Development of a Knowledge-Based Expert System for Intersection Improvement

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Abstract: Micro-simulation softwares were extensively developed for the past years because these represent the real-world system of traffic behavior. The high cost of acquisition and the tedious and time-consuming calibration and validation of the system hinders many potential end-users from utilizing this technology. End-users, especially the Local Government Units (LGUs), might not readily understand the system's output – this may create dilemmas in selecting the most effective traffic control alternative in addressing traffic congestion and traffic accidents alleviation. Moreover, these softwares do not include practical yet economical solutions. The study's aim is to develop an expert system for decision-making factors for the use of traffic engineers in government agencies, private companies, as well as civil engineering students who finished a course in traffic engineering. The system will be able to present mitigating measures and cross-classify potential alternatives for both the alleviation of traffic congestion and the reduction of accidents in an intersection.

Key Words: knowledge-based expert system, traffic Congestion, traffic accident, intersection

1. BACKGROUND OF THE STUDY

Traffic congestions as well as traffic accidents are ensuing problems that usually occur in fast growing metropolises due to the constant mobility of people and goods. With the increase of automobile usage each year, an evaluation of this demand is needed in order to balance the capacity of urban as well as rural road networks. Thus, traffic alleviation and road safety programs are now properly implemented for present and future scenarios. To put this program into a reality, a methodology for traffic management must be developed.

In key cities in the Philippines, particularly Metro Manila and Baguio City, traffic congestion is one major problem since the capacity of road networks is undersized and unable to accommodate the growing population and the increasing number of vehicles. Aside from traffic congestion, the number of traffic-related accidents that occurs should also be addressed. Based on actual consultations with the city government, Baguio City has no transportation plan on how to deal with this present congestion problem. There were piece-meal approached that eventually proved ineffective. One particular example is that traffic signals erected in some intersections in Baguio City were shut down since it created more congestion and conflicts rather than solutions. Another example is the construction of a flyover over a roundabout that is not yet justified if it is needed. Thus, a huge amount of taxpayers' money was wasted.

By being a metropolis alone justifies the need of a city for an expert system that may contribute in addressing traffic congestion as well as traffic accidents at intersections. Expert systems offer a practical means to assess traffic conditions so as not to waste resources (i.e. time, labor and money) and eventually save lives and properties.

Traffic simulation softwares were developed the past years. These softwares have the capability to simulate traffic situations and validate (and if necessary, modify) that the traffic control used is appropriate. However, other real-life problems in an intersection such as parking, loading and unloading of passengers, street vendors encroaching on sidewalks, etc. cannot be simulated in the software. Traffic accidents were also not included in the simulation scenario. Another disadvantage of using simulation software is that users are assumed to have a thorough knowledge of traffic engineering concepts as well as computer skills in order to calibrate and validate the system to local conditions. Otherwise, users undergo training for software use and this poses an additional expenditure. While it worthwhile to study intersections with traffic congestion and traffic accidents occurrence and how to alleviate these problems, the calibration and validation of these softwares are tedious and time consuming.

The formulation of a diagnostic methodology like a Knowledge-Based Expert System (KBES) for alleviating traffic congestion and traffic accidents is a probable answer to both problems. The occurrence of these problems can be worked out with a research of countermeasures that were provided by experts on well-documented traffic engineering references in the past years. Collecting the ideas of these experts can now be transformed into a computer-based knowledge system that end-users can consult. Using the physician-patient analogy, the problem is similar to a person who is being diagnosed by a physician of a certain kind of sickness that yet to be identified. The physician now asks the patient a series of questions that may lead to a conclusion on the patient’s probable sickness. Accordingly, the Expert System in a form of a computer program will now ask the user a series of questions that may lead to the most practical solution in alleviating traffic congestion and reducing if not eliminating accidents. The computer program was based on KBES, which is a collection of Artificial Intelligence (AI) techniques that enable a computer to assist people in analyzing specialized problems. A KBES provides human expertise through both the knowledge engineering language and the program-supporting environment. The KBES will be beneficial to traffic and transportation professionals, local government units as well as civil engineering students for a more viable decision making on the selection of traffic and accident control alternatives.

Intersections will be the focal area of this study since these have a higher collision rate and cause more delay than mid-block segments. Hummer (2004).

2. OBJECTIVES OF THE STUDY

The objectives of this study are the following:

a. To develop a Knowledge-Based Expert System to diagnose traffic congestion and accident problems within an intersection and apply corrective strategies with potential traffic control alternatives, specifically:

- Establish a theoretical foundation of solutions to accidents and congestions at intersections;
- Develop a diagnostic system algorithm;
- Develop a software to accommodate technical data and computation;
- Pilot test the software and acquire feedback from target users by questionnaire; and
- Incorporate necessary improvements on the developed software.

b. To demonstrate how the Expert System will make results clear and concise for public (i.e. Local Government Unit), and private sector end-users (i.e. traffic engineering students, etc.) for a more viable and practical decision making of the potential alternatives for mitigating traffic congestion and accidents in an intersection;
c. To illustrate how the Expert System will show the best possible alternative to ensure an efficient traffic congestion and accident control alternative for the intersection; and
d. To cross-classify studies on the potential alternatives between congestion and accidents on which is to prioritize in terms of finalization in the event that both problems occurred in the intersection.

