

DEVELOPMENT OF A RURAL ROAD SAFETY AUDIT EXPERT SYSTEM (RRSAES)⁺

Dr. Hussein Ali Ewadh *

Abstract

Road Safety Audit (RSA) is a proactive strategy that aims at treating the cause of traffic-accidents through a formalized examination of existing or future road projects in view of traffic safety principles. Expert system is a promising technique that can turn complex interpretation of auditing examination into simplified and friendly used procedures using power and storage capabilities of computers. This research aims at developing an expert system that can serve as a diagnosis knowledge-based system of traffic-safety condition at rural roads due to the principles of RSA. The expert system deals with the database of safety auditing examination according to checklists extracted from the program of RSA for rural roads in Iraq. The input data is coded in the environment of Microsoft Visual Basic 6, which is tightly integrated with Windows-Me operating system. The developed expert system nominated as Rural Road Safety Audit Expert System (RRSAES) enables auditors to optimize their outputs and maximize the safety benefits of RSA. After interactions with user (auditor) in the auditing course, the system displays the road safety audit indices that indicate the safety condition of road design elements at the audited site.

Key words: Rural Road, Road Safety Audit, Expert System.

المستخلص

تدقيق سلامة الطرق هو استراتيجية وقائية تهدف إلى معالجة السبب في الحوادث المرورية من خلال فحص مدوّن مسبقاً يستند إلى مبادئ السلامة المرورية لمشاريع الطرق المنفذة أو تلك التي ستنفذ مستقبلاً. النظام الخبير هو تقنية واعدة لتحويل التفسير المعقد للتدقيق إلى عمليات بسيطة وسهلة الاستعمال من خلال الطاقة الاستيعابية للحاسوب. يهدف البحث إلى استحداث نظام خبير يكون بمثابة نظام قاعدة معلومات تشخيصي لحالة السلامة المرورية على الطرق الخارجية استناداً إلى قواعد تدقيق سلامة الطرق. يتعامل النظام المستحدث مع قاعدة معلومات لفحص وتدقيق السلامة طبقاً إلى قوائم مستتلة من برنامج تدقيق سلامة الطرق الخارجية في العراق. تم تبويب البيانات المدخلة في بيئة مايكروسوفت القواعد المرئية (Microsoft Visual Basic-6) ضمن برنامج النوافذ (Windows-Me). البرنامج المستحدث والمسمى بالنظام الخبير لتدقيق سلامة الطرق الخارجية يمكن المدققين من ترشيد نتائج التدقيق ويعظم فوائد السلامة الناتجة عن تدقيق سلامة الطرق. بعد التفاعل الذي يحصل بين المستخدم (المدقق) والنظام خلال عملية التدقيق، يعرض البرنامج مؤشرات تدقيق السلامة لعناصر تصميم الطرق على موقع المدقق

Introduction

⁺ Received on 17/1/2005, Accepted on 29/6/2005

^{*} Assistant Prof./ Babylon Technical Institute, Commission of Technical Education

An expert system, also known as knowledge-based system, is defined as an interactive computer program, which documents judgment, experience, intuition, and other information aiming at providing knowledgeable advice [1,2]. The main applications of expert systems may be classified into [3]; diagnosis and / or advisory, design, planning or selection, configuration, data interpretation, scheduling, and training and support. An expert system includes three main components; user interface, inference engine, and knowledge base [4]. The main novel issue that expert system technology has brought to the design of computer systems, is the concept of the “knowledge base” of rules that are kept outside the main program and therefore the more readily managed [5]

Kirby and Montgomery (1987) envisaged an expert system to aid the statistical interpretation of data or of the output of model runs [5]. Such application was considered beyond the capabilities of simple expert systems. In this research, the proposed program makes that envisaging applicable aiming to gain safety audit indices by statistical interpretation of data based on the built-in knowledge base.

. Applications of Expert Systems in Road-Traffic Safety

1-Sayed (1996) developed a diagnosis highway safety expert system. A knowledge-based system is developed to identify the causes and the contributing factors of safety problems at accident-prone locations and to suggest appropriate countermeasures [6]. The output of that diagnosis phase is a set of applicable countermeasures for each accident-prone location and the degree of belief in each countermeasure.

