependability.

From the initial interview, we set out to refine the knowledge gained about the key areas. Refinement was done by presenting the experts with "what If" scenarios. The experts were asked questions, such as: "What is an example of an ineffective transit system?", "Is a bus uncomfortable if the temperature on the inside of the bus reaches 80 degrees in the summer?".

The initial interview produced an initial, unrefined knowledge base, and it was determined that the expert system EARS would provide an evaluation based on the four key areas identified. Figure 3 shows how EARS will rate the ridership satisfaction based on the key areas.

The five key areas were subdivided into five evaluation categories. The categories identified levels of effectiveness or ineffectiveness from Very , Somewhat and Very Safety and Dependability rated very high among the ridership satisfaction criteria.

EFFECTIVENESS:	**CUSTOMER-ORIENTED:**
1=Extremely Ineffective	1=Not customer-oriented
2=Somewhat Ineffective	2=Somewhat unresponsive to
3=Effective	3=Moderately customer oriented
4=Moderately Effective	4=Customer oriented
5=Very Effective	5=Very customer-oriented
COMFORT:	**SAFETY:**
1=Very Uncomfortable	1=Very Unsafe
2=Somewhat Uncomfortable	2=Somewhat Unsafe
3=Moderately Comfortable	3=Safe
4=Comfortable	4=Somewhat Safe
5=Very Comfortable	5=Very Safe
DEPENDABILITY:	
1=Not very Dependable	
2=Somewhat Dependable	
3=Moderately Dependable	
4=Dependable	
5=Very Dependable	

Figure 3: **Ridership Satisfaction Rate by EARS**

Knowledge Base

A knowledge base in an expert system contains all the facts and rules about a specialized domain and helps guide the system to a satisfactory solution of a problem. The knowledge contains all of the problem-solving information that a human expert would use when working on a problem in the domain. An expert system's knowledge is extracted from expert sources (books, humans, data bases, computer programs) and encoded in a knowledge base.

When designing an expert system, one must first decide, from the many possibilities, how the knowledge will be stored in the knowledge base. This is known as knowledge representation (Brachman, 1995). The various ways to represent information in a knowledge base include the following:

Semantic Network. Knowledge is stored using graph notation: nodes and links. Entities are represented using nodes in the graph, and a relationship between two entities are represented using a link. This form of representation is useful in depicting hierarchical knowledge structures (Sowa, 1984).

Frames. Each frame is a structure that contains information about a well understood, stereotyped situation or object, for example, a chair. A frame contains the object's name, the object's main attributes, and their corresponding values.

Decision Tree. Knowledge is stored in a treelike fashion, structured in a top-to-bottom manner. Initial and intermediate nodes in the tree represent the object attributes, and leaf nodes in the tree correspond to the identities of objects.

Blackboard Architecture. There are many knowledge sources, and each knowledge source may be thought of as a specialist in a limited area needed to solve a subset of the problem. A structure known as the blackboard contains the current problem state, and the knowledge sources make changes to the blackboard that incrementally lead to a solution to a problem (Erman, 1980).

Neural Network. Knowledge is encoded using a large network of nodes, which are simplified models of neurons. Knowledge is distributed throughout the network as connections and weighted links (Grossberg, 1988).

Production Rules Knowledge is encoded, as "if . . . then" rules. Each rule represents a small chunk of knowledge.

Each knowledge representation technique has its strengths and weaknesses. The particular technique to use for an expert system depends on many factors, including the application area for the expert system (e.g., medicine, geology), the anticipated size of the system, the developers, and the experts who will contribute the knowledge. Semantic networks and decision trees become quite cumbersome with large knowledge bases. Frames provide an excellent structure for organizing knowledge and have been used with other representation techniques. The main drawback detected, no standard methodology for using frames. Both the blackboard architecture and neural networks have been used in the design of many expert systems, due to their ability to simulate complex human behavior.

Production rules are perhaps the most common knowledge representation technique, and this was the representation we used for EARS. The "IF . . . THEN" format of the rules provides a natural mapping from the expert's knowledge to a representation in the computer. For our project, the knowledge base contains the knowledge, thought-processes, and all other useful information that a transit planning expert would use to assess and improve ridership satisfaction.

EARS knowledge base was constructed through a process known as knowledge engineering, a process where a human expert reveals his/her expertise about an area through extensive interviews and "what if" scenarios. To build our knowledge base we spent many hours of knowledge engineering, identifying the key elements used to assess ridership satisfaction, and determining how the various elements would work together to simulate the actions of a transit planning expert. Below are a few rules gleaned from our knowledge engineering process and stored in the final knowledge base; the complete knowledge base has about 50 rules. Some examples, include:

IF transfer_time = long THEN
    Transit_system = Ineffective.

IF public_information = not_visible THEN
    Transit_system = not_customer_oriented

IF bus_temperature = hot THEN
    Transit_system = uncomfortable

The first rule simply states that if the patrons of the transit system consider the bus transfer time to be too long, then the transit system was ineffective, not meeting the needs of the bus riders. The second rule states that if the transit system's public information was not visible to the patrons, then the system was not customer-oriented. Considering the inference engine, discussed next, was the program that ties the rules together and allows the system to simulate the behavior of an expert transit planner.

Inference Engine

The *inference engine* is the program that processes the knowledge base to solve problems by simulating the thought-processes and actions of a human expert. In the EARS system, the inference engine simulates a transit planning expert. The engine receives a problem from the user interface and uses the knowledge base to derive a solution to the problem. The inferring process consists of three stages: match, select, and execute. These stages are commonly called the recognize-act cycle. During the match stage, the current problem in the system's working memory is matched to one rule in the knowledge base. Rules that match are placed in a conflict set. One rule is then selected and executes action of the "THEN" part of the rule is carried out, possibly changing the contents of the system's working memory. The process is repeated until no rule matches the contents of the working memory, signaling a solution to the initial problem has been found.

The inference process can be viewed as a search through the rules to find a path to a solution to the problem. Recognizing the two ways to do this search, as follows: forward chaining and backward chaining (Winston 1992). With a forward chaining, sometimes called data-driven search, the inference engine begins with facts about the problem and then applies the rules to the facts to produce new facts. These new facts are then used by the rules to generate more new facts. This process continues until a path to the goal (solution) is found.

