2017 Jurnal Kejuruteraan, Teknologi dan Sains Sosial
Vol. 3 Issue 2 (Special Issue – IIPC '17)

DEVELOPMENT OF AN EXPERT SYSTEM TO MANAGE PAVEMENT DISTRESS OF RIGID PAVEMENT IN SABAH

Mohd Azizul, Ladin[1], Tan, Boon Yew[1], Lim, Chung Han[1]

[1]Faculty of Engineering, University Malaysia Sabah
azizul@ums.edu.my
[1]Faculty of Engineering, University Malaysia Sabah
tanboonyew1004@gmail.com
[1]Faculty of Engineering, University Malaysia Sabah
andrew.lim@ums.edu.my

ABSTRACT

Pavement distress is a concerned issue in Sabah, Malaysia as it will lead to traffic accidents and costly rigid pavement rehabilitation fees. This paper discusses the development of expert system (ES-RPDM) to manage rigid pavement distress. ES-RPDM is a computer program that able to perform problem solving tasks at same level with human expert. Hence, expert system can be an alternative solution to tackle inaccessible and shortage of human experts. Acquisition of knowledge from domain expert and various sources such as reference books, manual and journals is crucial for expert system knowledge base. A prototype ES-RPDM is developed using programming language Microsoft Visual Basic 2010. ES-RPDM has to be evaluated and validated at final stage to ensure the specifications, quality and acceptance by the end users. The evaluation are conducted using Likert skill questionnaire method which involved novice engineers. Based on the result, the acceptance of ES-RPDM by end users is high and it is able to provide optimum strategy to solve rigid pavement distress.

Keyword: Rigid pavement distress, expert system, highway, visual basic, pavement

1. Introduction

In this new era of technologies, people have strong reliability on internet and various applications. The development of smart phones, laptops and desktops convenient the usage of applications. People can access to particular applications whenever they need. Therefore, this research will develop an expert system (ES-RPDM) which is able to manage rigid pavement distress instead of consultation from experts. Expert system is a computer program that involves artificial intelligence (AI) techniques in order to provide consultation, suggestion and job performance

assistance within their specialized problem solving area. It is developed to carry out pronlem solving tasks at same level with experts (Parker,1990).

In Sabah, the maximum road load for vehicles varied from 6 to 38 tonnes. Although this number is lower than in peninsula, but with the increasing population in Sabah, more vehicles are on the road (Group, O. B., 2014). This can reduce the lifespan of roads and adds to the repair and maintenance cost, as well as boosting the number of traffic accidents. Moreover, natural disasters notably floods and landnslides which are common in Sabah's tropical climate. Pavement distress such as surface cracking and pothole can be one of the largest factors to fatal motor vehicle crashes (Fares *et al*., 2010). Table 1 shows the road accident data in Malaysia from year 1997 to 2014 (Malaysia Institute of Road Safety, 2016). Based on the statistics, road crashes accident tends to increase with the growth of population and there is an increasing trend for number road deaths. Therefore, this increased number should be concerned by public and a proper road pavement distress management is required to tackle this road accident issue.

Table 1.Road Accident Statistics in Malaysia

Year	Registered Vehicles	Population	Road Crashes	Road Deaths	Serious Injury	Slight Injury
1997	8,550,469	21,665,600	215,632	6,302	14,105	36,167
1998	9,141,357	22,179,500	211,037	5,740	12,068	37,897
1999	9,929,951	22,711,900	223,166	5,794	10,366	36,777
2000	10,598,804	23,263,600	250,429	6,035	9,790	34,375
2001	11,302,545	23,795,300	265,175	5,849	8,680	35,944
2002	12,068,144	24,526,500	279,711	5,891	8,425	35,236
2003	12,819,248	25,048,300	298,653	6,286	9,040	37,415
2004	13,828,889	25,580,000	326,815	6,228	9,218	38,645
2005	15,026,660	26,130,000	328,264	6,200	9,395	31,417
2006	15,790,732	26,640,000	341,252	6,287	9,253	19,885
2007	16,813,943	27,170,000	363,319	6,282	9,273	18,444
2008	17,971,901	27,730,000	373,071	6,527	8,868	16,879
2009	19,016,782	28,310,000	397,330	6,745	8,849	15,823
2010	20,188,565	28,910,000	414,421	6,872	7,781	13,616
2011	21,401,269	29,000,000	449,040	6,877	6,328	12,365
2012	22,702,221	29,300,000	462,423	6,917	5,868	11,654
2013	23,819,256	29,947,600	477,204	6,915	4,597	8,388
2014	25,101,192	30,300,000	476,196	6,674	4,432	8,598

