Hindawi
Complexity
Volume 2024, Article ID 9836065, 1 page
https://doi.org/10.1155/2024/9836065

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Retraction

Retracted: An Educational Web-Based Expert System for Novice Highway Technology in Flexible Pavement Maintenance

Complexity

Received 23 January 2024; Accepted 23 January 2024; Published 24 January 2024

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This article has been retracted by Hindawi following an investigation undertaken by the publisher [1]. This investigation has uncovered evidence of one or more of the following indicators of systematic manipulation of the publication process:

(1) Discrepancies in scope
(2) Discrepancies in the description of the research reported
(3) Discrepancies between the availability of data and the research described
(4) Inappropriate citations
(5) Incoherent, meaningless and/or irrelevant content included in the article
(6) Manipulated or compromised peer review

The presence of these indicators undermines our confidence in the integrity of the article's content and we cannot, therefore, vouch for its reliability. Please note that this notice is intended solely to alert readers that the content of this article is unreliable. We have not investigated whether authors were aware of or involved in the systematic manipulation of the publication process.

In addition, our investigation has also shown that one or more of the following human-subject reporting requirements has not been met in this article: ethical approval by an Institutional Review Board (IRB) committee or equivalent, patient/participant consent to participate, and/or agreement to publish patient/participant details (where relevant).

Wiley and Hindawi regrets that the usual quality checks did not identify these issues before publication and have since put additional measures in place to safeguard research integrity.

We wish to credit our own Research Integrity and Research Publishing teams and anonymous and named external researchers and research integrity experts for contributing to this investigation.

The corresponding author, as the representative of all authors, has been given the opportunity to register their agreement or disagreement to this retraction. We have kept a record of any response received.

References

[1] A. Milad, N. I. M. Yusoff, S. A. Majeed et al., "An Educational Web-Based Expert System for Novice Highway Technology in Flexible Pavement Maintenance," *Complexity*, vol. 2021, Article ID 6669010, 17 pages, 2021.

Hindawi
Complexity
Volume 2021, Article ID 6669010, 17 pages
https://doi.org/10.1155/2021/6669010

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Research Article

An Educational Web-Based Expert System for Novice Highway Technology in Flexible Pavement Maintenance

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Received 4 January 2021; Revised 28 January 2021; Accepted 8 February 2021; Published 24 February 2021

Academic Editor: Zhihan Lv

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Nowadays, higher education worldwide is affected by the COVID-19 pandemic. It has affected students' attendance in the universities and causes universities to close down in more than 190 countries. On the other hand, novice engineers studied only a few lectures related to highway engineering. Their lectures have included very little knowledge about asphalt pavement construction as highway engineering consists of many areas that are not studied in detail during their studying years subject to their traditional education. Due to all mentioned, a new drive to promote online learning paves the way to evaluate our future approach to curriculum development and delivery of educational materials for engineering courses. However, experts can offer solutions to these problems using their past experience. Hence, a system that allows experts to share their experience with other engineers after completing a project is needed. Nevertheless, the web-based expert system for maintaining flexible pavement problems in tropical regions (ESTAMPSYS) designed in this study is a novel concept. Prior to developing this system, the need for such a system was determined through literature review and validated through a questionnaire survey. Experts were interviewed, and a questionnaire survey was conducted to construct the knowledge base of the system. Knowledge was presented as rules and coded in software through PHP programming. Web pages that support the user interface were designed using a framework that consists of CSS, HTML, and J-Query. Furthermore, the system was tested by an array of users engaged in highway engineering, namely, experts, teaching experts, novice engineers, and students. The mean values of the overall system evaluation performed by 20 users using a five-point Likert scale were 4, 4.5, 3.75, 4.25, 5, 4, and 3.5. Expert and user satisfaction prove the effectiveness of the proposed system.

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1. Introduction

Nowadays, higher education worldwide is affected by the rapidly evolving COVID-19 pandemic [1]. This pandemic has affected student attendance in universities worldwide and causes universities to close down in 191 countries as of 20 April 2020 [2]. Due to the severity of the COVID-19 pandemic's threat to human health, a new drive to promote online learning paves the way to evaluate our future approach to curriculum development and delivery of educational materials for engineering courses. Hence, online learning is crucial for the teaching and learning of students in isolation [3]. Moreover, expert systems in education (ESEd) attempt to create data and find data to solve problems. In the process, this system will help the student based on expertise. It allows the user to use the computer system and use the computer in a specific context. The world's education uses expert systems to help the learning

process. [4]. However, the ESEd involves mostly advancements in "computers," which can carry out cognitive tasks that are generally related to human minds, especially problem-solving and learning [5].

Additionally, the novice highway engineers' courses only include limited information about asphalt pavement maintenance as highway engineering consists of many domains that cannot be covered thoroughly during course study. In traditional education, all students are provided with the same material [6]. An identical teaching methodology and rate of progress are utilized during their course [7]. After graduation, the engineers encounter many problems during site maintenance as they do not have adequate information. Hence, creating an academic knowledge-based system in this field that consists of a knowledge base with descriptions, causes, preventive measures, and solutions to issues arising is necessary as flexible pavement deterioration is a complicated process that involves not only structural damage but also numerous functional distress on the asphalt pavement [8]. It results from the climate, materials used, and quality of maintenance [9, 10].

Correct maintenance performance is the best approximate predictor of normal conditions due to the significant complexity of the pavement surface deterioration process [11, 12]. However, there is a shortage of skilled individuals who possess specialized training and expertise in evaluating pavement [13]. Executive decision-makers and pavement engineers in the highway sector face the problem of maintaining and reinstating pavements to a state whereby they are serviceable [14]. A significant amount of engineering judgment is required for a diagnosis of pavement distress. However, this skill is rare, particularly in maintaining flexible pavements in Malaysia and other tropical countries. When implemented effectively, maintaining pavement is one of the most cost-effective, socially, and environmentally sustainable means of management to avoid pavement deterioration [15, 16].

This study aims to build a web-based educational system for novice engineers and highway students to solve potential problems in maintaining pavements. This system will help them to study how to resolve problems as they appear. This paper discusses the development and evaluation stages of the novice system, namely, acquiring knowledge, representation of knowledge, system building, and verification and validation of the system. A literature review acquires initial knowledge. Then, expert knowledge is obtained through a questionnaire survey and interview. This knowledge is documented, analyzed, represented, and converted to computer software using the PHP programming language. The system has been verified and validated by stringent testing, namely, user satisfaction testing, unit testing, and integration testing using questionnaires. The developed system renders expert knowledge about decision-making approaches for maintenance issues in restoring flexible pavements using an adaptable and straightforward interface to make the training process simpler for users. The proposed system can be repeatedly utilized by novice engineers and civil engineering students in learning the study domain. Furthermore, the web-based system is developed for pavement maintenance to address the following:

(i) A decision-making process that considers flexible pavement maintenance must be facilitated and successfully applied in tropical weather conditions

(ii) Maintenance of flexible pavements can be expensive if problems are not controlled or avoided promptly

(iii) Novice highway engineers cannot manage such issues as selecting the most appropriate maintenance treatment for deteriorated pavements

(iv) The computerizing and transferring the knowledge from current experts to the next generation of engineers are problematic in the maintenance field

2. An Overview of Educational Expert Systems

The expert system boosts decision-making processes, which are increasingly demanded by new generations' uses for educational purposes. As such, there has been growing interest in explainable educational system methods to track human-interpretable decision steps originating from algorithm [17–20]. In addition, advancements have reached the stage in which a knowledge-based expert system is nearly as competitive as a human expert in specialized problem domains such as Computing, Engineering, Geology, Education, Computer Systems, Science, Knowledge Engineering, and Medicine [21]. Education Systems have utility in applications involving diagnosis, maintenance, instruction, planning, and prediction [22, 23]. Moreover, such information can be utilized to address distinct educational issues involving the development of adaptive systems, the attraction of novice engineers and students' experiences, and obtaining recommendations. Over time, there has been the use of distinct machine learning approaches to assess these data. However, only recently, deep learning approaches' usage was found in educational expert systems [24]. In order to enhance planning and maximize this educational approach's advantages, the e-learning system's success depends on growing user satisfaction. In the asphalt pavement industry, few systems have ever been instituted. An example of such a system is the RC-MSS, a prototype system that aids pavement designers in terms of selecting the most economical materials [25]. A knowledge-based expert system was developed by Deprizon et al. in 2009 to aid designers in structural designs for asphalt pavement layers [26]. In order to enhance the choice of routes during road geometric design stages, an expert system was developed by Syamsunur et al. [27]. This confirmed that a system was absent in the area of pavement maintenance [28]. Even though these systems had suitable educational systems, their lack of tests within an educational environment has discouraged developers from utilizing them. Alternatively, the system that was generated in this investigation was assessed within an educational environment. Notwithstanding, the evaluation outcomes proved the system's validity. This makes it a novel system within the pavement industry. Likewise, such similar assessments can be carried out on other systems to assess

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their validity as educational systems. Sufficient alterations may be necessary to modify these systems concerning the users' recommendations.