With backward chaining, sometimes called goal-driven search, the inference engine starts with the goal, or possible solution to the problem, and then determines which rules could be used to generate that goal. The condition of these rules, the "IF" part, becomes the new goals. Rules are then sought which could generate these new goals. The search continues until the engine works back to the data of the original problem. Backward chaining is the primary inference mechanism used in EARS, although tuning the system to use a limited form of forward chaining is possible.

User Interface

The *user interface* is the component of the expert system that interacts with the person using the expert system. The user interface provides a means for the user to present a problem to the expert system and displays any results that the system generates, any conclusions reached by the system. The user interface of the EARS uses a questionnaire presented to the user to gather the facts about the current transit system. The questionnaire asks for a summation of a survey presented to the patrons of the system. An interface is a GUI (Graphical User Interface); the questions are presented as dialog boxes, pull-down menus, and fill-in-the-blank forms. Below is a subset of the questions posed to the user by the user interface.

a) How long have you been riding the bus?

b) At what time do you ride the bus?

c) Rate the courtesy of the bus driver?

d) How easy is it to find out when and where the buses are running?

e) How well are you protected from sun, wind, and rain at the bus stop?

Prototype development

As mentioned previously, VP-Expert was chosen as the platform to develop EARS. In this section an overview of VP-Expert will be given showing features used to develop EARS.

Once VP- Expert is installed on an IBM compatible computer, it can be started with the command

C >vpx

This brings up the initial screen (See Figure 4: Screen 1).

VP - EXPERT

Version 3.1
© Copy right 1988-94

Press any key to begin

Figure 4: Screen one

The system is then ready to begin the expert system development. The initial screen is followed by the main screen (Figure 5: Screen 2). Which request rules and facts. The facts are determined utilizing the council of experts. Other information may be obtained from this screen.

The user presses the number corresponding to the function desired to perform the assessment. The "1" option displays help information about VP-Expert, displayed by categories to make it easy for a person to find a particular topic. The second option is for creating a knowledge-base automatically from a file of data. To create or modify a knowledge-base, the second option is used. Option four is for running an existing expert system. Options' five and six are for setting the name of the knowledge-base and its location. To end VP-Expert, choose option "eight."

The first step for EARS was to create the knowledge-base, the rules that will control the expert system. As mentioned above, option "3" is for editing a knowledge base. Note that in Figure 6 Below I part of the knowledge-base for EARS is shown in the VP-Expert editor. This knowledge base specify actions accompanied by four rules concluded with choices. The editor constitutes fundamentals effort in the development of EARS.

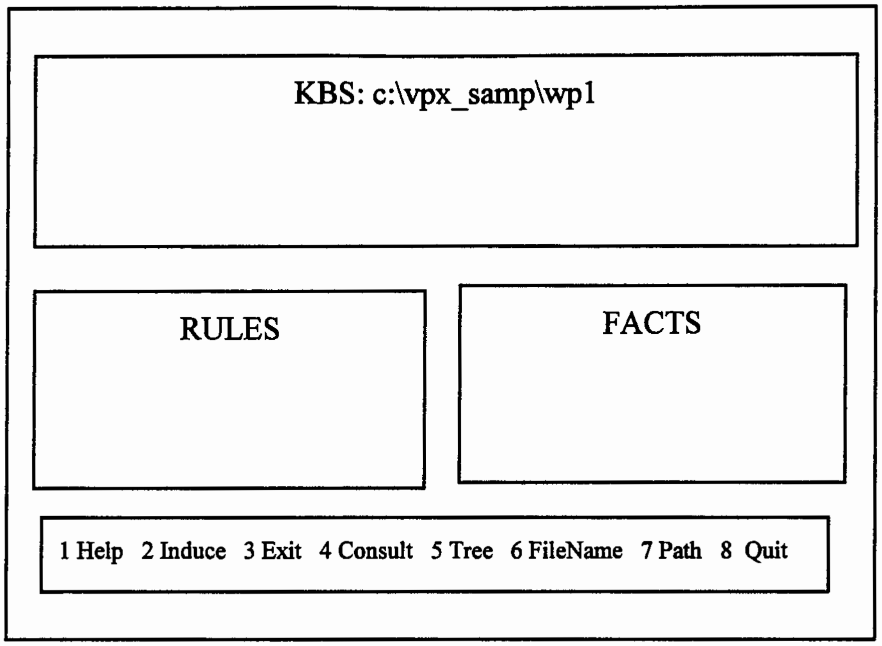

Figure 5: Screen two

```
ACTIONS
        DISPLAY "WELCOME TO EARS"
        CLS
        FIND Assessment

RULE 1
        If timeliness = slow THEN

        Transit_system = extremely_ineffective

RULE 2
        If bus_breakdown = frequent THEN

        Transit_system = extremely_ineffective

RULE 3
        If bus_temperature = hot THEN
        Comfort_level = uncomfortable

RULE 4
        If bus_cleanliness = CLEAN

ASK Timeliness: "is the bus usually on time?'

CHOICES Timeliness: slow, on time;

ASK bus_breakdown "Does the bus breakdown Frequently?"
CHOICES bus_breakdown: frequently, infrequently;
```

Figure 6: Knowledge Base for EARS

EARS: The user interface

As indicated in Figure 7, the user will interact with the expert system through its user interface. EARS has a menu-driven interface. When EARS is started, the screen noted (Screen 3) appears, directing the user to choose an option to begin the consultation.

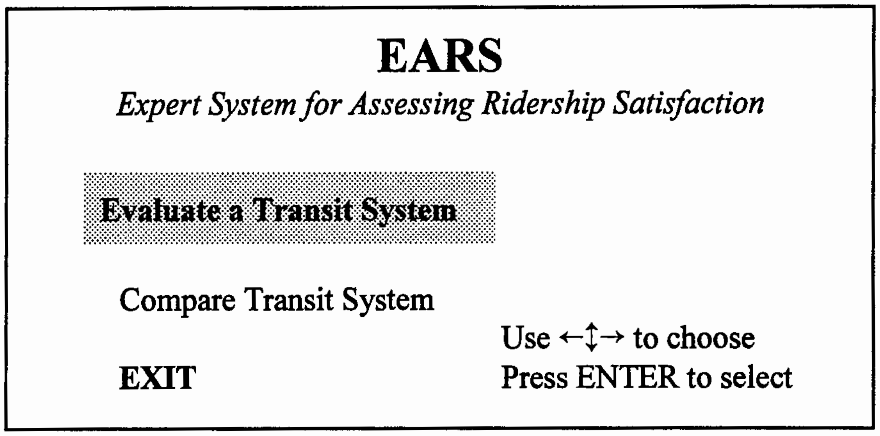

Figure 7: Screen Three

To make a choice, the user moves the highlighted block with the arrow keys and then presses the return key. If the user chooses the first option, Evaluate a Transit System, the following screen appears (Figure 8: Screen Four). This screen enter survey from a file, modify parameters and allow one to main menu