Source: Malaysian Institute of Road Safety Research, 2016

In fact, road pavements start to defected when they are opened to the traffic and the life span of pavement is usually limited to ten years. Normally, new paved roads deteriorate at low rate in the first ten or fifteen years then the rate of defection will increased gradually (Wee S.Y. *et al*., 2009). Pavement represents half of the total highway expenditure and the cost of maintenance and rehabilitation are increases continuously with the life span of pavement. This can be improved by regular maintenance for road pavement. In the aspect of cost saving, expert system can provide reliable effective solutions for pavement distress management which can reduce pavements cost over the long run.

On the other hand, expert system is able to solve inaccessible and shortage of human expert. Human expert is not always available and ready to solve problems. For example, human expert with specialized knowledge will retires, falls sick or outstation so there is a limitation of human expert in solving the problem when

needed[6]. In contrast, expert system has high feasibility and consistency which can solve problem continuously with high degree of reliability. Therefore, expert system can be an effective way to manage rigid pavement distress.

2. Methodology

The development of ES-RPDM aims to provide optimum strategies effectively to solve the pavement distress for end users. In the process of developing ES-RPDM, the first step needed is to determine the reasons of implementing the expert system and the main development objectives that required to achieve. Thus, user needs to understand the basics of the problem or the problem statement that encountered in the aspect of rigid pavement distress in order to define the objectives.

Next, in order to develop ES-RPDM, information and relevant knowledge have to be collected from various sources such as journals and books. However, the most influential source is the consultation with domain expert who was expertise in road pavement distress. Therefore, knowledge engineer required to prepare a questionnaires to domain expert during the interview section. The questionnaire included 10 rigid pavement distress related questions and several options of solution for each distress have been provided. The questionnaire is created using Google Forms as shown in Figure 1 and sent to domain experts via email. The information collected is coded in computer programming using Microsoft Visual Basic 2010.


RIGID PAVEMENT DISTRESS MANAGEMENT SURVEY

Please tick (/) the best solution for each question. You may choose more than one solution. If the solution is not stated in the selections please write the solution in the black space given.

1. Based on your expertise and experience, what is the suitable solution for spalling in rigid pavement which is less than 75mm?

- ○ Crack sealing
- ○ Partial-depth patch
- ○ Full-depth patch
- ○ Stitching
- ○ Other : _____

Figure 1 Questionnaire for Rigid Pavement Distress Survey

RIGID PAVEMENT DISTRESS MANAGEMENT EXPERT SYSTEM (ES-RPDM) EVALUATION

Please rate the expert system by ticking (/) at the appropriate column.

No.	Feature	Strongly Disagree 1	2	3	4	Strongly Agree 5
1	I think I would like to use this expert system frequently.					
2	I thought this system was accessible.					
3	I could easily understand the instruction of the system.					
4	I thought this system was easy to use.					
5	I thought the system was able to provide optimum solution.					
6	I found the solutions provided were explainable.					
7	I thought the system was consistent.					
8	I could understand the pictures in system.					
9	I could read clearly the letter in this system.					
10	I felth that the colour design of the system was comfortable viewing.					