3. Developing Web-Based Expert System

The methodology used to develop ESTAMPSYS involved three steps. The first step was determining the demand for the system based on literature reviews and the usefulness of this requirement by a questionnaire survey among human experts in the field of flexible pavement. Secondly, pavement distress problems that pavement engineers may face while carrying out professional duties were specified through a knowledge acquisition process. In the next step, ESTAMPSYS was constructed, and the general knowledge representation, which included structures of different plans of the system and system computerization, was described. Lastly, verification, validation, and evaluation of ESTAMPSYS were done as shown in Figure 1.

In this step of the methodology, a primary questionnaire survey was adopted to examine the need for a web-based expert system. This survey was conducted among 16 pavement engineers with various levels of experience and specific with four research questions:

Q1: Developing a web-based expert system for maintaining flexible pavement is essential for road asphalt pavements.

Q2: Engineers and trainees could use the system to know the details of the problem domain.

Q3: Engineers could address road pavements by using the exchange system of experiences.

Q4: The number of experts in the domain of flexible pavements is insufficient to accommodate the web-based system's need.

The respondents were required to rate their answers using a five-point Likert scale where one represents "strongly disagree" and five represents "strongly agree." The response answers are summarized in Table 1. Table 1 displays the mean values and standard deviations (SD) of the questionnaire's statements, as presented in

$$\mathrm{SD} = \sqrt{\frac{\sum (x-\mu)^2}{N}}, \tag{1}$$

where SD is the standard deviation, x is each value, μ is the average of all values, and N is the number of values.

The results obtained revealed that the mean values related to the statement questions are 4.25, 4.05, 4.65, and 4.15. As shown, the participants confirmed the demand for developing the flexible pavement web-based expert system.

3.1. Knowledge Acquisition and Categorization. Eliciting knowledge is an essential stage in formulating an intelligent system [29]. A knowledge-based system will need a comprehensive analytical approach, which is time-consuming and complicated [13, 14]. Knowledge acquisition denotes collecting knowledge from different resources [30]. Usually, manuals, books, guidelines, and other written sources related to the problem domain are reviewed to create an initial knowledge engineering methodology. Besides, more knowledge is acquired from domain experts. Knowledge from both sources can be combined and examined together [31]. This study's groundwork knowledge is obtained from a wide range of reviews from different sources to realize the problems faced at different maintenance stages. This knowledge is then analyzed and improved repeatedly to serve as the foundation for the final knowledge base. The system is capable of specifying the problems with their remedies. A highway engineering student or novice can learn how to select the best treatments for these problems by using this system repeatedly. Table 2 displays the problems according to their category. Trainee engineers can diagnose the problem, visually or by testing based on its features to adopt the correct solution with the help of the system.

3.2. Selection of the Building Tool for ESTAMPSYS. A framework that consists of HTML, CSS, and J-Query is used to create web pages that support the user interface. A responsive web interface is ensured by using the bootstrap framework to facilitate browsing on mobile devices. On the server-side, a proxy or agent processes the data extracted from the webpages. Processing is carried out on the server-side by programming hypertext preprocessor (PHP), which is a high-level programming and easy to use scripting language that does not need extensive understanding of object programming required to use C++, C#, or Java. PHP is selected because it is easy to learn, scalable, and object-oriented, and fixing problems is simple. Nowadays, PHP provides support for most web servers. The database utilized for storing the acquired knowledge is a structured query language (MySQL), a proprietary, nonstandard implementation of entry-level SQL. The expert system supports a GUI Interface. Hence, users with minimal expertise in data management can access it easily. Users are unaware of their dependency on the MySQL database and do not require any understanding of structured query language (SQL). Thus, novice users can acquire and enhance their knowledge related to maintaining flexible pavements.

3.3. Knowledge Representation. The web-based expert system's knowledge representation base consists of IF-THEN rules programmed in PHP that access necessary knowledge data stored in the MySQL database. More than 200 rules were created according to the flexible pavement distress type and implemented using PHP to create a rapid prototype system (RPS) with a complete full system (CFS). The IF-THEN rules are an efficient and useful technique to allow forward chaining within the graphical inference engine whereby the decision-making process is initiated depending on the data entered by the user [32]. This interaction with the user terminates when the following goal is achieved. The following examples of system rules are used in the expert system.

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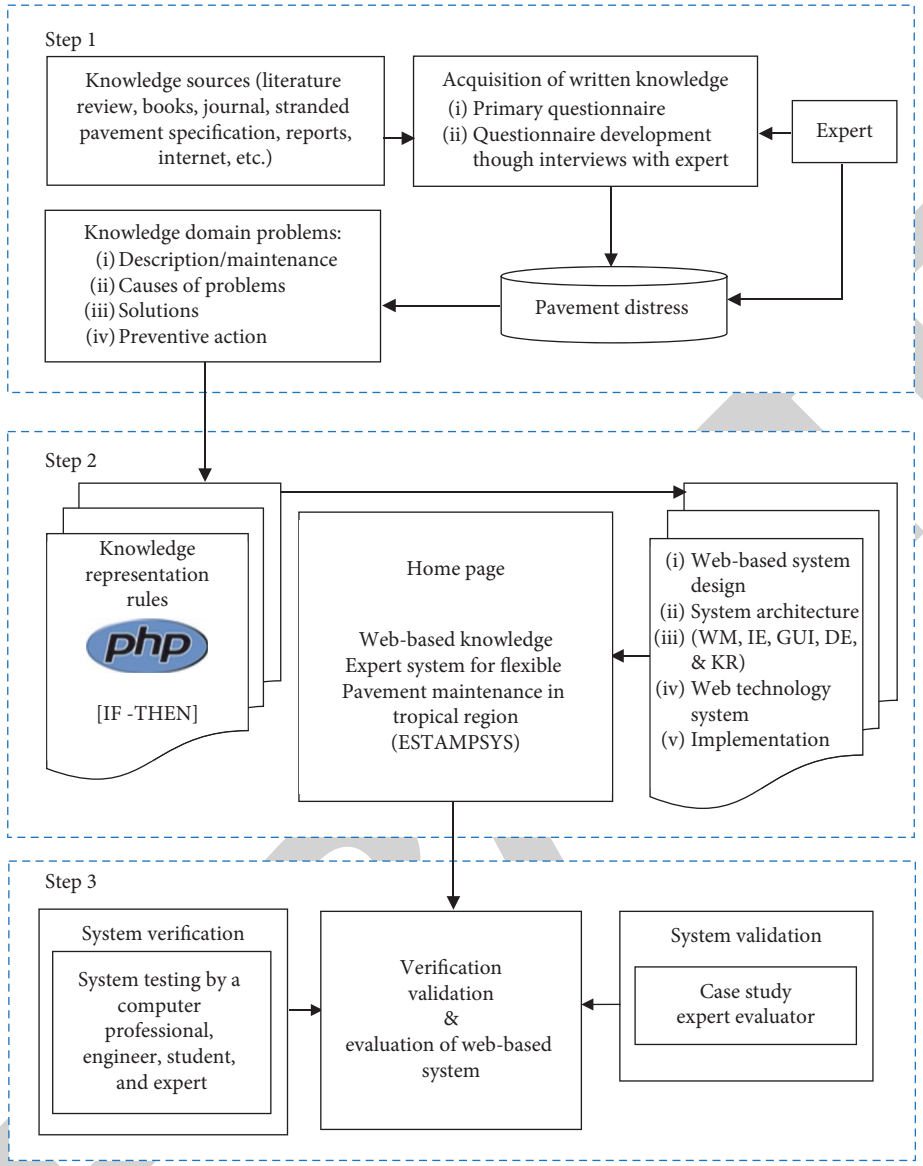

Figure 1: Flow chart of the system construction.

Table 1: Questionnaire results for the importance of the system building process.