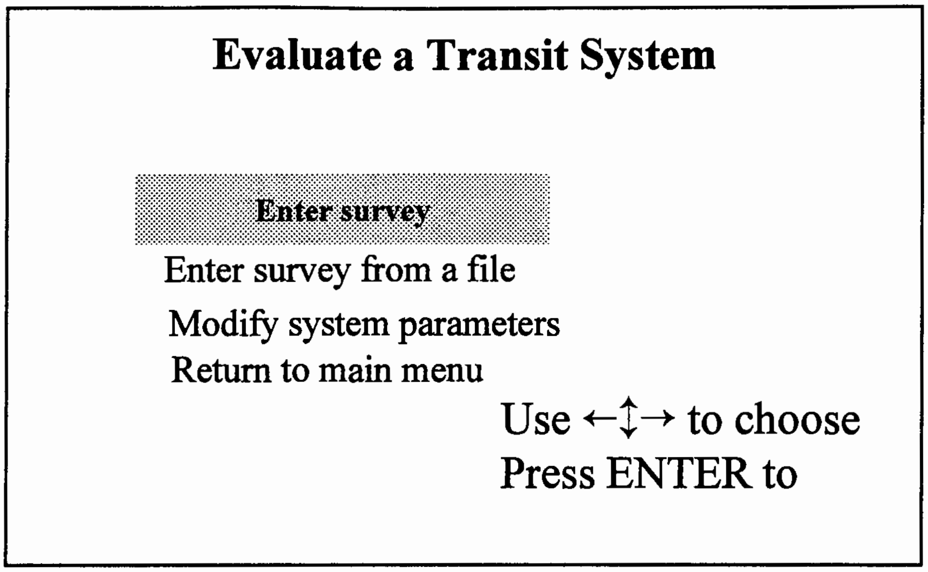

Figure 8: Screen four

An example of a simulated survey computer screen for EARS is noted in Figure 9. Only nine questions are included in the EARS questionnaire. The questions range from length of time using transit to destination and scheduling information.

WELCOME TO EARS

Expert System for Assessing Ridership Satisfaction

How long have you been riding the transit system? 0 - 1 year ☐ 1-2 years ☐ 3 - 5 years ☐ 6 or more years ☐

Why do you ride the bus (check all that apply)? Don't drive ☐ Don't have a car ☐ Save money ☐ Convenience ☐

How would you rate existing bus services? Excellent ☐ Good ☐ Fair ☐ Poor ☐

How would you rate bus equipment? Excellent ☐ Good ☐ Fair ☐ Poor ☐

How would you rate your driver? Excellent ☐ Good ☐ Fair ☐ Poor ☐

Are you concerned about safety on the bus? Yes ☐ No ☐

Are you concerned about safety while at bus stop? Yes ☐ No ☐

Is the driver courteous ? Yes ☐ No ☐

How easy is it to find out the destination and schedules of buses?

Difficult ☐ Fairly easy ☐ Very easy ☐

Figure 9: Sample survey screen for EARS

Limitations of Study

During the development period of EARS, there were limitations of the study. Noted are the following:

1) The Expert Choice System rules on the accuracy of the information provided.
2) An expert choice system is only a tool to assist in the decision making process.
3) This is no substitute for the reliable surveying of customer and potential customers' view of the transit system.
4) This system needs to be field tested with several transit agencies to assess its worth as a decision making tool.
5) The Expert System for Assessing Ridership Satisfaction (EARS) has not been sufficiently field tested with existing transit systems.

Further Research

Further, research is warranted on this topic with the present trend of utilizing systems to provide a more defined value upon which to base a decision. Six noted recommendation are made in the development of the concept.

1) EARS has no limitations to the number of rules that can be considered in an assessment. The idea of using EARS can be expanded for use in other decision making capacities within the transit industry.
2) Increase the knowledge base with more rules to improve the accuracy of the decision making process.
3) EARS needs to be field tested with several transit systems.
4) The knowledge base of EARS can be expanded by combining several knowledge representations in addition to the rules (i.e., frames, neural nets).
5) EARS should be compared with other assessment tools to determine the precision and similarities of conclusions.
6) Determine how EARS can be generalized to evaluate customer satisfaction in industries other than transit.

Conclusions

The development and expansion in use of the personal computer can give the transit planner unlimited ability to use artificial intelligence to aid decision making. The planner now can consume volumes of data and still reach meaningful and consistent conclusions in a short period. The use of the "Expert Choice System" is one that can be user friendly, consistent and fast. Although it is not a substitute for the planners own judgement, it can help the planner in forming conclusions for decision making regarding customer satisfaction.

The selection of the expert choice model does not exclude the options of transit planners' using other means to evaluate customer satisfaction. This determination was made based on our previously stated rationale and analysis. Other researchers using similar techniques may very well determine that one or more of the unselected models may be appropriate.

As software and hardware technology progresses, artificial intelligence will continue to enhance the efficiency of transit decision making. These improvements and changes will affect the type of "tool" used by transit planners in this decision making process.

In summary, an expert system can be developed either from "scratch," that is, by designing all the various components oneself, or by using an expert system shell. A shell provides an environment for helping an expert system developer build the various components of the system. We chose to use the VP-Expert shell (Pigford, 1995). This tool runs on IBM-compatible computers and allows one to construct expert systems that run the same platform. By the VP-Expert shell we constructed a rule-based expert system that contains three components: knowledge base, inference engine, and user interface. The knowledge collected during the knowledge engineering stage was entered a VP-Expert knowledge base using the knowledge editor that comes with this tool.

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APPENDIX

Article Summaries

A. Fuzzy Logic & Fuzzy Sets

Fuzzy Fundamentals

Fuzzy logic is a method of easily representing analog processes on a digital computer. These processes are concerned with continuous phenomena that are not easily broken down into discrete segments, and the concepts involved were difficult to model conventionally with mathematical or rule-based lines.