3. SCOPE AND LIMITATIONS OF THE STUDY

The following are the scope and limitations set forth for this study:
a. It is assumed that the user is knowledgeable on basic intersection-related problems upon observing congestion and accident location patterns based on pre-evaluation diagrams as well as historical data;
b. Automobile mechanical error will not be considered as causes for traffic congestion and accidents;
c. Grade-separated intersection and work-zone related intersections will not be considered in the study;
d. Highway Capacity Manual (HCM, 2000), Akcelik method, and other traffic engineering concepts will be incorporated to further enhance the accuracy of the selection process;
e. The study will deal with 4-legged, T-intersections and skewed intersections; and
f. The KBES will show screened summary of potential alternatives. The task for selecting the best alternative/s is given to traffic engineers and planners using traffic engineering concepts solution for further details.

4. SIGNIFICANCE OF THE STUDY

The Knowledge-Based Expert System will serve as a tool for traffic engineers in improving conditions at intersections. If adopted, this will be a pioneering start for further development in alleviating intersection congestion and accidents and suited for traffic engineers and students concerned. The system shall include provisions that are not normally provided in traffic engineering manuals (i.e. Highway Capacity Manual (HCM), etc.) in alleviating traffic congestion in an intersection. The same system will provide public and private sector end-users a management system for the addressing traffic congestion and traffic accident issues . The system also encourage users in the adoption of the traffic control alternative as further shown in Figure 4.1. The KBES is a means to ensure safe and efficient movement of people and goods.

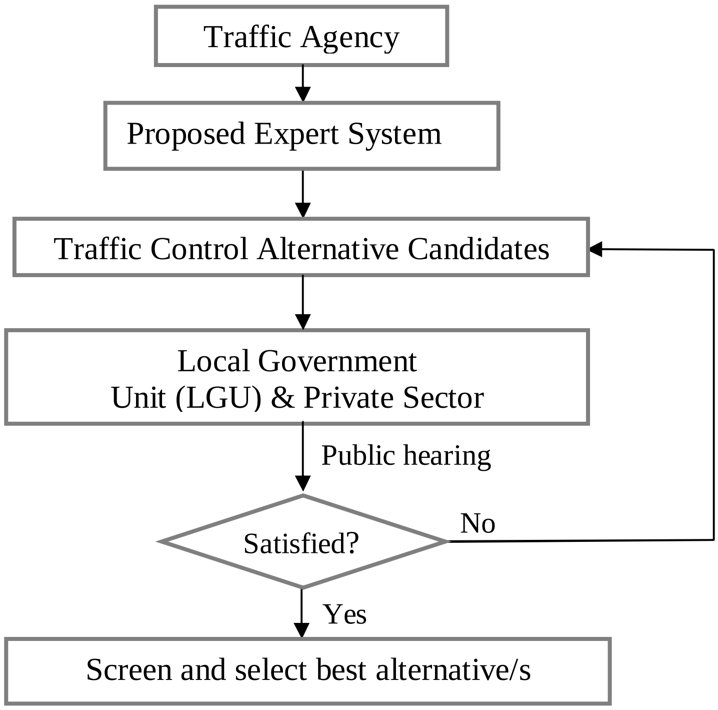

Figure 4.1. Public involvement

5. REVIEW OF RELATED LITERATURE

In the mid-1970s one of the most significant accomplishments in the field of artificial intelligence (AI) has been the development of the Knowledge Based Expert Systems (KBES). These systems are interactive computer programs that employ a collection of judgment, experience, rules of thumb, intuition, and other expertise in a particular field, coupled with inferential methods of applying this knowledge, to provide expert advice on the variety of tasks. Gasching *et al.* (1970).

A KBES provides human expertise through both the knowledge engineering language and the program-supporting environment. Harmon and King (1985). The AI/KBES application requires development of a generalized knowledge base that permits traffic engineers to interact with the following components: the traffic characteristic data, the theoretical or simulation results, and the specific hypothesis for measuring the effects of traffic control measures. KBES have high potential for solving problems that lack explicit algorithms (e.g., problems for which a numerical model does not exists).

"The structured guidelines for traffic engineering problems are suitable for KBES applications because explicit algorithms do not exist and the traditional programs can provide only restricted problem-solving capability (Chang, 1987)."

Currently, ill-defined problems can only be solved in a limited fashion by employing an algorithmic approach after extensive knowledge is summarized and a simple model is created. There are some generally experts in every field who can solve such ill-structured problems using past experience and knowledge. Ill-structured problems are real-world problems such as designing an optimal transit route structure, rehabilitating a major highway, repairing a retaining wall, etc. The transportation field is mostly concerned with such problems in which human behavior, social and political considerations and decision-making are involved. Thus, in this study, basic transportation-related problems that are worth exploring will be traffic congestion and traffic accident problems specifically in intersections. The data needed for the solution of the problem does not only include engineering concepts but environmental factors, geometric properties, obstructions, etc. that cannot be solved by engineering solutions. To be able to solve this, the knowledge of experts from different traffic engineering practices will now be incorporated as a database of solutions since ill-structured problems is utilized through their past experience and the theoretical concepts they derived.

5.1. The Expert System

An expert system (ES) is a software system that incorporates concepts derived from experts in a field and uses their knowledge to provide problem analysis to users of the software. The expert system utilizes what appears to be reasoning capabilities to reach conclusions.

There are five major components of artificial intelligence (AI) applications in ES designs: (a) expert system, (b) domain expert, (c) knowledge engineer, (d) expert systems building tool, and (e) end-user. Figure 5.1 shows the basic AI/ES components and their relationship.

5.1.1. Domain Expert

A knowledgeable person with a reputation for producing good solutions to problems in a particular field.