Question No	Mean value	Standard deviation (SD)
Q1	4.25	0.70
Q2	4.05	0.65
Q3	4.65	0.45
Q4	4.15	0.85

3.3.1. Single Distress Problem Rule. IF (distress observed is single distress) AND (severity of transverse cracking is low) AND (density of transverse cracking is rare) AND (road functional class is minor) AND (climate is tropical rainforest) THEN (Crack_ Routing_ and _Sealing).

3.3.2. Combined Distress Problem Rule. IF (distress observed is combined distress) AND (severity of raveling potholes is low) AND (density of raveling potholes is rare) AND (minor road functional class) AND (tropical rainforest climate) THEN (Spray_ Injection_ Patching).

3.4. ESTAMPSYS Structure. Two major sections make up the expert system. The development environment utilized to insert expert knowledge into the expert system environment makes up the first section. Another part is the consultation environment utilized by nonexpert users to obtain information shown in Figure 2 which is the structure and relationship among the parts of the primary system.

3.5. ESTAMPSYS Knowledge Base

3.5.1. Module to Represent Flexible Pavement Distress. Development of different techniques and exploration of treatment techniques are essential stages prior to discovering

Table 2: The categorization of domain classification problems.

Category	Parameters	Description
Flexible pavement distress	Type of distress observed	Pavement distress is of many types in flexible pavement evaluation and varies from one agency to another. Malaysia includes 15 types of distress in its survey measures based on JKR (2008). Single or combined distresses.
	Severity of distress	The severity of distress appearance indicates how poor a problem is based on low, medium, and high ratings.
	Density of distress	Density characterizes the percentage of the pavement surface covered by distress based on the density rating (rare, intermittent, frequent, and extensive).
	Road functional class	Functionally related road parameters are classified as major and minor.
	Climate change	Climate change depends on the rainforest or dry climate.

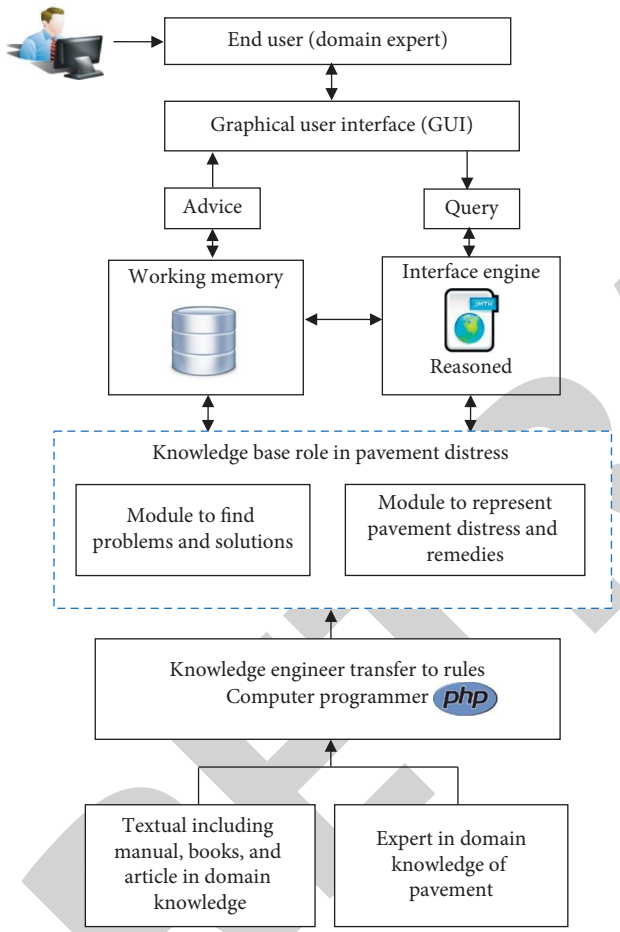

Figure 2: ESTAMPSYS structure and relationship among the parts of the primary system.

solutions to distress issues. In this case, information on flexible pavement distress is collected from available sources, including pavement maintenance manuals, reports, related books, and journal articles. Consultation with domain experts also improves the overall knowledge of the subject and has provided successful outcomes in flexible pavement distress studies that have been conducted in different locations with consideration of tropical regions. Notably, the web-based expert system's knowledge base can be improved via the implementation of the instructions, the design process, and advantages and drawbacks. Transverse cracking pavement (TCP) results from expansion and contraction due to temperature changes and shrinkage of the asphalt binder with aging (Table 3). These cracks may extend partially or entirely across the roadway.

3.6. Working Memory. Since the working memory undergoes a continuous update, it is an expert system's dynamic part. The holding of information related to distinct domain issues is the role of the ESTAMPSYS's working memory. As such, in order to decide appropriately, information that is obtained from the working memory is utilized by the ESTAMPSYS's inference engine together with the knowledge base's regulations. The examples of information for utilizing the ESTAMPSYS's modules that are held in the working memory for distinct ESTAMPSYS knowledge-based modules are shown in Table 4.

3.7. Graphical Interface Engine. The GUI controls the direct interaction between the user and the web-based system. GUI is a method to communicate with the user. It provides facilities, such as lists of the graphical interface, for the dialogue's success to the user. The user interface's responsibility is to transform the system of internal representation (which the user does not understand) into a form of user concept. A user interface that is designed appropriately is able to reduce the number of errors throughout the expert system's usage. Besides, it can also aid users in familiarizing themselves with the expert system at a faster rate. The ESTAMPSYS's GUI is clear, attractive, and user-friendly. It can also enable access to the system's use. As illustrated in Figure 3, the interface or design window comprises few controls, including combos, labels, drop-down lists, videos, checkboxes, text boxes, buttons, option buttons, image boxes, and command buttons.

3.8. ESTAMPSYS Coding. ESTAMPSYS is user-friendly and possesses a powerful web-based that was developed based on front-end and back-end web programming languages. The front-end user interface system is developed using HTML, CSS, and JavaScript. To keep the interface design intuitive, J-Query, a JavaScript library, is added to the design process. However, the server is powered by the use of PHP and MySQL. Many months of development resulted in a sophisticated web-based expert system for road pavement

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Table 3: Criteria for the maintenance of transverse cracking.

Evaluation		Road functional	Treatments' techniques	Pavement condition
Severity	Density			
Low	Rare	Minor	Routing and seal >6 mm	Corrective
		Major	Routing and seal >6 mm	Corrective
	Intermittent	Minor	Routing and seal >6 mm	Corrective
		Major	Routing and seal >6 mm	Corrective
	Frequent	Minor	Routing and seal >6 mm	Corrective
		Major	Routing and seal >6 mm	Corrective
	Extensive	Minor	Routing and seal >6 mm	Corrective
		Major	Routing and seal >6 mm	Corrective
Medium	Rare	Minor	Routing and seal >6 mm	Corrective
		Major	Routing and seal >6 mm	Corrective
	Intermittent	Minor	Routing and seal >6 mm	Corrective
		Major	Routing and seal >6 mm	Corrective
	Frequent	Minor	Chip seal	Preventive
		Major	Chip seal	Preventive
	Extensive	Minor	Reconstruction (CIPR)	Emergency
		Major	Reconstruction (CIPR)	Emergency
High	Rare	Minor	Crack fill	Corrective
		Major	Crack fill	Corrective
	Intermittent	Minor	Chip seal	Preventive
		Major	Chip seal	Preventive
	Frequent	Minor	Reconstruction (CIPR)	Emergency
		Major	Reconstruction (CIPR)	Emergency
	Extensive	Minor	Reconstruction (CIPR)	Emergency
		Major	Reconstruction (CIPR)	Emergency

Table 4: Examples of facts contained in the working memory.

Module	Measurement	Parameters	Option subparameters
Flexible pavement distress	Single distress	Severity	Low
			Medium
			High
		Density	Rare
			Intermittent
			Frequent
			Extensive
	Combined distress	Road functional class	Minor
			Major
		Climate condition	Tropical rainforest

maintenance that was ready for sharing of knowledge. A list of ESYAMPSYS coding is presented in Figure 4.

3.9. Operating ESTAMPSYS. Novel approaches to share and distribute knowledge are possible via the development of technologies for Internet access and the expert systems field. Nonetheless, ESTAMPSYS is essentially an expert system that is based on the web, in which access is possible via keying in the ESTAMPSYS's address into the Internet browser's address bar. The interface window (start page) opened via ESTAMPSYS includes data regarding the system developer and the system, as shown in Figure 5. Knowledge is accessible to users online. Large data sets are also accessible in the organizations' intranet and also within web databases. In ESTAMPSYS, users are allowed to assess the treatments suggested by the system according to the source of flexible pavement distress.