Once the fuzzy model had been constructed, the process of simulation and proto cycling begins. The model was compared against known tests to validate the results. When the results were not as desired, changes were made either to the fuzzy set descriptions or to the mapping encoded in the rules. Tools were available to help project managers and system designers evaluate fuzzy set or rule level. These tools measure such factors as the statistical compatibility between the model and test-bed data and the stability of the model based on a loss of information. In general, a methodology will only be as good as the designer's understanding of the problem.

Improved Freeway Incident Detection Using Fuzzy Set Theory (Changa and Wang, 1993)

Changa and Wang (1993) research noted that freeway incidents often occur unexpectedly and cause undesirable traffic congestion, mobility loss and environmental pollution with computerized traffic management systems in operation. Automatic incident detection, being one of the primary functions of computerized freeway traffic management systems, must be able to detect all freeway incidents instantly with minimum false alarms.

This study evaluated the applications of fuzzy set theory for improvements in existing incident detection algorithms. The potential system performance was compared with that of conventional systems using real world volume and occupancy data that were collected earlier. Further, this study explored the use of fuzzy logic to improve the operations of California Incident Detection. Three design approaches were investigated and found to be equal or superior in performance to the conventional systems for effective freeway management. Several issues still remained for the practical development of automatic incident detection techniques. These issues are as follows:

1) Evaluation of the original effectiveness of existing incident detention algorithm(s) in the field,
2) Assistance in developing users' guidelines to provide the suitable operator interface and setting during different conditions,
3) Recommendation about how to integrate an altemative data survey and improve existing automatic incident defection system design.

The fuzzy rules represented by the linguistic in fuzzy set systems were much easier to understand and debug than the set rules that were commonly used in the non-fuzzy conventional approach. Fuzzy systems are also easier to maintain and adjust to various traffic control environments. Because different operating states can be used to represent degrees of severity of the freeway incidents, fuzzy rules can be grouped to simplify the operating states with similar behavior in the decision tree analysis. These simplified rules can further improve future operational efficiency and maintenance of fuzzy systems.

However, the performance of incident detection systems depended on how to generate suitable "threshold values" or "membership functions" in the fuzzy systems. Changa and Wang noted two problems that existed with the use of fuzzy reasoning: lack of methods to determine proper thresholds and lack of automatic learning functions or adaptability in the algorithm. A fuzzy incident detection design with automatic learning design can greatly improve the performance of an incident detection system. In addition, the conventional (Measures of effectiveness) MOEs were not sufficient enough to evaluate among different fuzzy systems. A composite index was needed to improve the incident detection evaluation during the intermediate phase. Additionally, the index may be used to reflect the degree of information usage and to measure the quality of information received for further system improvements.

Fuzzy Logic and Embedded Control
Motorola Background Information

Fuzzy logic was mentioned in the same breath as another technology, neural net computing. The two have some fundamental characteristics in common and should be viewed as complementary. In brief, neural nets are arrays of interconnected processing nodes, called neurons, loosely modeled on biological nerve cells. Each neuron receives one or more inputs, which multiply by so-called weighing factors and sum together to produce an output. Neurons were arranged in layers, with the first layer receiving primary inputs then passing its output to a second layer. Second layer neurons perform their own weighing and summation and so on until a final output was produced.

Of primary importance, the network was designed so that they were self modifying. If the final output was incorrect, the system adjusted the weights applied to each input to produce a new result; this was done in accordance with certain training algorithms. The training process was interactive: input data was run through the network repeatedly and each time the weights were tuned to improve the result. Eventually the desired output was achieved. In this way neural nets learn from experience.

Neural nets are said to be "data driven": presented with a mass of data, the net itself derived a solution to a problem. Neural nets were good at sorting through complex data and finding underlying patterns or rules. Their many practical applications include pattern recognition database search and retrieval and image processing.

B. Neural Networks

Applications of Artificial Neural Networks
to Intelligent Vehicle-Highway Systems (Hya 1993)

The potential applications of artificial neural networks (ANNs) to intelligent vehicle-highway system (ITS) are evaluated and the extent of use and the position of ANNs in future ITS implementations were discussed. The state of the art and the potential implementation needs of ITS were reviewed. The characteristic, properties, limitations and application domain of ANNs to ITS were concluded. A technical demand-supply matrix was provided to indicate the most possible potential application domains of ANNs to ITS. As an application case study of ANNs in the implementation of ITS, an ANNs-based model was established for vehicle travel time estimation. The results and findings associated with the development of the neural network-based travel time estimation model were also reported. The researchers concluded that (a) ANNs can provide most techniques needed by ITS and (b) for some ITS implementation domains, ANNs may be superior to conventional techniques. The case study demonstrated the modeling feasibility of ANNs, for potential ITS implementations.

ANNs provided many properties that met a number of technological requirements of ITS, especially information processing and modeling. The intelligent operations provided by ANNs were, in many aspects, in accordance with the application orientation of ITS. Some ANNs techniques, such as pattern recognition and control logic modeling, were expected to contribute to excellent performance when used in ITS. There was a great potential for ANNs techniques to be superior to conventional techniques in such areas as pattern operation and modeling process in certain ITS applications. The vector-level operations of ANNs handling multiple input - output levels will also better meet the complexity of transportation systems.

The application example, Back Propagation (BP) formulated a model that was able to reasonably estimate the average travel time for a given roadway segment on the basis of two types of information--the traffic volume and lane-blockage index. This model took into consideration irregular roadway conditions. With the neural networks, the complex procedures of formulating traffic weaving movement, car following movement, and tourist lane-blocking detection/reaction behavior could be avoided. The average estimation error was 5.5 seconds, whereas the simulation result of travel time at free flow was 27.3 seconds for going through the roadway segment (on the basis of results obtained from the Highway Capacity Manual).

Overall, the application potential of ANNs to ITS was significant. Suitability to ITS was found in the ANNs properties of pattern recognition, classification, data compression, prediction and control logic modeling. However, the superiority of ANNs to other technologies was not identified in this study. Further, there exists the possibility that ANNs provides feasible alternatives to conventional techniques in numerous ITS application domains. Finally, the use of ANNs was expected to be considered further in the future.