5.1.2. Knowledge Engineer

The knowledge engineer is usually a person with a background in computer science and AI technology with the purpose on how to build expert systems. The knowledge engineer interviews the domain experts, organizes the knowledge, decides how it should be represented in the expert system, and may assist in the development of a specific program.

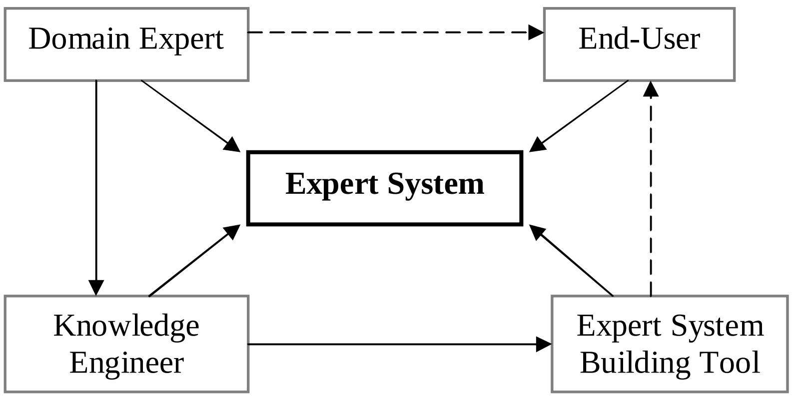

Figure 5.1 Main components of expert systems design

5.1.3. Expert System Building Tool

The expert systems building tool is the computer-programming environment and language used by the knowledge engineer or computer programmer to build the expert system.

5.1.4. End User

The user or the end user is the person for whom the expert system is developed and uses the system for its problem solving assistance.

The domain expert may add new knowledge to the existing system while the knowledge engineer refines the knowledge in the system. The knowledge engineer converts a domain expert's specialized knowledge into sets of IF-AND-THEN-ELSE rules using instructions that a computer understands. The domain expert may be the knowledge engineer and this may be of an advantage in the accuracy of the expert system. The user may not be a traffic engineer but it is recommended that the user be a traffic engineer or a civil engineering student who finished a course in traffic engineering. The user seeks advice on the system for decision-making processes that may solve a certain problem.

5.2. Components of the Expert System Design

To explain further Figure 5.1, the expert system building tool can be categorized further as knowledge base, inference engine, working memory, and explanation module as shown in Figure 5.2.

5.2.1. Knowledge Base

The heart of an expert system is its knowledge, which is structured to support decision-making wherein a knowledge base is the power base of the expert system. It is a collection of facts, rules, and computational procedures that represent the knowledge-based expert system. An illustrative example of facts and rules are shown in Figure 5.3. Common strategies for representing knowledge that are mostly used in engineering concepts are semantic nets, frames, and rules.

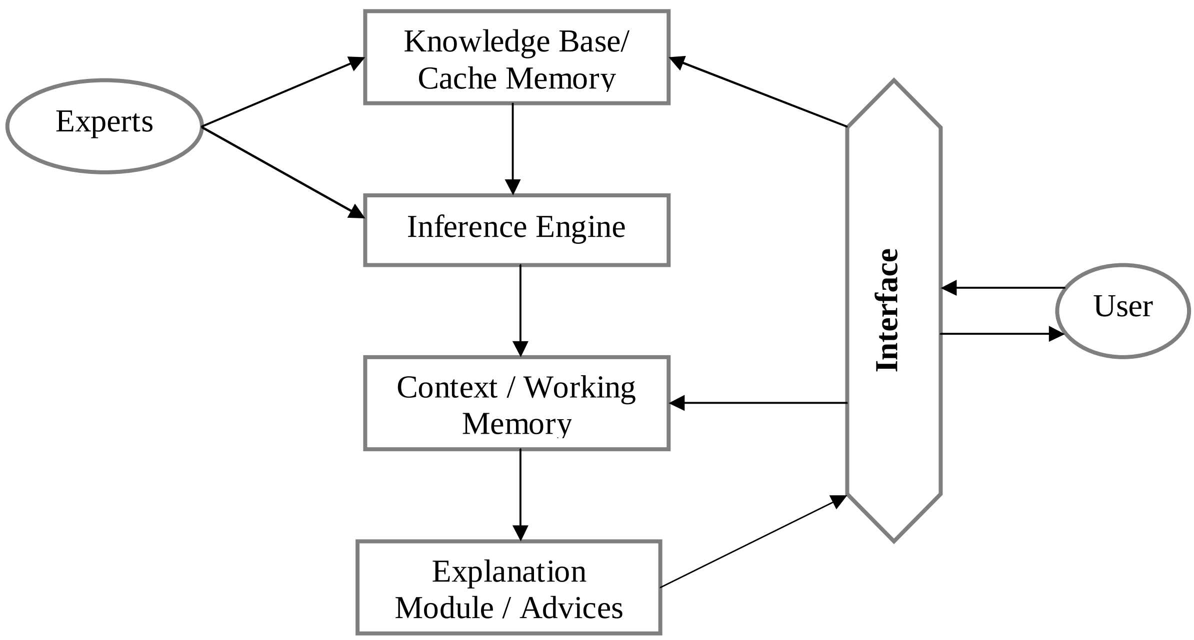

Figure 5.2 Main components of expert systems building tool

Rules, the most popular type of knowledge representation technique, provide a formal way of representing recommendations, directives, and strategies. Rules are often suitable when the domain knowledge results from solutions developed through years of problem solving experience. These results may come from paper concepts authored by experts or direct interviews from experts. Rules are generally expressed as conditional (if-then) statements. An example is shown in Figure 5.3.