2-Sayed *et al.* suggested developed a highway safety expert system that identifies accident-prone locations and implementing appropriate countermeasures based on the analysis of accident and roadway environment data [7]. The system is able to process a large amount of accident data and enhance existing methods used in highway safety improvement programs.

3-Australian Road Research Board -Transport Research (ARRB TR) had been commissioned to produce a nation-wide demonstration version of the computerized RSA advisory system [8]. The produced system is able to standardize the format and facilitate the managing of RSA reports.

4-Wilson (1999) and Wilson *et al.* (2000) state that the Road Safety Audit checklists which are the primary means used to identify safety problems, can be paper forms or in a computerized “expert system” [9,10].

5-Institution of Transportation Engineers ITE Technical Council Committee (1995) reports that a number of PC-based programs containing checklists or prompts were coming on the market and these would help facilitate the audit process [11].

6-The British Columbia Ministry of Transportation and Highways in conjunction with the University of British Columbia has initiated a project to develop a highway safety expert system that is capable of performing the highway safety improvement programs (HSIPs) [12]

7-Cairney *et al.* (1999) consider adopting of expert systems to assist in carrying out safety audits as one of the promising developments in road safety [13]. The Road Safety Audit Advisory System (RSAAS) is currently being developed. Improvements were achieved :

the checklist display, printing capability, and quality of the scanned references. The expert system was expected to be applied as part of existing road- stage. This enhancement might guide in identification of deficient road design elements, and in the priority process to achieve any improvement.

8-Ewadh (2001) developed a safety audit program including a rating technique to evaluate the safety condition of the rural roads in Iraq [14]. The program includes sets of checklists that govern the decision-making in the road traffic safety. The checklists are produced using “Delphi” method to extract expertise knowledge. Academic and field experts in road traffic engineering represent the source of expertise knowledge. Numerous items and topics included in the developed RSA checklists make it difficult to follow auditing and to display ratings as well. There was no attempt to make use of this expertise knowledge in a technique of expert system.

In summary, there is no attempt to use a technique of rating or safety indices in the safety audit process using expert system. This research is a first attempt to include rating technique in a diagnostic expert system.

. Development of Rural Road Safety Audit Expert System (RRSAES).

There is a lack in expertise and experience in the domain of road-traffic safety and rather road safety audit. As such, of great value is to develop a system that provides expert knowledge base and facilitates the process of auditing in a way easy to follow by auditors with moderate experience and expertise.

The process of knowledge acquisition begins by studying the problem at hand and locating the source of expertise. The knowledge acquisition, which was drawn by Ewadh (2001), includes a credible source for field and academic expertise knowledge [14]. For developing RRSAES, expertise knowledge which is represented by the safety audit checklists, is extracted from the road safety audit program in Iraq [14].

The safety audit checklists are reproduced into rules for building RRSAES system. The rules of road safety audit of rural roads are incorporated into a micro-computer-based package nominated as RRSAES. Figure (1) illustrates the structure of the proposed system. Coding represents the process of embedding knowledge base (database) in the expert system package. The proposed RRSAES is concerned with the use of Microsoft Visual Basic 6 to build a data base system. Microsoft Visual Basic 6 is tightly integrated with Window-ME and uses a powerful programming language, which is Visual Basic language.

RRSAES is a diagnostic expert system that interacts with the user (auditor) in the Road Safety Audit course. In the diagnosis process, the system estimates the safety audit indices of the audited site due geometric design topics, traffic operation topics, and all topics of safety audit checklists. As the main task of the auditors is to identify the safety deficiencies, the advisory phase is limited within offering ranking of the audited sites due to the safety condition. The ranking serves in enhancement of existing methods used in highway safety improvement programs, which are based on Road Safety Audit.

Demonstration of RRSAES System

The following steps demonstrate the sequence in conducting the proposed system RRSAES. The user (auditor) may use the relevant steps to a specified task according to type of road, type of auditing stage, within a specified topic or all topics of safety.