Characteristics of Random Nets of Analog Neuron-like Elements (Amari 1972)

Amari (1972) reported on the dynamic behavior of randomly connected analog neuron-like elements that processed pulse-frequency modulated signals that were investigated from the macroscopic point of view. By extracting two statistical parameters, the findings were that macroscopic state equations were derived in terms of these parameters by the hypotheses of the statistics. The report demonstrated that a random net of statistically symmetric structure was monostable or bistable, and the stability criteria were explicitly given. Random nets consisting of many different classes of elements were also analyzed. Special attention was given to nets of randomly connected excitatory and inhibitory elements. Also, the report noted that a stable oscillation exists in such a net; in contrast with the fact that no stable oscillations exist in a net of statistically symmetric structure even if negative/positive synaptic weights are permitted simultaneously. The results were checked by computer-simulated experiments.

From the macroscopic point of view, a neuron was considered to be an analog information-processing element that processes pulse-frequency modulated signals. The macroscopic behavior of random nets of analog neuron like elements were investigated, and the results were compared with those composed of discrete threshold elements or McCulloch-Pitts formal neurons. The statistical parameters, which are sufficient to determine the macroscopic state equations, were derived in terms of these parameters. The simplified state equations were also derived. The behavior of random nets was studied with the help of these equations.

A random net consisting of one homogenous class of elements has been proven to be monostable or bistable according to the statistical parameters, even when both positive and negative synaptic weights were included in the elements. However, a random net consisting of excitatory and inhibitory classes of elements can be not only monostable, bistable, or tristable but also astable with stable oscillation. The stability criteria were explicitly given in terms of the statistical parameters, and results were checked by computer-simulated experiments.

The most interesting feature of random nets seems to be that the stability changes with the average threshold H or h which can be controlled by other networks. In this connection, random analog type nets have similar structures to those of digital type without any refractory period. This fact seems to show that the non-linear character of the output function is essential for the preceding characteristics of random nets, and the existence of the refractory period was responsible for them only through the non-linear character of the output function.

"Neural" Computation of Decisions in Optimization Problems (Hopfield and Tank 1985)

Hopfield and Tank (1985) found that highly-interconnected networks of nonlinear analog neurons were shown to be extremely effective in computing. The networks rapidly provided a collectively-computed solution (a digital output) to a problem on the basis of analog input information. The problems solved must be formulated in terms of desired optima, often subject to constraints. The general principles involved in constructing networks to solve specific problems were discussed. Results of computer simulations of a network designed to solve a difficult but well-defined optimization problem--the Traveling-Salesman Problem--were presented and used to illustrate the computational power of the networks. Good solutions to this problem were collectively computed within an elapsed time of only a few neural time constants. The effectiveness of the computation involved both the nonlinear analog response of the neurons and the large connectivity among them. Dedicated networks of biological or microelectronic neurons provided the computational capabilities described for a wide class of problems having combinatorial complexity. The power and speed naturally displayed by such collective networks contributed to the effectiveness of biological information processing.

Electronic Implementation of Associative Memory
Based on Neural Network Models (Moopenn 1987)

Moopenn (1987) described an electronic embodiment of a neural network model in which the synaptic network takes the form of a binary connection matrix. The associative recall properties of the binary matrix memory based on the outer-product storage algorithm have been examined. Memory retrieval errors corresponding to the appearance of extra ones in the memory output vectors were intrinsically eliminated by using a simple form of local inhibition for dilute vector coding in the auto-associative mode. Another type of retrieval error, namely the appearance of false memories, however, imposed a fundamental limitation on the information storage capacity of a binary connection memory. A near exponential growth in the number of false memories with memory loading was observed in a computer simulation study. However, for small memory loading (less than or equal to 25 percent), the number of false memories was significantly reduced to a small fraction (less than or equal to 10 percent) of the prescribed memories. The use of asymmetric connections to map false memories to nearby prescribed memories without the need for an error-correction was a major finding of this study. The stability, dynamic behavior and convergent properties of binary connection matrix memories were investigated in an electronic hardware using a programmable 32 x 32 binary switch matrix memory system. The hardware system, with full dynamic feedback and local inhibition, has indeed demonstrated stability in accordance with the energy function formalism. In addition, the 32 x 32 system exhibited a high degree of content addressability and fault tolerance, as well as fast recall capability.

A Model of Human Associative
Processor (HASP) (Hirai 1983)

In understanding brain functions, Hirai (1983) reported that one should always keep in mind that our brain consists of neural networks, and what the brain can perform depends on the structure of the networks. Our memory was characterized by its associative, distributed, and content addressable structure. To represent associative brain functions in terms of such structures, a model of an associative processor named HASP was proposed and its performance as associative memory was described.

HASP solved two critical problems in associative memory models: crosstalk noise elimination and multiple-match resolution. The former function was necessary to avoid an explosion of crosstalk noise in such a structure as mutually linked associative networks. With the latter function, various operations were available in retrieving information embedded in a complicated data structure as a multi-list.

Neocognitron: A Neural Network Model for a Mechanism of Visual Pattern Recognition (Fukushima 1983)

Fukushima (1983) demonstrated in his research that the neocognitron recognized handwritten numerals of various styles of penmanship correctly, even if they are considerably distorted in shape. Although, the result was shown for the recognition of Arabic numerals, the neocognitron can be trained to recognize other sets of patterns, such as alphabets, geometrical shapes, and others.

The number of cell planes of each layer should be changed adaptively, depending on the set of patterns which the neocognitron should learn to recognize. The program for the computer simulation was made in such a way that the number of cell planes was chosen freely and may readily be increased when necessary.

Although each S cell has a large number of modifiable input synapses, all are not generally reinforced by learning. On the contrary, most remain at the initial state in which their efficiencies are zero. Furthermore, the modifiable synapses tend to be reinforced in clusters. In the computer program, full use of the characteristics of the synapses reduced the required memory capacity and increased the computation speed by eliminating unnecessary calculations.

In the simulated model, the researchers made two to one thinning-out in several parts of the network to increase the computation speed. The thinning-out between layers U_{s1} and U_{c1}, was too coarse when compared to the five x five spread of the input synapses of the cells of layer U_{S2}. If the thinning-out was not done at this stage, the possibility of improving the capability of the network further existed.

A Simple "Neural " Optimization Networks:
An A/D Converter, Single Decision Circuit,
and a Linear Programming Circuit (Tank & Hopfield 1986)

Tank & Hopfield demonstrated how interconnected networks of simple analog processors can be used to solve decomposition decision problems and linear programming problems. Networks for both problems were designed using conceptual tools which allowed one to understand the influence of complicated feedback in highly interconnected networks of analog processors. Also, Tank & Hopfield demonstrated that for "simple" computational tasks and well-defined initial conditions, the networks can sometimes be guaranteed to find the global optimum solution. The major advantage of these architectures is their potential combination of speed and computational power. Interesting practical uses of such circuits for complicated problems necessitate huge numbers of connections (resistors) and amplifiers.