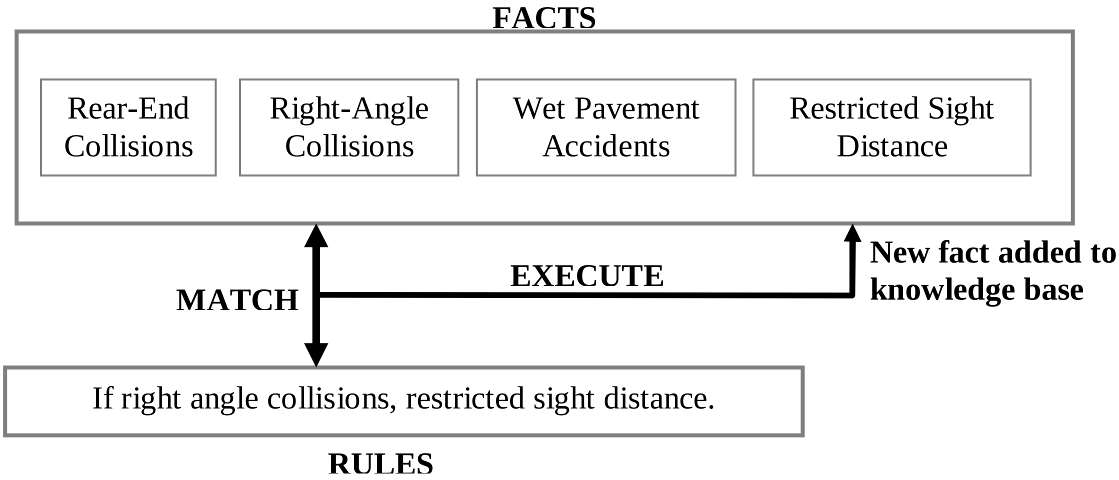

Figure 5.3 Inference chain

5.2.2. Inference Engine

Inference engine is the set of procedures for manipulating the information in the knowledge base to reach conclusions. The objective of the inference engine is to find one or more conclusions for a sub-goal or for a main goal of the consultation. It searches the facts and rules in the knowledge base then identifies and stores conclusions to use in new facts for subsequent inferencing. There are two common types of control that manipulates the inference engine, - forward chaining and backward chaining. If the possible goals are known and these are reasonably small in number, then backward chaining is very efficient. On the other hand, if the number of goals is relatively large, then a forward chaining strategy is often practical.

5.2.3. Context/Working Memory

Contains all the information derived from the inferencing process. This information describes the problem being solved, the rules that have been "fixed," and the conclusions derived from them.

5.2.4. Explanation Module

The Explanation Module contains explanations for every inference made or piece of advice given.

5.2.5. User Interface

User Interface provides for a dialogue between human and machine.

5.3. Past Studies on Expert Systems

A text graph is shown in Figure 5.4 to summarize past studies from 1983 to 2006. The first phase of the development of the expert system in transportation from 1983 to 1986 dealt with the maintenance, scheduling and traffic control on some aspects of transportation modes such as the locomotive trains, space shuttle, and air planes. Other developments are the design of noise barriers, traffic signal setting assistance, post-disaster traffic recovery strategies, and traffic network design. It is observed that in the first phase, the traffic network design is starting to progress that will lead to the development of an expert system in alleviating traffic congestion.