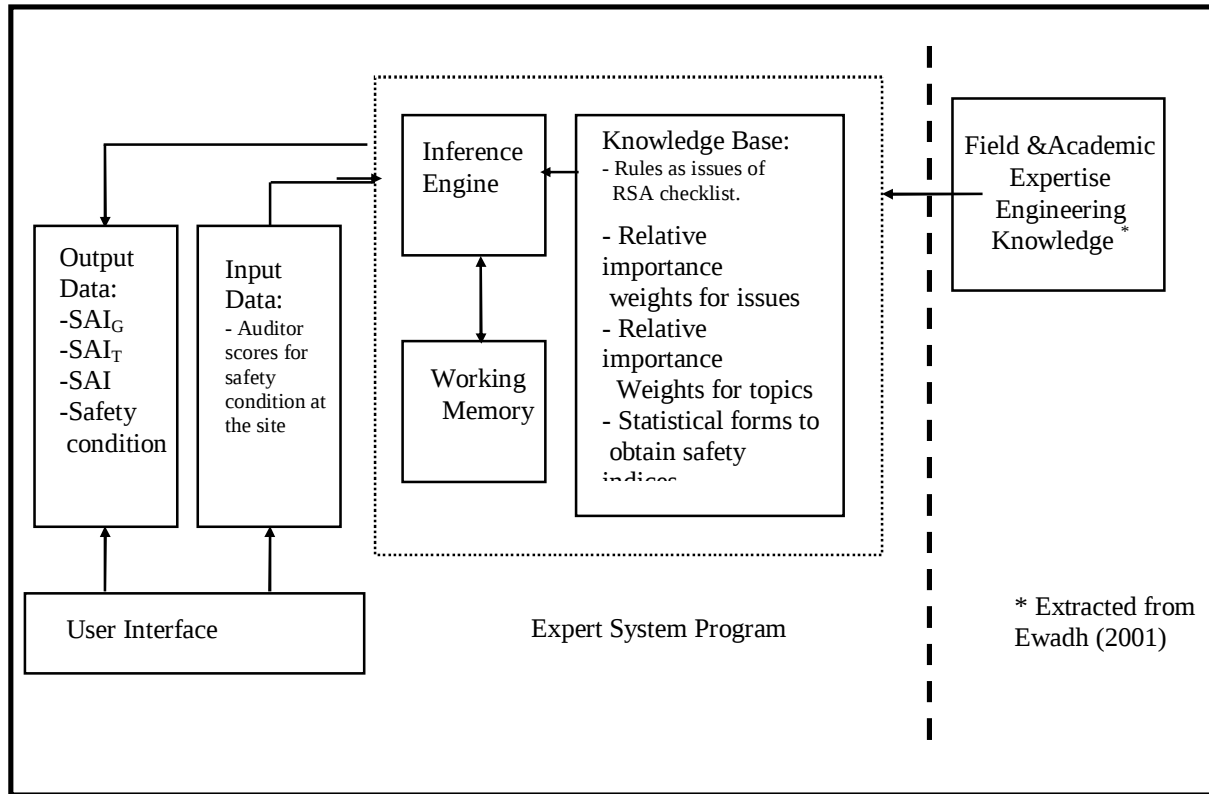


Figure (1) Structure of Rural Road Safety Audit Expert System (RRSAES)

Step 1:

The system operates to present the main menu, which contains the main title of the program “Rural Road Safety Audit Expert System RRSAES”. An icon is provided with arrow in the right direction to continue forward to other menus. Reference: Figure (2-a)

Step 2:

The system documents all information that may be entered by the user (auditor) during an auditing task for a specified site. This information includes site identification, weather, time, average annual daily traffic (AADT), start and finish positioning, date, segment length, name of auditor(s). An icon with arrow in the left direction may be clicked to move backward and another in the right direction to continue forward to other menus. Reference: Figure (2-b)

Step 3:

To make a preliminary guidance about the scale reference of the auditing scores, a separate menu demonstrates five semantic scores. According to these scores, the auditor will identify the safety condition at the site in any stage of auditing. If the auditor inserts a value outside the specified range (1 to 5), the system will display a message of error concerning invalid process. A correction should be done to continue auditing.