3.9.1. Toolbox of Flexible Pavement Distress. In ESTAMPSYS, a powerful page toolbox is built to help the user select different measures for flexible pavement categories, which are classified according to the distress that has been previously described. Through clicking on each target category, web-based users can select flexible pavement distress based on their roles. Each category has characterization, features, typical examples, and maintenance considerations. A snapshot of the toolbox that is meant for flexible pavement distress with their categories is depicted in Figure 6. This toolbox contains 13 subcategory problems for single distress and 5 for combined distress with their solutions.

(i) *Toolbox of Single Distresses Problems*. In this stage for selecting single distress, different category measures are classified according to distress type. Figure 6 depicts the toolbox for the problem of selecting parameters following the pavement's degeneration.

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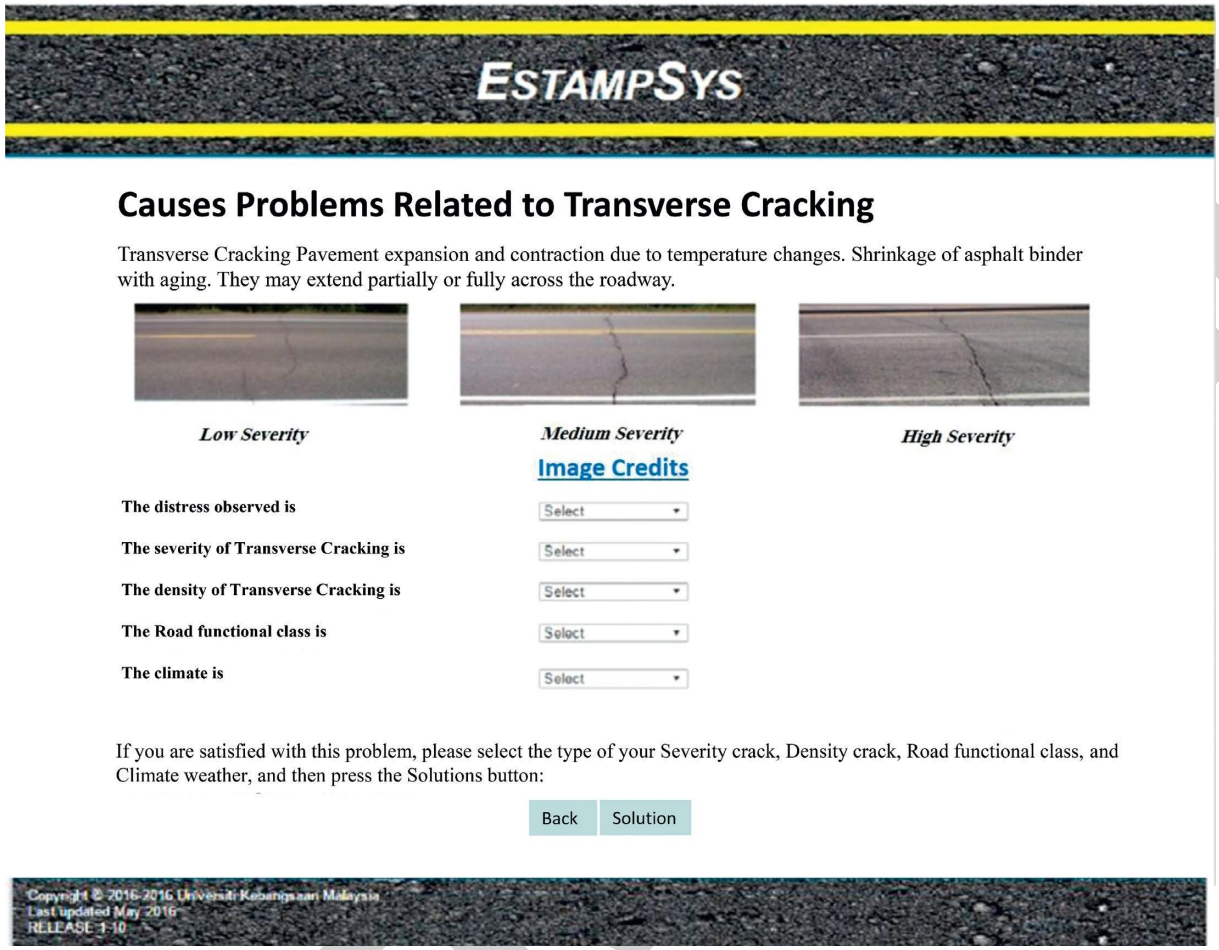

Figure 3: Example of the ESTAMPSYS design inference window.

The information of single distress with criteria presents a list of five groups, which were explored previously. This section allows users to pinpoint the issues and distress found, density, climate, severity, and functional road class. The web-based expert systems' users can see a description of issues, which can help users and engineers determine problems and their effect on maintenance.

(ii) *Toolbox of Combined Distresses Problems*. In this step to select combined distress, different category measures are classified according to distress type. Figure 7 depicts the toolbox for the problem of selecting parameters following the pavement's degeneration. A list of 5 categories, which have been described previously, is presented in the information of single distress with criteria. Users can pinpoint the distress and issues seen, functional road class, climate, density, and severity. The issues' descriptions are observable by the web-based expert system's user. This aids the engineers and users in identifying the issue and its impact on maintenance. For instance, as illustrated in Figure 8, should the issue highlighted be combined transverse and alligator cracking, rare density, minor functional road class, tropical rainforest climate, and low severity, the rectifying approach presented hereinafter would be cold mix-patching.

3.9.2. Toolbox of Treatment Techniques. ESTMAPSYS promotes treatment techniques for decision-makers for the development of reasonable and reliable recommendations to end-users. The treatment techniques are for preventive and corrective maintenance on flexible pavements. When pavement preservation treatments are correctly applied, the pavement's life is extended in an excellent overall condition. Using the correct treatment and applying it correctly for pavement preservation extends the life of the pavement. The use of the right treatment on the right road at the right time is shown in Figure 9. On this page, 16 hyperlinks for the types of treatment techniques serve as a useful resource for engineers and novices.

3.9.3. Toolbox of Green Measurements. In the green measurements, the arrangement of asphalt pavements is maintained comprehensively to look after such pavements. An approach that treats the correct pavement at the appropriate time with the right treatment and proper means is