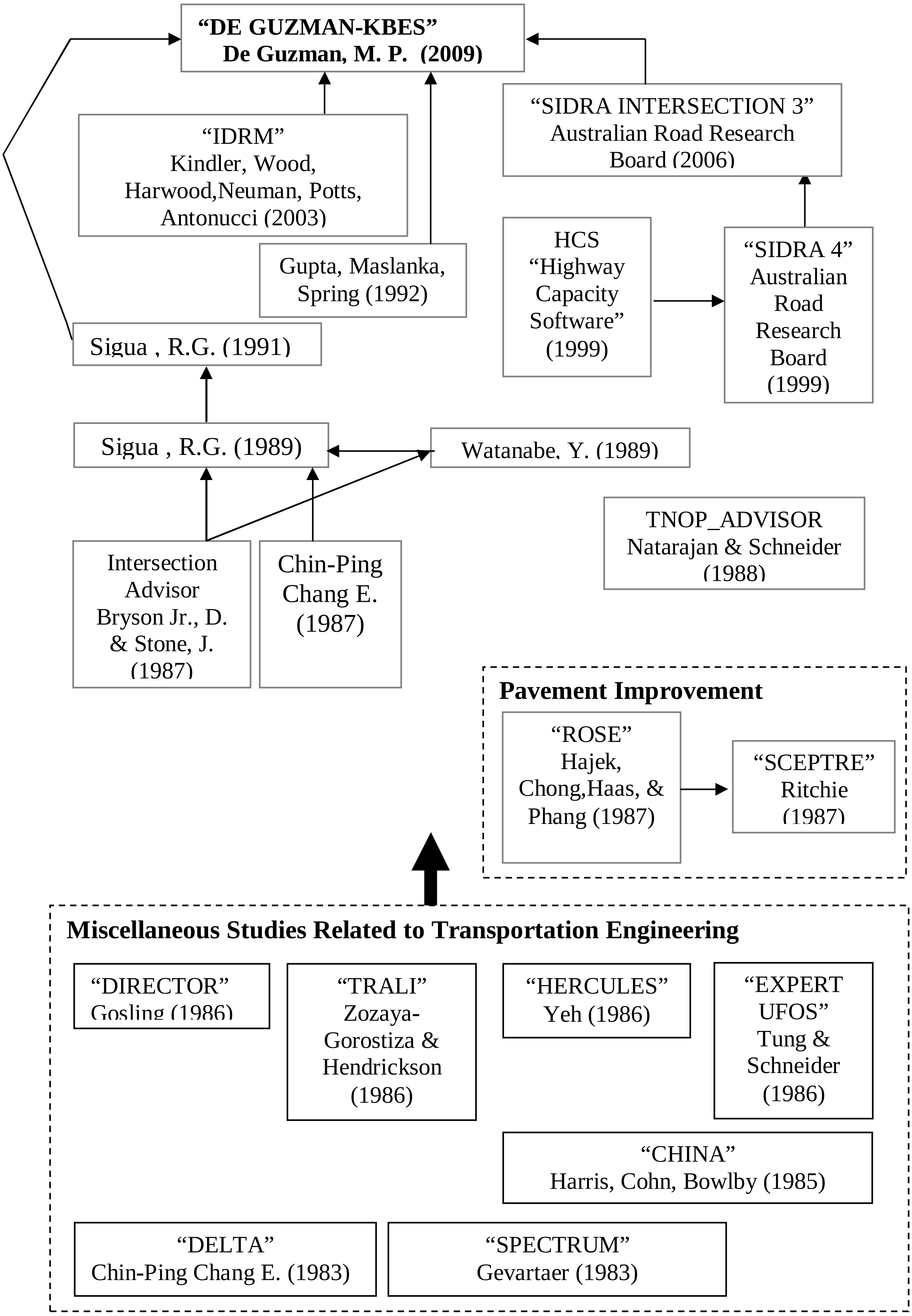

Figure 5.4 Text graph of past studies

In the second phase, intersection improvements are starting to develop particularly left-turn signal treatment and intersection design for traffic congestion alleviation. The third phase of the development of the expert system for transportation is now focused on measures of performance and traffic congestion engineering evaluation particularly at intersections with the development of the HCS (Highway Capacity Software), IDRM, and SIDRA.

A study was made by Yeh *et al.* (1986) entitled “Potential Applications of Knowledge-Based Expert Systems in Transportation Planning and Engineering.” Their significant suggestions include the development of an expert system for traffic congestion diagnosis and the other would be road safety diagnosis. Traffic congestion is highly dependent on a variety of physical, environmental, operational, geometric, land use, human, etc. Hence, a series of traffic engineering experts would be needed to diagnose the problem but they are scarce and expensive for consultation. Road safety is an important issue since accidents are caused by poor design. It is not possible, in practice, for every accident to be reviewed by an expert.

No studies were made on expert systems for traffic accidents in recent years. Past studies were not able to develop an expert system for traffic congestion with traffic accident problems particularly on an intersection. The study by Yeh *et al.* (1986) suggested traffic congestion diagnosis or road safety diagnosis expert system. But it would be more significant if we combine traffic congestion and road safety diagnosis especially at intersections where congestion and accidents are inevitable. The expert system is intended for improving intersection at minimal level in terms of resources and efficiency. The expert system will also provide a systematic user-friendly system for a more viable accurate decision-making.

6. FRAMEWORK OF THE STUDY

The author desires to develop a Knowledge Base Expert System in improving intersections. Recent developments dealt with engineering solutions and eventually decide on how to improve the intersection based on the performance measures results. The expert system to be developed will investigate the relationship between traffic congestion vis-à-vis traffic accidents on intersection improvement that were not studied at present. The intersection to be observed and investigated will cover all traffic congestion problems and traffic accident incidents that took place. Traffic control measures will now be analyzed by using rules for inferencing by forward chaining to achieve potential alternatives. The general framework is shown in Figure 6.1.

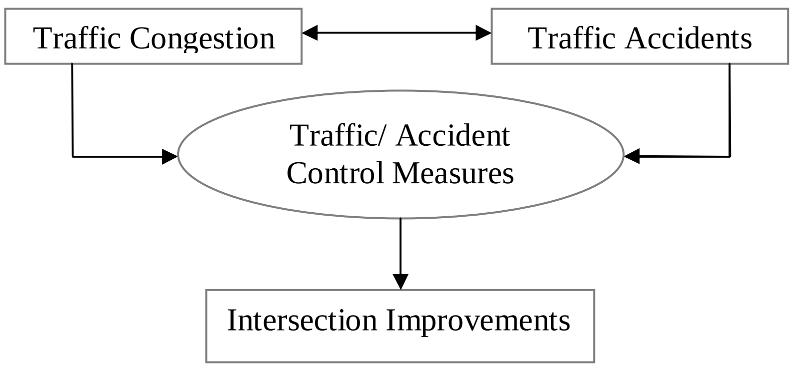

Figure 6.1 General framework

6.1. Hierarchy of Solutions

Traffic control measures will be in the form of a hierarchy of solutions, as follows: 1. Operational Solutions, 2. Geometry Modifications, and 3. Regulations/Enforcement.