Reference: Figure (2-c)

Step 4:

The system offers two options that represent two types of roads; rural roads, which are the main task of the research, and urban roads, which are hoped to be a future expansion of the program. Four stages are also displayed for the auditor to deal with.

Reference: Figure (2-d)

Step 5:

If any icon (in step 4) concerning any stage of audit is clicked, the program will continue to the menu of that stage as follows:

a- Planning Stage:

A planning stage checklist consists of a single form including twenty-two issues. If an issue is applicable at the audited site, the auditor may click the icon of correct arrow and hence, the weight of the issue due to Delphi score will appear in a square preceding the issue. Afterwards, the auditor may insert a suitable semantic score closest to expressing his expertise according to the scale reference in step 3. If an issue is not applicable at the audited site, the auditor may click the (n/a) icon and hence, the weight and score will be Zero automatically. Zero score is by no means representing a high safety deficiency but it means that the program will not consider that issue in weights and calculation of any safety index. After going through the whole form, the system will display a safety-auditing index (SAI) for the site in relation to a reference scale.

b- Design Stage:

A click on design stage icon may be followed by a click on the geometric design icon or the traffic operation icon. Figure (2-e) demonstrates eight topics included in the geometric design features while seven are in the traffic operation as shown in Figure (2-f). A click on an icon of any topic is needed to enter into the relevant checklist form. If any topic is not applicable at a specified site, the (n/a) icon may be clicked. The same technique, which is previously explained for planning stage, is used in other checklists of the design stage. At the end of each checklist of a specified topic, the system will display a partial safety index for the audited site in relation to that topic.

After finishing the geometric design topics and the traffic operation topics, the system will display three indices describing the safety condition of the audited site;

- Safety Audit Index for geometric design features (SAI_G).
- Safety Audit Index for traffic operations (SAI_T).
- Safety Audit Index of the site due to all topics (SAI).

Reference: Figures (2- g)



Scale Reference of Auditing Scores

1

Safety deficiencies are observed in all related features

2

Safety deficiencies are observed in few related features

3

Safety characteristics are at poor condition with high margin of safety

GEOMETRIC DESIGN

SAI_U

n/n

1-a: Driving Expectancy

SAI_U

n/a

1-e: Cross Section :
Roadway Elements

n/n

1-b: Design Consistency

n/n

1-f: Cross Section :
Roadside elements

FINAL REPORT

Final Report Of Rural Road Safety Audit

Name: _____ Site Identification: **ILLW**

Time: _____ Weather: _____

Start

Finish

Position (RS or Side road): _____ Segment Length: _____

Position (RS or Side road): _____

Audited by: _____ Date: _____

c- Pre-opening and Existing Stages:

Within these stages, the auditor is requested to check the site due to some issues. The principal issue in these checklists is a review of the design checklist. As such, the evaluation of the safety condition at the audited site is intended to be due to the design checklist. The auditor as a memory aid reviews other issues that represent supplementary notes in the auditing report. The auditor may click on the icon preceding the issue of design review to enter into the design stage checklists. The safety indices are also displayed for the site in these stages.

Testing of RRS AES

The first check for the system is testing the syntax of the knowledge base including [3]:

- checking that objects and statements are of matching types.
- review and correction of typing errors.
- a case study for prototypical problem.

Objects and statements as well as typing are tested to assure consistence and correctness of the system. Furthermore, calculation of safety indices which is manually previously done is conducted to test the correctness of the system's structure.

The auditor judgments, which are outside the system, may be changed frequently. This may affect the testing process of the developed system. Assumption that the auditing is done perfectly, is a necessary criterion to achieve a sound testing. One section at a two lane- two-way highway of Baghdad-Baaquba road is taken as a real life site that has particularly a pre-defined safety deficiency according to residents near to the site. The system after conducting an auditing course to the site, displays the following safety audit indices:

$SAI_G = 2.1$ (Safety deficiencies are observed in few related geometric design features).

$SAI_T = 1.2$ (Safety deficiencies are observed in all related traffic operation features).