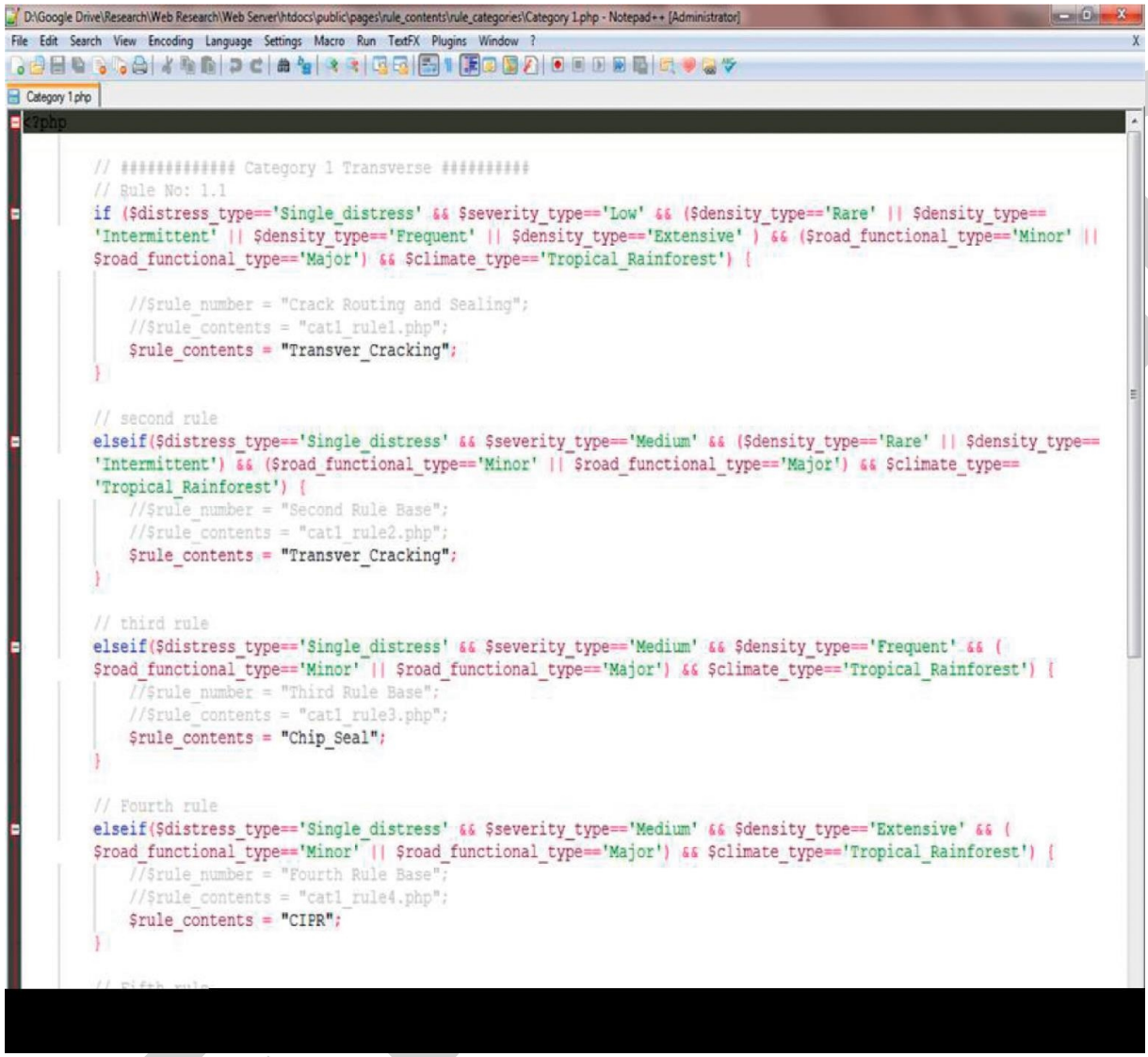

Figure 4: Example of the ESTAMPSYS code window.

necessary for ethical decision-making regarding roads. Implementing these procedures and treatments by the decision-maker in the surface treatment process results in reasonable and reliable recommendations to end-users; treatment methods can be used for preventive and corrective maintenance on flexible pavements. When appropriately applied, pavement preservation treatments can extend pavements' service life, as shown in Figure 10.

A beneficial tool for novices and engineers would be the nine hyperlinks for the green measurement page types. For instance, the performance of a specific asphalt pavement appears via clicks on hyperlinks. The strategy shows the benefits of green asphalt pavement remediation and how this remediation extends pavements' service life by 15–20 years. The detailed procedure is shown in Figure 11.

Moreover, the strategy considers the impact such remediation has on nature. The focus is on dealing with green asphalt pavement maintenance and being environmentally friendly during treatment selection. This approach was and is still the way by which many agencies maintain their roads. Over the years, in collaboration with the asphalt industry, organizations began developing and implementing green or sustainable road maintenance approaches. The reason for this switch was not only for environmental benefits but also because lasting treatments are cost-effective. Asphalt pavements are green because, in addition to old asphalt, they also integrate other waste products into the mix to produce a new one.

4. Results and Discussion

There is a discussion about the creative methods of improving treatment selection and concepts of web-based systems for flexible pavements. Nonetheless, the fields of distress issues and flexible pavement still have loopholes. Novel methods to highlight issues and their respective solutions are utilized in this research. Useful feedback from respondents can be collected by developers, especially in terms of content

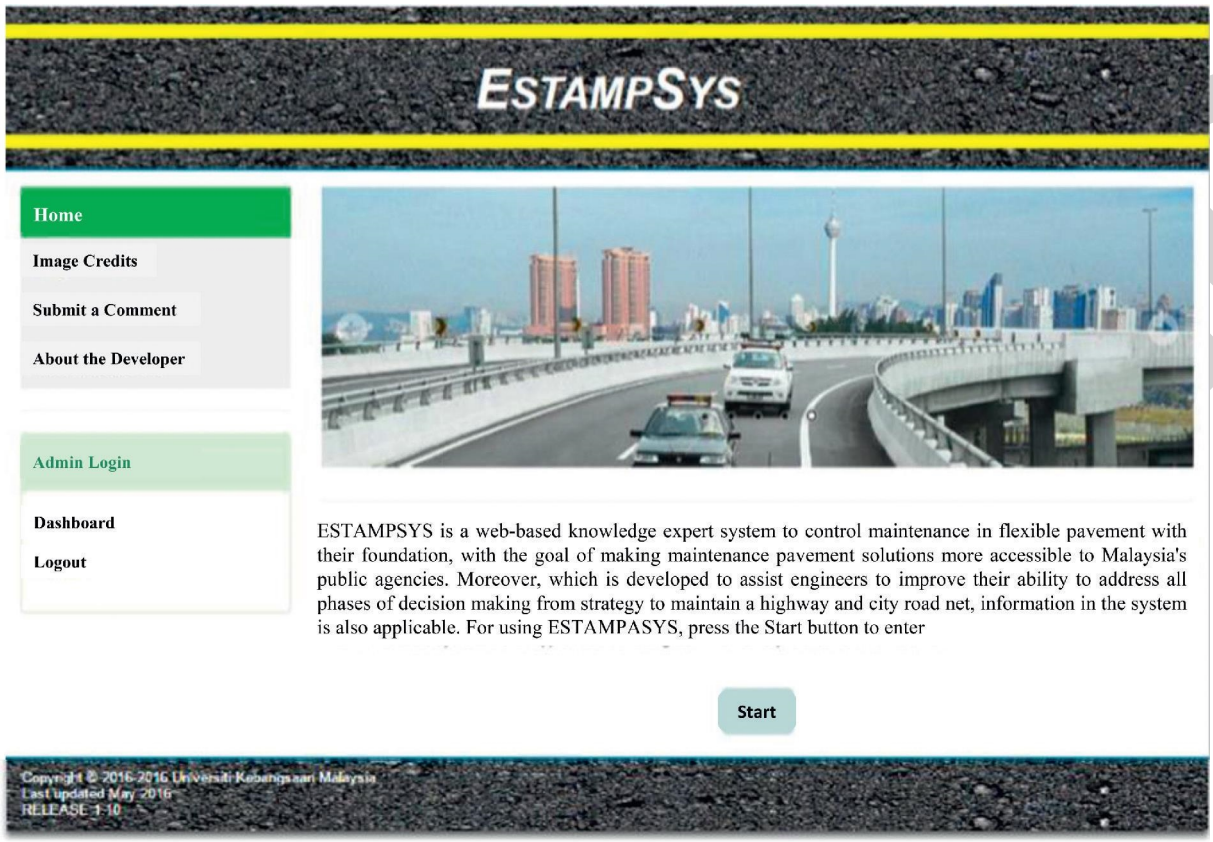

Figure 5: Screenshot of the ESTAMPSYS start page.