An Introduction to Computing
with Neural Nets (Lippman 1987)

Lippman reported that the greatest potential of neural nets remains in the high speed processing that could be provided through massively parallel VLSI implementations. Several groups were currently exploring different VLSI strategies demonstrating those existing algorithms for speed and image recognition can be performed using neural nets. In many cases a probabilistic model was used to model the generation of input patterns from exemplars and the matching score, representing the likelihood or probability that the input pattern was generated from each of the possible exemplars. The back propagation algorithm has been tested with a number of deterministic problems, such as the exclusive or problem, on problems related to visual pattern recognition. Computing with neural nets was found to perform well in most cases and found good solutions to the problem posed.

In a speech recognizer the inputs might be the output envelope values from a filter bank spectral analyzer sampled at one time instant, and the classes of speech might represent different vowels. In an image classifier the inputs might be the gray scale level of each pixel for a picture, and the classes might represent different objects. Advances in these areas and in VLSI implementation techniques could lead to practical real-time neural-net systems.

Short-term Traffic Flow Prediction: Neural Network Approach (Smith and Demetsky 1993)

Smith and Demetsky (1993) reported that much of the current activity in the area of intelligent transportation systems (ITS) focused on one simple objective: to collect more data. Clearly, improvements in sensor technology and communication systems allowed transportation agencies to more closely monitor the condition of the surface transportation system. However, monitoring alone cannot improve the safety or efficiency of the system. Surveillance data were used to manage the system in a proactive rather than a reactive manner. Proactive traffic management required the ability to predict traffic conditions. Previous predictive modeling approaches were grouped into three categories: (a) historical, data based algorithms, (b) time-series models, and (c) simulations. The neural network offers an attractive alternative because neural networks can model undefined, complex nonlinear surfaces. In a comparison of back propagation neural networks model with the more traditional approach of a historical, data-based algorithm and a time-series model, the back propagation model was clearly superior, although all three models did an adequate job of predicting future traffic volumes. The back propagation model was more responsive to dynamic conditions than the historical, data-based algorithm and did not experience the lag and over prediction characteristics of the time-series model. Given these advantages and the back propagation model's ability to run in a parallel computing environment, it appears that such neural network prediction models hold considerable potential for use in real-time ITS applications.

ITS technology allows for vastly improved data collection and data communication capability. However, a very real risk is that the world will become data rich and information poor. Thus, a critical effort in the development of ITS was to create real-time decision support software that relied on advanced technology, such as expert systems and models. A critical element of such support software that has been identified in this paper was a short-term traffic condition prediction model. This paper has demonstrated the potential of neural networks to accurately predict short-term traffic conditions in real time. A neural network developed with data from an operational traffic management system performed comparably well to traditional prediction approaches when tested with an independent set of validation data. The neural network model out performed other models during peak conditions, demonstrating its ability to model complex traffic characteristics. On the basis of these promising results, research was continuing to further neural network model for ultimate implementation in traffic management systems.

Self-Organizing Feature Maps and the Traveling Salesman Problem (Ang'eniol 1988)

Based on Kohonen's work on self-organizing feature maps, an algorithm for solving the classical traveling salesman's problem was derived. A small set of cities was taken from Tank and Hopfield (1985) and from Durbin and Willshaw (1987). These cities were defined by their positions in the plane; and evolving population of cells, featuring duplication and selection, literally organizes toward a quasi-optimal solution. Simulations on sequential machines have been cited as a problem with thousands of cities. The algorithm naturally lends itself to implementing a network of interconnected, analog processing elements.

C. Artificial Intelligence

Artificial Intelligence for Transit Railcar Diagnostics (Mulholland and Oren 1994)

This study presented the results of an evaluation of seven Artificial Intelligence (AI) techniques, which may be applicable to the diagnosis of malfunctioning transit railcar systems and subsystems. The seven AI techniques were expert systems, case-based reasoning, model-based reasoning, artificial neural networks, computer vision, fuzzy logic, and knowledge-based systems. These techniques were chosen for evaluation because they have already shown potential for performing diagnosis in other industries and operations. With the exception of computer vision, all of the AI techniques were found to be appropriate for use in railcar systems diagnostics. A criterion based on maintenance operational requirements was developed to prioritize the AI techniques.

Surveys of transit railcar maintenance personnel and system manufactures were conducted to determine the status of current and planned maintenance and diagnostic operations. These surveys revealed a need to improve diagnostic capability in their systems and showed an appreciation for the potential cost savings that could result from such an improvement. Although such issues as cost, system support, and personnel capability should be addressed in any AI diagnostic program implementation, the personnel surveyed believed that the program would be acceptable if the program were user friendly and proved to be an effective tool for improving diagnosis. The maintenance personnel also indicated that the greatest impact in cost savings could come for improvement in diagnosis of the railcar propulsion system. Also, the surveyed population believed that the initial AI program should be developed to perform as an assistant to the maintenance technician rather than to perform the complete function itself.

Use of System Characteristics to Define Concepts for Automated Highway Systems (Stevens 1993)

Stevens reported that the Automated Highway System (AHS) was a surface transportation system program that used modern electronics to instrument highways and vehicles to provide "hands-off" and "feet-off" vehicle operation. Research to date shows that AHS had the potential to double or triple the nation's highway efficiency and to dramatically increase highway safety. The impact of AHS on the nation's highways was comparable to the impact the jet engine had on aviation 40 years ago. FHWA has established an AHS program that (a) identified and analyzed alternative AHS concepts and (b) demonstrated the potential feasibility of AHS in 1997. Analysis, modeling, simulation, and testing were used in comparing and evaluating the concepts to assist FHWA in defining the AHS program, once initial definition and assessment of alternative AHS concepts has been made. The processes by which AHS concepts were defined using the primary system characteristics of an AHS were described, and those characteristics that may vary from one concept to another were identified. From this, those distinguishing factors, termed concept definition factors, were used to postulate the initial set of AHS concepts.

On the basis of the study summarized here, the following conclusions were drawn:

[1] A process can be developed to identify AHS concepts in a structured manner. The structured process developed and used in this paper seems to allow most, if not all, concepts to be identified.