$SAI = 1.7$ (Safety deficiencies are observed in few related geometric design and traffic operation features).

The displayed indices are compatible with the accident experience at the site. A large-scale application for the system is expected to test correlation between the safety indices and the accident experience at the audited roads

Conclusions

1-Knowledge base, which is included in the developed expert system, RRSAES, is acquired from credible sources and thus can be used as a decision support system. The system can also be used to train new personnel with little or no expertise in road traffic safety.

2-The developed expert system is capable of handling single topic of safety in geometric or traffic operation as well as different combinations of topics.

3- The developed expert system provides an environment of friendly concept, which is necessary for the intended users, as they may have little or no experience in programming languages.

4-The developed expert system provides safety audit indices that help the users (auditors) to make a final report based on the safety condition. Making a semantic scoring for the audited sites will enhance the process of potential improvement in some sort of priority due to the developed indices. In addition, these indices serve as ranking tool in enhancement of existing methods used in highway safety improvement programs, which are based on Road Safety Audit.

5-The developed expert system is flexible and open for any future updating such as changing built-in weights for issues, addition of issues or topics, and any other modification.

6-Although the developed expert system application has been aimed at Iraq there is ability to adapt and filter the flow of knowledge to meet the needs for other developing or even developed countries. An organized reviewed Delphi process can update the knowledge base within the same structure of the system. In addition, urban roads can be considered for a future research.

References:

1. Gasching, J., Reboh, R., and Reiter, J. *Development of Knowledge-based System for Water Resources Problems*. Technical Report SRI Project 1619, SRI International, Stanford, Calif, 1981.
2. Hanna. P.B. "Knowledge-based Advisory System for Flexible Pavement Routine Maintenance". *Canadian Civil Engineering*, Vol. 20, pp. 154-163, 1992.

3. Allwood, R.J. *Techniques and Applications of Expert System in The Construction Industry*. Ellis Horwood Series in Civil Engineering, 1st edition, England, 1989.
4. Harvey, J.J. "Expert Systems: an Introduction". *International Journal of Computer Applications in Technology*. Vol. 1, No. ½, pp. 53-60, 1988.
5. Kirby, H.R., and Montgomery, F.O. "A Rule-based Approach for Traffic Signal Design". *Civil Eng. Syst.* Vol. 4, No. 3, pp. 20-26, 1987.
6. Sayed, T. "The Highway Safety Expert System: Diagnosing Accident Prone Locations". *Civil Eng. Syst.*, Vol. 14, pp.251-267, 1996.
7. Sayed, T. and Navin, F. "Highway Safety Expert System: A New Approach to Safety Programs". *Proceedings of The International Conference on Application of Advanced Technologies in Transportation Engineering ASCE*. New York. USA, pp. 346-362, 1996.
8. Appleton, I.. "Australia & New Zealand Experience". *ITE 2000 Annual Meeting*. Washington D.C., U.S, 2000.
9. Wilson, E.M.. "Tailoring Road Safety Audits for Local US Applications". *Proc. Traffic Safety on Two Continents 10th International Conference*. Malmo, Sweden. 13A, Part 6, pp. 177-188, 1999.
10. Wilson, E.M. and Lipinski, M.E. "The Use of Road Safety Audit by Local Agencies". *ITE 2000 Annual Meeting Compendium*. Washington D.C. U.S, 2000.
11. ITE Technical Council Committee 4S-7. "Road Safety Audit: A New Tool for Accident Prevention". *ITE Journal*, Vol. 65, No. 2, pp. 15-19, 1995.
12. Sayed, T., Navin, F, and Abdelwahab, W.M. HA "Countermeasure Based Approach for Identifying and Treating Accident Prone Locations". *Canadian Journal of Civil Engineering*, Vol. 24(3), pp. 683-691, 1997.
13. Cairney, P., Tziotis, M., and Swadling, D. "Promising Development in Road Safety". *ARRB Transport Research*. pp.1 to 12, 1999.
14. Ewadh, H. A. *Development of Rural Road Safety Audit Program in Iraq*. Ph.D. Thesis, Engineering College, Al-Mustansria University, Baghdad, Iraq, 2001.