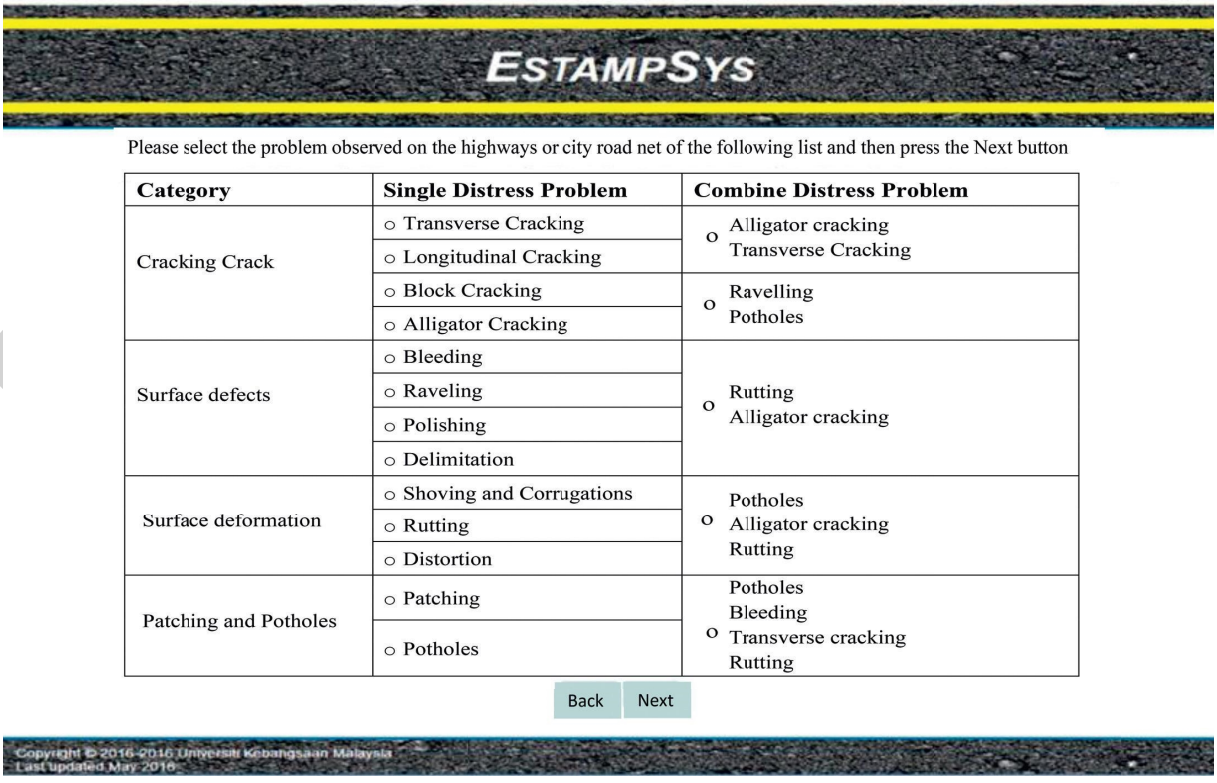

Figure 6: Screenshot of the flexible pavement distress page.

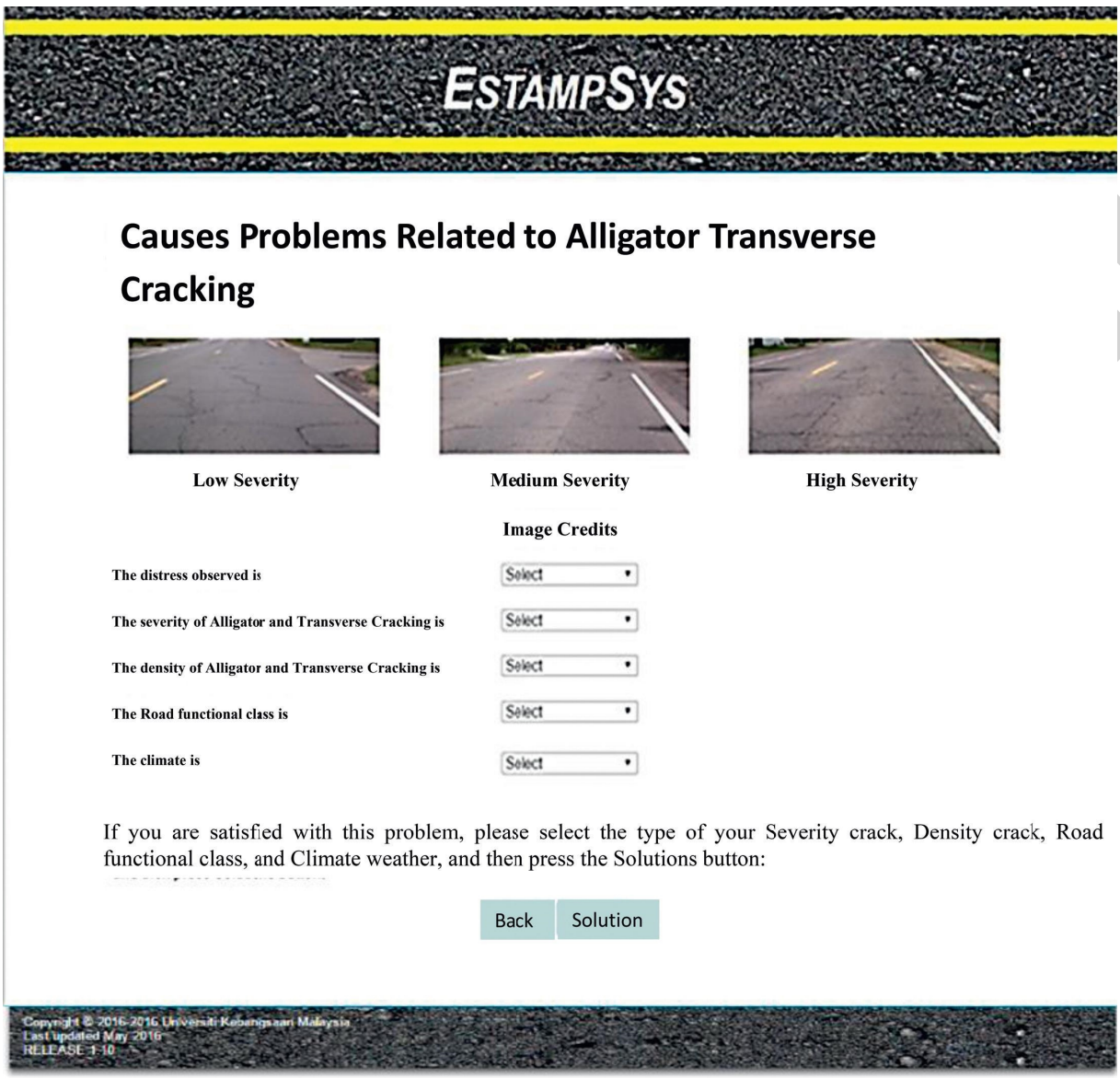

Figure 7: Screenshot of the combined distress problem page.

enhancement and limitation of system domains' boundaries. Distinct scenarios may benefit from a clear comprehension of past investigations' weaknesses and strengths. Furthermore, the comparisons between ESTAMPSYS as an expert system for flexible pavements' maintenance using treatment selection strategies and related expert systems whose functions and features are analogous to ESTAMPSYS are achieved. Comparisons between ESTAMPSYS and other expert systems are highlighted. Three types of expert systems were selected for comparison with ESTAMPSYS; these three are flexible pavement maintenance expert systems, treatment recommendation/selection expert systems, and pavement management expert systems.

4.1. Comparison with ROSE Expert Systems. ROSE facilitates the choice of suitable treatments for cracks in asphalt pavements in cold areas. Forty-one variables of data transmission, which includes pavement distress type, pavement serviceability, and age, are integrated by ROSE. ROSE's decisions are based on the width and amount of cracks. Besides, pavement serviceability is also influenced by pavement serviceability, presence of other pavement distress (rutting, raveling, flushing, etc.), type of crack, presence of pavement maintenance treatment systems, and pavement's age and structure [33].

ESTAMPSYS is an expert advisory system that implements maintenance and selection of proper treatments for single and combined distresses for more than 18 types of distress in a tropical region. The system is designed to enhance the selection of appropriate treatments for failures on road pavements considering the following contributing factors: distress's cracking severity, road function class, and climate region observed distress's type and distress's

Figure 8: Screenshot of the combined distress solution page.

cracking density. The system considers these factors along with seven factors in the formation and choice of pavement treatment. Following current literature and interviews with experts in the field of asphalt pavement, each factor mentioned above is separated into specific groups. For example, ROSE expert systems only give user recommendations and suggestions regarding the specific treatment of routing and sealing [33]. In contrast, ESTAMPSYS directs