6.1.1. Operational Solution

This consists of modification of signal timing-cycle length, green split, or phasing. Phasing may be difficult to modify though, since it normally entails hardware change. This may also include removing obstructions that may cause accidents to drivers, overlaying slippery pavements, etc. This may be the priority of all solutions since it is easy to manipulate and less monetary cost is achieved. NCTS Transportation Science Series (1983)

6.1.2. Geometric Modification

This involves the utilization of the median to provide an additional bay for right left turn traffic, providing right turn lanes, increasing right turn radius, channelize intersections, adding extra lanes etc. This solution though may be costly. NCTS Transportation Science Series (1983)

6.1.3. Regulation/Enforcement

This considers measures such as parking and waiting prohibitions, turning regulation, speed limits, installing barriers for unloading zones, installing barriers for non-pedestrian crosswalks, etc. This may not be appealing to drivers and pedestrians since they are compelled to follow regulations. NCTS Transportation Science Series (1983). To incorporate these hierarchies of solutions in the general framework of Figure 6.1, a conceptual framework is shown in Figure 6.2.

6.2. Building the Expert System

The expected output of the study is shown in figure 6.2. For this output to materialize in a systematic manner, the establishment of a database expert system for traffic congestion and traffic accident problems would be appropriate to have an accurate analysis of the potential alternatives to be recommended. Figure 6.3 shows the expert system process.

6.3. Programming techniques

The expert system will use a web-based, open-source, and cross-platform project. The following web technology will be used. The program will use a php script by using the three most important web development tools: The Apache, MySQL, and PHP. Web applications are commonly used for selling products, publishing information, and web enabling traditional applications. These web applications have one thing in common and that it is composed of a web server, application layer and a database. The table below shows roles in reality of each application. The web server can be compared to a “waiter” to which if you request something, it can return something prepared on demand such as ham sandwich etc. the application layer is the “cook” who accepts request from the waiter to prepare the ham sandwich amd may need other sources to get information on how to prepare it. The database server is the “cook book” that stores recipes and organizes them by categories and indices as shown in Table 6.1.

Table 6.1 Web Development Tools

	Function	Web Development Tools
Web Server	"Waiter"	Apache
Application Layer	"Cooks"	PHP
Database	"Cook book"	MySQL

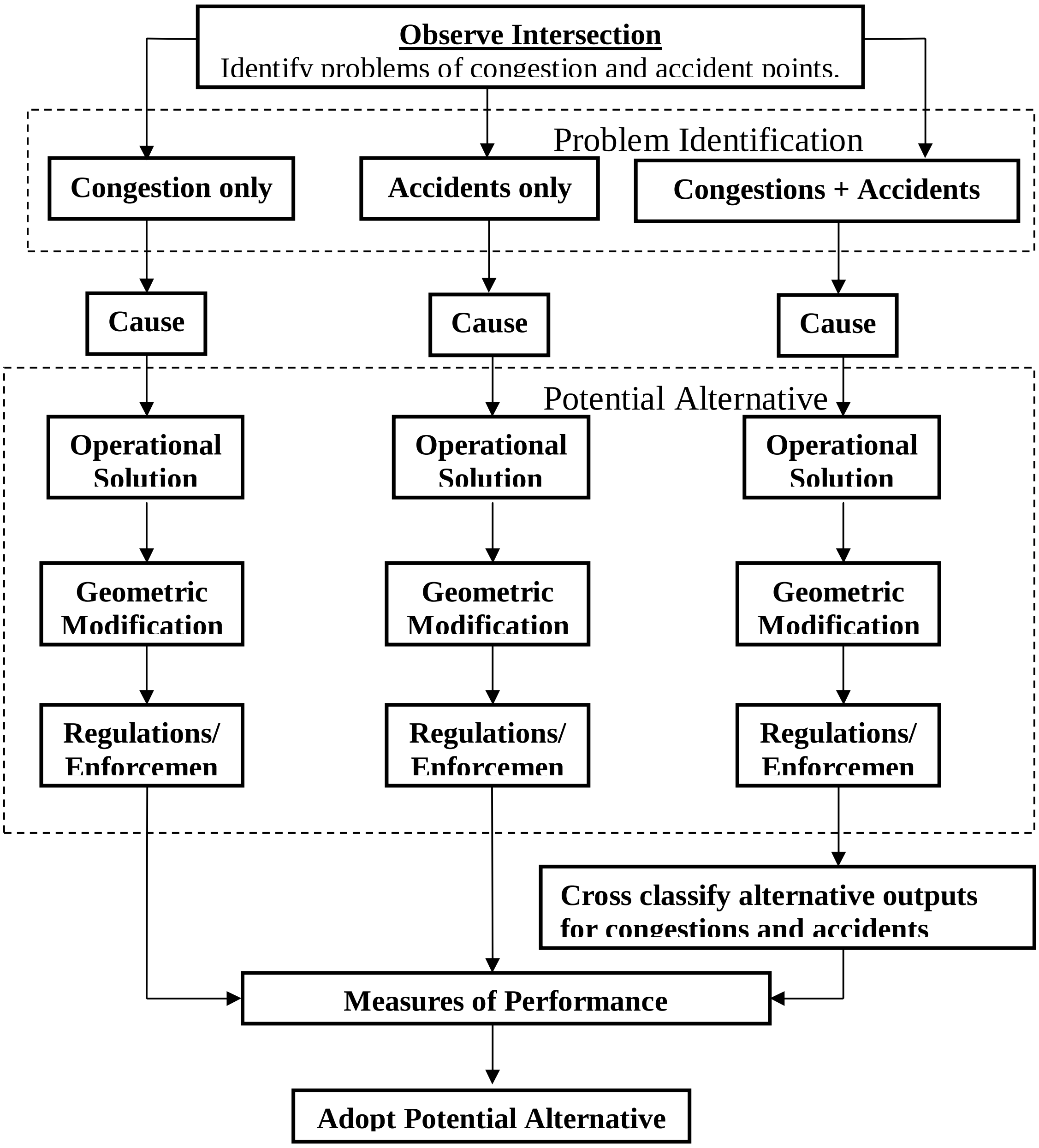

Figure 6.2 Conceptual Framework

6.3.1. Apache

Apache is a free software/open source web server. Web server is a computer program that is responsible for accepting HTTP requests from clients (user agents such as web browsers), and serving them HTTP responses along with optional data contents, which usually are web pages such as HTML documents and linked objects (images, etc.) HTTP (hypertext transfer protocol) is a protocol used to transfer hypertext requests and information between servers and browsers