[2] There was at least one approach for structuring an AHS into its major components. An initial definition of each component's functional and physical characteristics can be made, and the major variations from one concept to another can be identified. These major variations were termed the concept definition factors; they can be used to identify a set of AHS concepts.

[3] By eliminating the unlikely combinations of the concept definition factors, the number of AHS concepts defined in this paper was 37. Eventual AHS deployments probably were combinations of two or more of these concepts.

[4] The 37 concepts were not necessarily a complete and definitive set of AHS concepts; that complete set was defined while the AHS program pro-ceeded. However, they did provide an adequate basis of scoping and to define AHS programs in this early planning phase.

D. Intelligent Transportation Systems

Models of Commuters' Information Use and Route Choice: Initial Results Based on Southern California Commuter Route Choice Survey (Abdel-Aty 1993)

Abdel-Aty used a Computer Aided Telephone Interview (CATI) survey carried out as part of a research project at UC Davis. This survey was designed to gain a basic understanding of the drivers' route choice behavior, to collect detailed information about their commute routes and to explore how commuters use traffic information to decide on what route to travel to work.

An analysis using general descriptive statistics shared several tendencies in the commuters' route choice decisions. Only 15.5 percent of the respondents reported that they do not always follow the exact route to work, which indicated a potential benefit from an information system that would make more commuters aware of alternative routes.

The most common reasons cited for changing from a primary route were (a) the desire to decrease the trip time, (b) receiving traffic reports, and (c) the time the commuters leave their homes. High income and high level of education were two social demographic factors noted. Commute distance did not seem to have a significant effect on using alternative routes.

Finally, the statistical exploration of the data also indicated that gender influences the use of traffic information. Women tend to listen to pre-trip traffic reports more frequently than men and tend to use freeways less frequently than men.

Bivariate probit models were developed to determine the factors that influence information used and the propensity to use alternative routes. The models showed the significant influence of income, education, frequency of driving to work, and listening to traffic reports on the commuters' route choice. Also, perceived variation in traffic condition, gender, commuter distance, and travel time uncertainty affected the likelihood of listening to traffic information.

Negative binomial models were developed to assess a commuter's frequency in changing routes. Two models were developed: the first modeled the number of route changes per month on the basis of pre-trip traffic reports, and the second modeled the number of route changes per month on the basis of en route traffic reports. The models showed the significant effect that commuters' perceptions of the accuracy of traffic reports and variation in traffic conditions, travel time, and level of education had on the frequency of changing routes on the basis of pre-trip information. Also, traffic conditions, perceptions of information accuracy and traffic variation, freeway use, commute distance and car pooling were among the variables influencing the frequency of route changes on the basis of en route traffic information.

The finding of this study suggests at least two important directions for future research. The first direction was methodological in nature. There was a need to develop a final procedure for estimating simultaneously with the commuter's choice to use information and the frequency of route changes. This task was not easy because of the complexity of the error term structure, but there were potentially many applications of such a procedure to the analysis of route choice behavior and other Advanced Traveler Information System (ATIS) related concerns.

The second direction related to the need for information on the specific routes used by travelers. Such information was to include highway geometries, signal timings, and the temporal distribution of traffic. This effort was noted to be tedious and time consuming to process. Information was gathered and used to explore many detailed relationships that had a direct impact on ATIS utilization.

Criteria and Methods for Evaluating Intelligent Transportation System Plan and Operational Tests (Brand 1993)

An evaluation process used for the preparation of Intelligent Transportation System (ITS) plan that was sensitive to the differences between ITS and conventional transportation improvements was described by Brand (1993). The term "intelligent transportation system" replaces "intelligent vehicle-highway system (IVHS)." A relatively complete set of evaluation criteria for ITS improvements was presented and structured to clarify the confusion between the supply and demand impacts of ITS. This separation between "efficiency" and " output" measures means that one must distinguish between ITS technology supply and efficiency benefits. The individual and corporate demand responses to ITS actually increased output (benefits). The proposed criteria structure also incorporates the time scale of the impacts.

This highlighted certain fundamental correlations between the criteria that lead to double counting of benefits and to highly correlated outcomes, which are not helpful in choosing between alternatives. The criterion's structure facilitates selection by decision makers of greatly reduced criteria sets to simplify ITS evaluations. By recognizing the separate supply (efficiency) and demand (increased output) impacts of ITS, under estimating the benefits of the new technology was dramatically avoided. Further, serious mistakes were avoided in assessing the safety, environmental, and energy impacts of ITS alternatives default values, especially when these values are used to evaluate ITS improvements for inclusion in transportation systems. The criteria and default values highlighted where research and operational tests can provide improved values and information that will most quickly advance the state of the art of ITS evaluation.

ITS plans and operational tests were developed and evaluated in a way that was sensitive to the differences between ITS and conventional transportation improvements. They were developed by recognizing the separate supply (efficiency) and demand (increased output) impacts of ITS and avoided dramatically underestimating the benefits of the new technology. The methodology and criteria presented in this paper provided the required structure and default values to evaluate ITS improvements for inclusion in transportation system plans. The criteria and default values provided also highlight where research and operational tests provided improved values and information that most quickly advance the state of the art of ITS evaluation.

Regional Approach to Strategic Intelligent Vehicle Highway System (IVHS) Planning in Orange County (Harinoviski 1993)

The Orange County, California, IVHS (ITS) study developed a framework under which advanced technologies were deployed to improve the operation of the county's highway and public transportation systems (Harinoviski, 1993). The most significant challenge of the study was to reconcile an overall high-level transportation vision with the needs, concerns, responsibilities and financial limitations of all the local and regional agencies. The process used to develop a regional IVHS strategic plan was described and a review of the required areas of emphasis in developing such a plan was discussed. A multi-agency regionally oriented effort has emphasized an interagency consensus and the incorporation of an existing system infrastructure as the basis for a higher level of transportation management improvements. The following are the three areas of emphasis identified by the consultant team:

1) a county wide traveler information (pre-trip and en route)
2) integrated corridor traffic management and
3) real-time management and information for public transit

To satisfy these areas of emphasis, the detailed study has focused on developing an infrastructure (physical system as well as management) capable of integrating various information and management elements (both roadway and transit) and supporting the extensive inter-jurisdictional coordination required. Additional effort was required to provide all the agencies with the means (technical as well as financial) to support the operation and maintenance of the system.