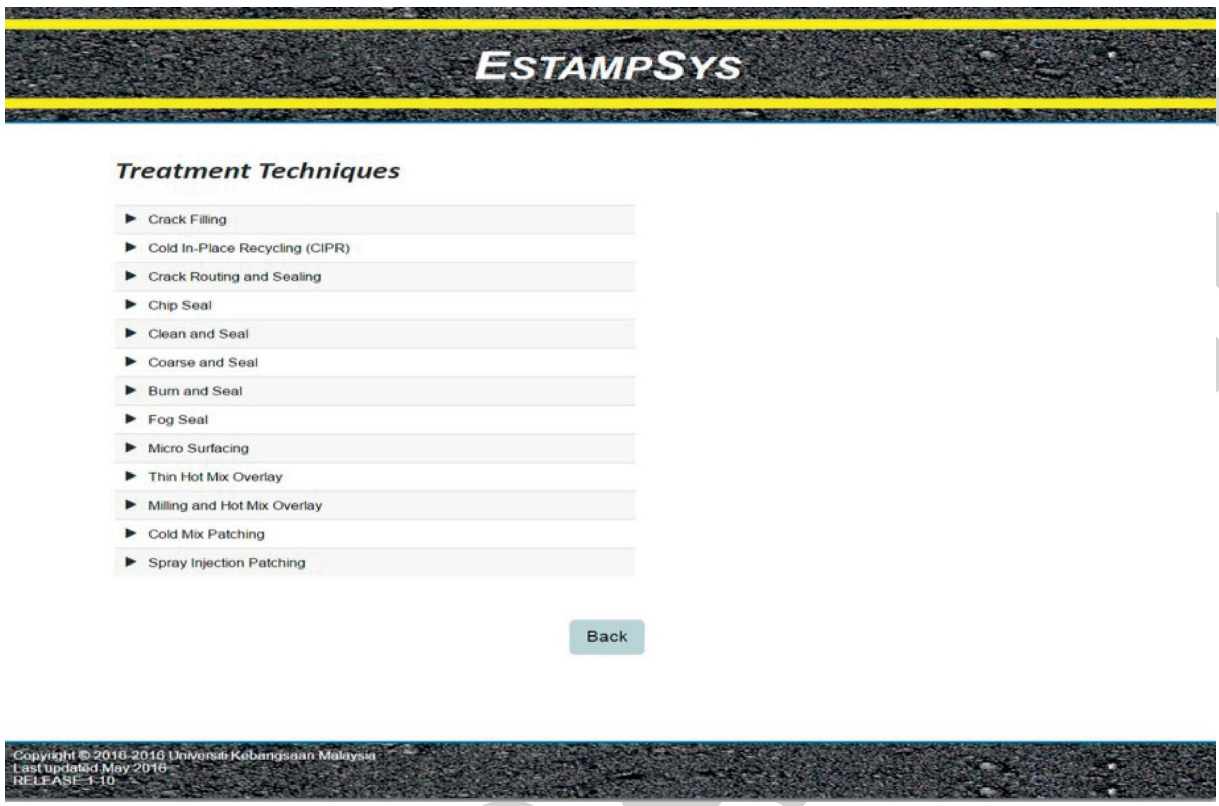

Figure 9: Screenshot of the treatment technique page.

users to the module representing treatment techniques to implement in engineering flexible pavements. ROSE is a Windows-based expert system, and its programming language is FORTRAN.

Meanwhile, ESTAMPSYS is coded by PHP programming; it is essentially a web-based expert system that is able to capture users' interest and promote the application's effectiveness. Unlike users of expert systems based on Windows who need to download patches or updates, the updates in ESTAMPSYS are frequently integrated into the system. ESTAMPSYS is accessible to users worldwide with the aid of the web-based expert system. The enhancement of the system is attributed to the collective contribution of experts from different institutions and nations.

4.2. Comparison with SCEPTRE Expert Systems. An expert system termed SCEPTRE built surface condition expert system for pavement rehabilitation and treatment purposes. It also serves as a tool of instruction in evaluating flexible pavement surface conditions and providing suggestions of solutions at the project level.

Two pavement rehabilitation specialists from Texas and Washington provide the experience for which the system's knowledge base was built. Considerations are only made for four surface distress forms: transverse cracking, longitudinal cracking, rutting, and alligator cracking in wheel paths [34]. Meanwhile, ESTAMPSYS considers 13 categories of flexible pavement single distress. ESTAMPSYS provides a selection text toolbox, single distress, and issue type. Based on natural causes, the forms of distress are separated into groups and are each denoted with a distress severity that reflects each form of distress's severity level. The variables measured by distress severity include a relative percentage of the project's area, which is impacted by each combination of distress severity and type, amount of distress density, and degree of deterioration.

SCEPTRE has ten basic treatment strategies with six fundamental factors, and the system was developed using the EXSYS knowledge engineering environment. It is also Windows-based [34]. Meanwhile, ESTAMPSYS permits easy access online with the use of the worldwide Internet.

4.3. Comparison with ES^{2}P^{2}S Expert Systems. ES^{2}P^{2}S developed an expert system for sustainable approaches toward pavement preservation. ES^{2}P^{2}S quantifies the effects of various pavement maintenance strategies from environmental, economic, and social perspectives. The analysis of various performance criteria in ES^{2}P^{2}S also allows for the evaluation of the overall sustainability of pavement preservation. It can be used to assist pavement maintenance decision-makers in understanding how the core sustainability concept can be inserted into pavement maintenance decision-making. In this system, a long-term sustainability strategy is not considered [14]. In ESTAMPSYS, most of the remediation strategies were selected based on expert experience for sustainable use.

An example is the cold in-place recycling process described in the treatment technique. In-place recycling reuses

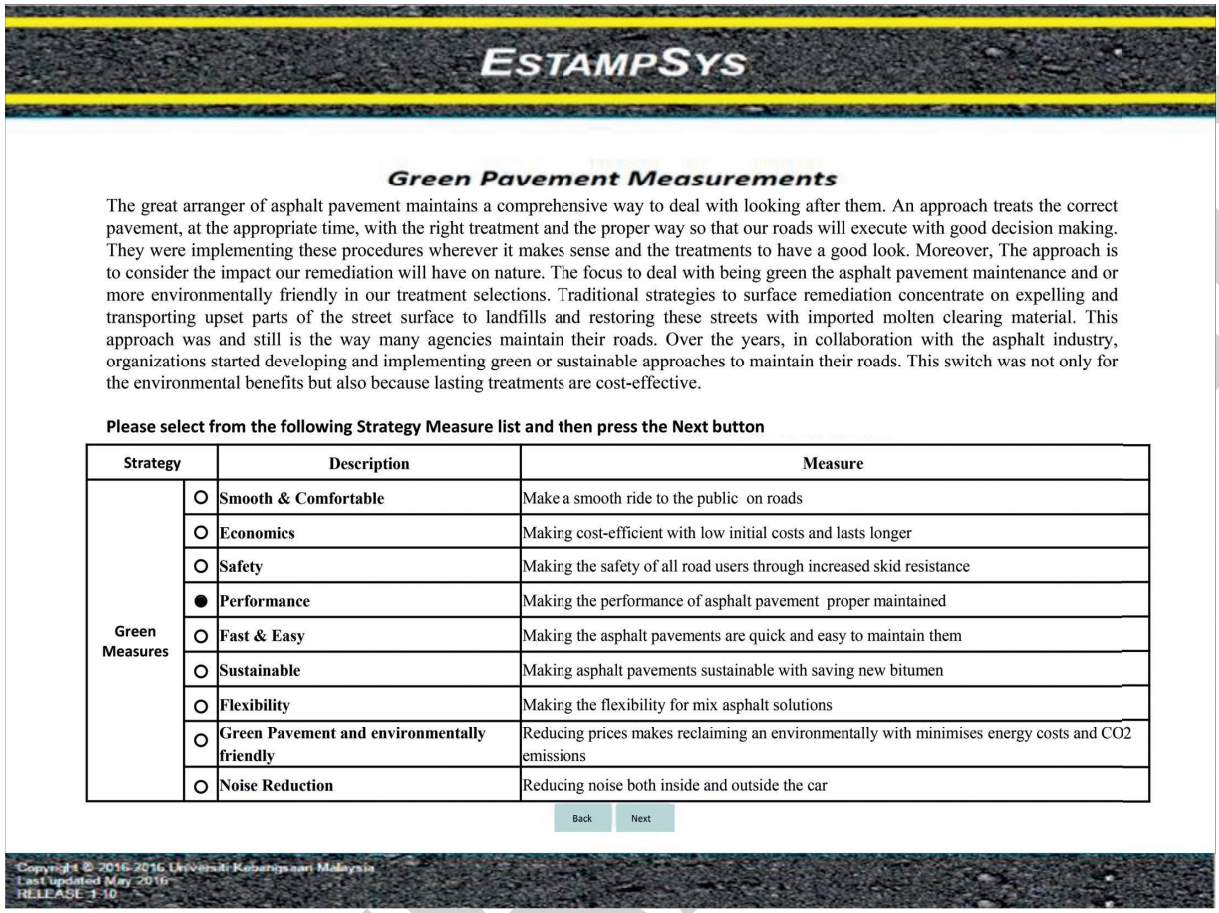

Figure 10: Screenshot of the green measurement page.

existing asphalt and aggregate, thus decreasing the costs of new raw material and transportation. Moreover, in ESTAMPSYS, pavement maintenance treatments' proper application extends pavement life and its good overall condition. The system promotes using the right treatment on the right road at the right time. When used correctly, pavement maintenance treatments increase the service life of pavements.