6.3.2. PHP: (recursive acronym for PHP: Hypertext Preprocessor)

PHP is a widely-used open source general-purpose scripting language that is especially suited for web development and can be embedded into HTML. PHP is a server side scripting language for making logic driven websites. *"PHP is an HTML-embedded scripting language. Much of its syntax is borrowed from C, Java and Perl with a couple of unique PHP-specific features thrown in. The goal of the language is to allow web developers to write dynamically generated pages quickly* (http://www.cs50.net/resources/, 2008)."

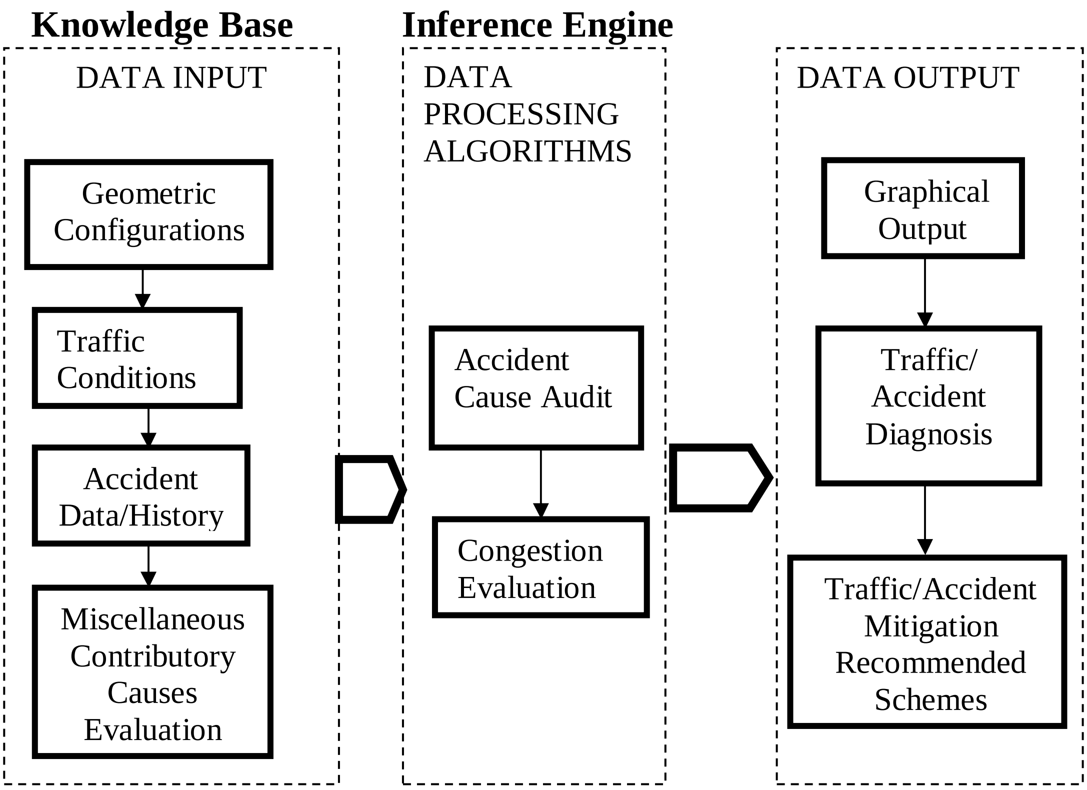

Figure 6.3 Expert System Process

6.3.3 MySQL

MySQL is a relational database management system (RDBMS). Popular for web applications and acts as the database component of different platforms (Linux/BSD/Mac/Windows-Apache-MySQL-PHP/Perl/Python).

6.3.4. MySQL Workbench

MySQL Workbench is a visual database design tool that integrates database design, modeling, creation and maintenance into a single, seamless environment for the MySQL database system.

6.3.5. Adobe Flash

Adobe Flash is used for visual presentation.

6.3.6 Javascript

Javascript is a scripting language most often used for client-side web development.

7. DATA AND RESULTS

Most intersection improvements originate from congestion problems and accident problems but not as a combined problem. In the case of congestion problems, an engineering solution might be adequate to the alleviation of this problem with reference to different traffic engineering concepts from HCM, MUTCD, etc. Accident problems are well taken into account since existing countermeasures are already published from different traffic engineering books. As we can see from Figure 6.2, the whole idea of this study is to analyze intersection improvements if traffic congestion problems as well as accident occurrence are present. There are cases when traffic control measures for both traffic congestion and accident incidents will emerge. In this case, the question of which traffic control measure to prioritize arises. Table 7.1 shows Scenario 1 on congestion and accident occurrence. Potential alternatives are shown and result indicates that traffic signal would be the best alternative to improve both problems since they matched.