Although the program emphasis was oriented more to the near term, the architecture developed in the study was highly appropriate for support of efforts toward in-vehicle navigation devices and automated vehicle control and efforts that are integral to the overall direction of the IVHS program. The nature of this regional IVHS strategic plan has been to emphasize the practicality of implementation as a key criterion.

Urban Rail Corridor Control Through Machine Learning: An Intelligent Vehicle-Highway System Approach (Khasnabis 1993)

Traffic control along an urban rail corridor with closely spaced stations can be considered a sequence of decision-making stages (Khasnabis 1993). A train on an urban rail corridor that connects two terminal points with a number of intermediate stations can follow various regimes of moving and stopping, which identify individual driving scenarios. The execution of these regimes may result in different values of attributes that describe driving scenarios, namely, travel time, energy consumption, passenger comfort, and others. An attempt was made to demonstrate how to develop decision rules for driving scenarios along an urban rail corridor that can optimize travel time, energy consumption and passenger comfort, using the concept of machine learning. Machine learning was a science that deals with the development and implementation of computational models of the learning processes, the concept of knowledge acquisition through inductive learning processes. The concept of knowledge acquisition through inductive learning as an intelligent vehicle-highway system approach was explored to establish some initial decision rules. A computer model, REGIME, was developed for estimation of values of evaluation criteria, such as travel time, energy consumption, and passenger comfort levels for a hypothetical rail corridor for various driving scenarios. Next, a commercial learning system, ROUGH, was used in conjunction with the examples created through REGIME to develop decision rules. The learning algorithm was based on the theory of rough sets. The feasibility of machine learning in automated knowledge acquisition to develop decision rules for complex engineering problems (i.e., urban rail corridor control) was demonstrated. Further research is needed to verify the rules developed before these can be applied.

The objective of this paper was to explore the concept of knowledge acquisition through inductive learning to establish decision rules for an urban area. The study demonstrated the feasibility of using machine learning in automated knowledge acquisition about complex engineering problems such as urban rail traffic control.

The rules developed are based on three separate evaluation criteria: passenger comfort, travel time, and energy consumption. Additionally, a set of rules was developed with all the three attributes combined. No effort was made in this study to explain these rules, to validate them, or to assess how they may be applied in actual rail corridor control. The large number of decision rules and their interaction reflect the completing problem of the rail corridor control. To gain further insights into this problem, an automated rule verification method was recommended on the basis of the performance of the learning system, measured by various empirical error rates.

Machine learning in rail traffic control was new, complex and interdisciplinary research, and more work was needed to determine a better understanding of the problem and to prepare a program that would lead from research to practical application of results.

E. Other Related Concepts

Advanced Public Transportation Systems: The State of the Art Update '92 (Labell 1992)

This report documented a limited investigation on the extent and adoption of advanced technology in providing public transportation services in North America. The report was an update to a similar report published previously (May 1991). The report was not an exhaustive search of every city or transit authority, which have tested, planned, or implemented an advanced technology concept. Rather the focus was on some of the most innovative and comprehensive implementations categorized broadly during four different types of an operational test: Market Development, Customer Interface, Vehicle Operations and Communications, and High Occupancy Vehicle Facility Operations.

The goal of market development projects was to increase the utilization of high occupancy vehicle modes. Providing travelers, especially regular commuters, with traffic and transportation service information prior to embarking on their trips would allow travelers to make the most informed choices of modes and routes.

Customer-interface provided services to passengers of the system so that their travel was made easier. Services that were intended to satisfy the customer included information on arrival times, general conditions of the system, and a simplified method of payments. Each of the strategies was designed to ease trip-making, from the point of departure to arrival at the destination.

The principal goal of Vehicle Operations and Communications techniques was to improve management of existing fleet resources through technological innovations. Noted in the High Occupancy Vehicle Facility Operations include those technologies designed to improve the flow of high occupancy vehicles (HOVs). This was accomplished by giving preference to these vehicles on existing facilities or by constructing special guide ways to control their movement.

Workbook for Estimating Demand for Rural Passenger Transportation (SG Associates, Inc. 1995)

The demand estimation methodology treated separately two distinct types of passenger transportation demands. These types are program-related demand-trips that would not occur but for the existence of specific social service program activities and non-program-related demand that include all other trips. Program-related demand was estimated as a function of program enrollment. Methods are provided for estimating enrollment in individual program types based on population characteristics. Non-program-related demand, including "general public travel," was estimated as a function of (a) the size of the three population groups most likely to use a rural passenger transportation service (i.e., the elderly, persons with disabilities, and persons in poverty); (b) the size of the service area; and © the amount of service (measured in annual vehicle-miles) available to each of the population groups. The "county" was the service area unit for which these relationships were developed.

Two approaches to applying the developed methodology were provided. An incremental method, designed for use where passenger transportation services already exist, estimates the expected change in demand when population composition or service supplied changes. A synthetic method, designed for uses where there are no current services for one or more groups, estimates the demand to be expected if a given amount of service was supplied.

The methodologies contained in the final report and in this workbook enabled agencies to prepare consistent estimates of the demand for passenger transportation services in rural areas. The methods proved useful not only to local agencies involved in the operation of services but also to the state agencies engaged in the administration of funding programs and the preparation of state transportation plans.

Synthesis of Practice Planning for Small and Medium-Sized Communities

In the synthesis of practice for small and medium-sized urban areas, twenty-six (26) case studies were presented in four distinct topical areas:

1) assessing growth effect
2) assessing data collection and management information system
3) assessing public transportation services
4) assessing programming financial and communication with decision makers.

The objective of the synthesis report was to provide transportation practitioners, who are responsible for delivering transportation services and planning with case study examples of effective planning approaches toward solving local transportation problems. The synthesis report did not imply endorsement of any particular technique, but only attempted to stimulate thinking about a particular approach.

Transit: An Innovation in Public Transportation
(Nisar and Khan 1992)

This report presents analysis results based on actual service and cost information. The report provides further insights in the comparative assessment of bus transit-way and LRT-based systems for medium-sized urban areas in terms of level of service, cost efficiency, and cost effectiveness criteria achievements levels. These achievements' levels were transformed into relative values on a scale from zero to one and then weighed by the importance of criteria. The comparative assessment does not extend to the intermediate capacity rail rapid transit system, such as Vancouver's ALRT system. Bus rapid transit systems are more flexible to implement than the ALRT systems because these systems offer the opportunity to tailor service to meet demand.