5. Evaluation of the System

Albeit a complicated process, assessment of expert systems is a crucial step [35–37]. Besides, assessments are essential in confirming the expert system's ability to carry out its function. The method of assessments is separated into two categories. In order to assess satisfaction as reported by users of ESTAMPSYS, ten entrants were selected and separated into two groups. There are five computer engineers and five domain experts in the second and first groups, respectively. In assessing the ESTAMPSYS, the users assigned a mean value exceeding five should they feel satisfied. Via making sure that the system accurately combines human expertise, the assessment addresses a correct expert system's generation. As such, an important factor in the assessment stage is the experts' satisfaction. System verification mean value of 4.4000, which was $4.4000/5 = 88\%$, was generated by the cohort of experts within the field of pavement engineering. This value is representative of the sample's proportion that affirms the acceptable functionality of the system. A system evaluation mean value of 4.5750, which was $4.5750/5 = 91.5\%$, was generated by a group of computer scientists. This value is representative of the sample's proportion that affirms the system's correct functionality. An independent t-test sample was utilized to assess the information from questionnaires.

Nonetheless, the t statistic's value was -1.297 with 8 degrees of freedom. Thus, the test's p value was 0.231 which indicates that there is an absence of statistical difference between these groups at the alpha value of 0.05. As illustrated in Table 5, the groups had no critical distinctions for any of the research questions.

Moreover, Figure 12 displays the results obtained from the questionnaire for evaluation items, overall assessment, and learnability of system application to authorize end-users learning how to work with the prototype, ease to use, lack of bugs quickness in the running.

6. Maintenance and Updating the System

In this stage, ESTAMPSYS maintenance and update are implemented in two steps. One of the steps involves identifying issues and bugs that occur while the system's

Figure 11: Screenshot of the asphalt pavement performance page.

Table 5: Expert responses for evaluation statistically by t-test.

Group	N	Mean	SD	t	DF	p value
Pavement engineering	5	4.400	0.231	−1.297	8	0.231
Computer science	5	4.575	0.190			

web-based runs, along with adaptation according to requests by users. The other step is making sure that the system stays updated and includes the latest and most accurate information regarding the application's domain in the integration of novel modified knowledge. Any information data modifications are noted and integrated into the design of the document appropriately. Such alterations may reflect a few modifications in implementation [35]. Besides, the necessary alterations are carried out on the system's development version. All alterations are also documented and integrated into the ESTAMPSYS's user manual, as shown in Figure 13. The second step necessitates periodical meetings with domain experts. This stage involves discussing the latest updates in the domain, acquiring and augmentation of requisite knowledge into the knowledge base, and reviewing domain knowledge. Under a highway pavement engineer's supervision, any qualified PHP programmer user or knowledge engineer can maintain the ESTAMPSYS. The ESTAMPSYS's source code is inclusive of directions to

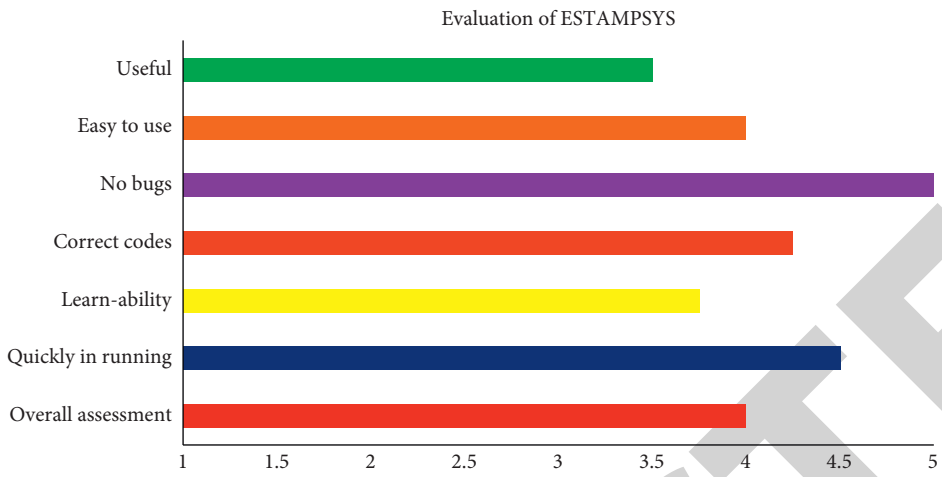

Figure 12: Result of ESTAMPSYS evaluation.

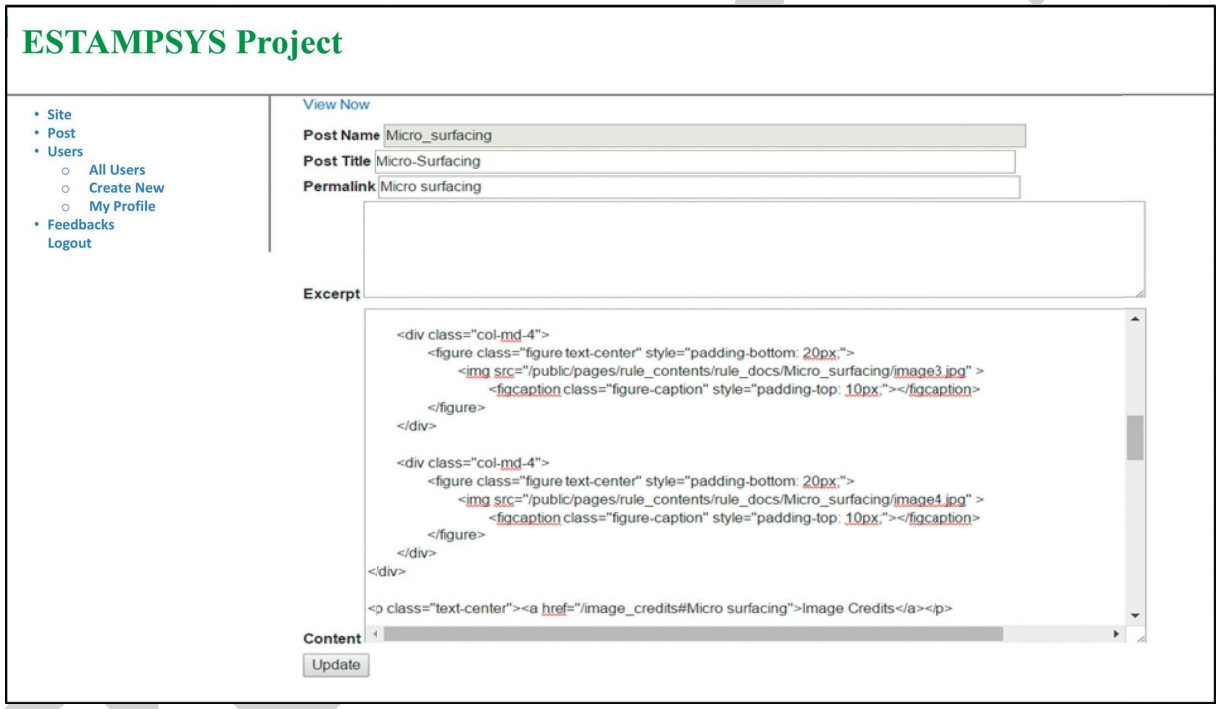

Figure 13: Screenshot of the update system page.

clarify the update operation, especially if the developer or knowledge engineer does not carry out an update.

7. Conclusions

Computer-supported education has been brought forward to a new light thanks to the growth of artificial intelligence. The incorporation of human intelligence allows a computer system to be an intelligent tool, tutee, or tutor and facilitate the process of making decisions within educational environments. The development and assessment of a new educational knowledge-based system in asphalt pavement construction issues are presented in this study. Trainee civil engineers and civil engineering students utilize this system to practice diagnosing and responding to domain issues. The system's knowledge base is primarily the expertise of humans and secondarily relying on literature review. The main objective of this study was accomplished with the web-based expert system. ESTAMPSYS was developed for recommending proper treatment strategies for correcting deteriorating flexible pavements. ESTAMPSYS was rated by independent experts from government and nongovernment authorities, and observations and recommendations for the system were provided. The experts opined that ESTAMPSYS provides strong recommendations that will be useful to new and experienced engineers; they can use ESTAMPSYS to check their recommendations obtained by using approaches to problem solutions. With Internet facilities, ESTAMPSYS

can be utilized as an educational program for young engineers in tropical regions. In addition, the system may function as the base for the advancement of other systems within the field of pavement maintenance. Since help facilities within its source code are included in the system, it is relatively easy to update the system to include novel experiences. Under a highway pavement engineer's supervision, a knowledge engineer or any other PHP user who is competent is able to run a system update.

Data Availability

All the data used in this research can be provided upon request.

Conflicts of Interest

The authors have declared that no conflicts of interest exist.

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