Scenario 2 shows that there is no potential alternative that matched. Thus, there is one alternative candidate for each problem. Two possible alternatives for congestion problem were analyzed with the possibility of choosing either a traffic signal or a roundabout. This case would require further studies for the user in terms of cost effectiveness for either constructing a roundabout or installing a traffic signal. However, if constructing a roundabout would improve traffic safety then a roundabout would be considered.

Table 7.1 Potential Alternative Selection Results

Scenario 1. Stop control present at minor road.				
Unsignalized Intersection	**Cause**	**Congestion**	**Accident**	**Result**
Congestion	Excessive delay to the minor road movements	**Traffic Signal** Roundabout Yield control MTWSC		Installstall **Traffic signals** (Check signal warrants)
Accidents	Right angle collisions	match	Install warning signs Install stop signs Install yield signs Restrict parking near corners Reduce speed limit Remove sight obstructions **Install traffic signals** Install/improve lighting Channelize intersection Install rumble strips	
Scenario 2. Stop control present at minor road.				
Unsignalized Intersection	**Cause**	**Congestion**	**Accident**	**Result**
Congestion	Excessive delay to the minor road movements	Traffic Signal Roundabout Yield control MTWSC		Traffic signal Roundabout
Accidents	Wet pavement		Provide “SLIPPERY WHEN WET” signs Reduce speed limit Provide adequate drainage Groove existing pavement Overlay existing pavement Install raised/reflectorized pavement markings.	

A sample of the expert system interface in relation to Table 7.1 is shown on Figure 7.1. The accident scenario is almost complete as of this writing with some modifications while the congestion scenario is still on-going.

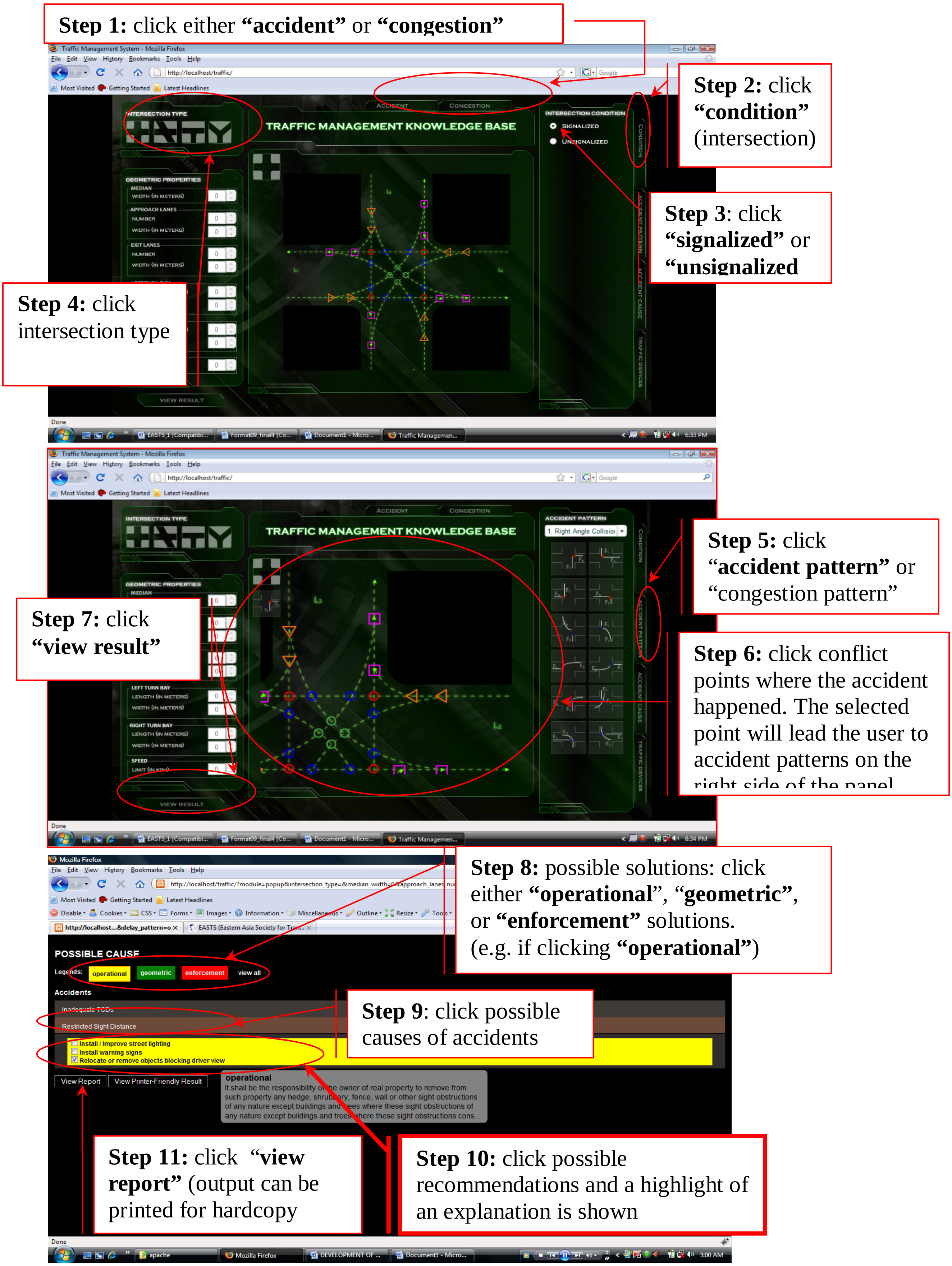

Figure 7.1 Sample interface of the expert system

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