Figure 2. Evaluation Form for ES-RPDM

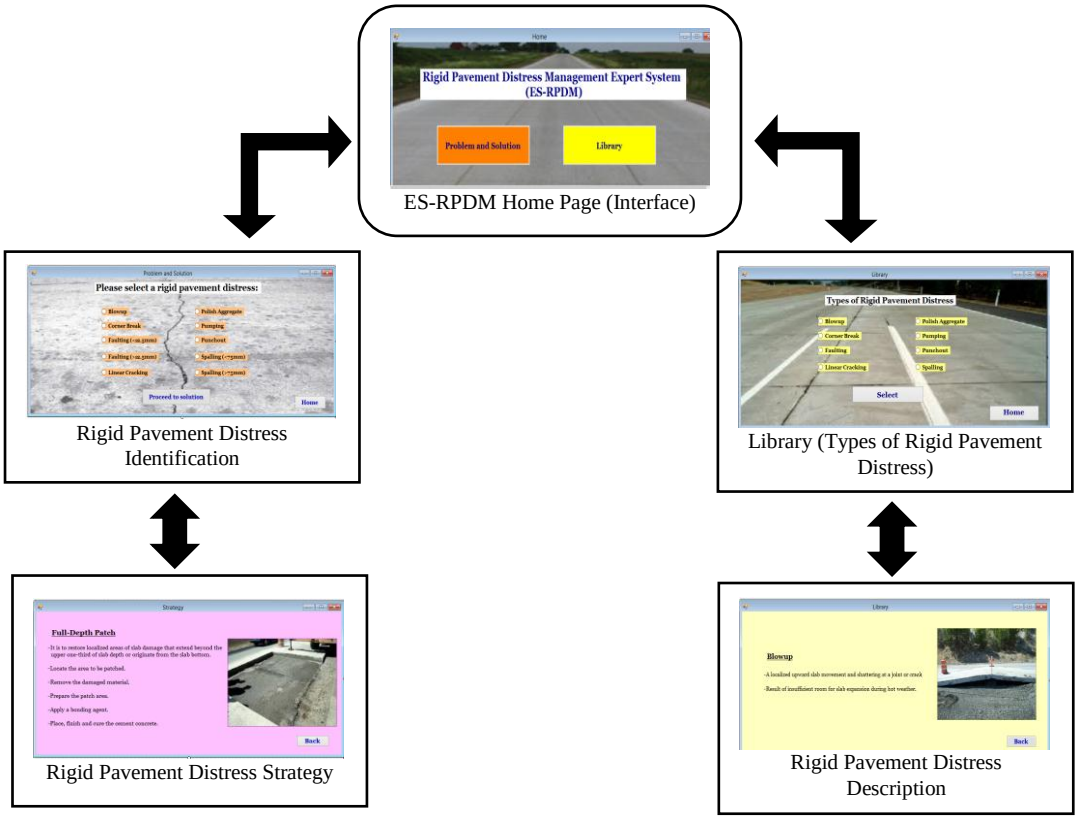
Lastly, the ES-RPDM has to be validated by expert evaluators and evaluated by novice engineers as end users. Evaluation is a process to measure system's accuracy and effectiveness which involves end users in system utility determination (Liebowitz 1986). Hence, the expert system is eventually evaluated through evaluation form method as shown in Figure 2. The evaluation covered several crucial criteria such as user-friendliness, convenience, correctness and efficiency. The questionnaire is to evaluate the usability of ES-RPDM application using Likert scale values 1 to 5. There are total 10 questions and respondents required to rate from strongly disagree to strongly agree according to their evaluation.

Validation was normally applied at the end of system development in order to ensure compliance with the original requirements of the project (Kent, 1994). It was carried out by comparing the solutions provided by another domain expert as expert evaluator with the solutions provided from ES-RPDM.

3. Results and Discussion

Typically, the development of expert system for rigid pavement can be done extensively by covering road pavement design activities, management or supervision during construction and also troubleshooting during fabrication. However, this study will only cover the management of rigid pavement distress after the road has been utilized.

Once all of the information is extracted and coded. Hence, the ES-RPDM was completed and shown in Figure 3. Users can access to interface of ES-RPDM and select particular rigid pavement distress in order to obtain the optimum strategy. Besides, the description of various types of distress can be accessed at library page with aids of illustration. Each of the window is revesible which means user can back to the previous window or proceed to next window.



Fiigure 3. Flow Chart of ES-RPDM

The ES-RPDM has been evaluated by a novice engineer and four students. The result collected was performed in Figure 4 and Figure 5. The usability level of each attribute was demonstrated according to user acceptance level. Therefore, the accessibility and convenience of ES-RPDM in first and second questions were in good usability level which were satisfied by users. On the other hand, user-friendliness of ES-RPDM was in the range of excellent in questions number 3 and 4. Questions 5, 6, 7 and 8 indicated the correctness and efficiency of system and they were within the excellent range of usability level. Lastly, questions 9 and 10 represented the features and design of ES-RPDM which were in the range of excellent and good respectively.

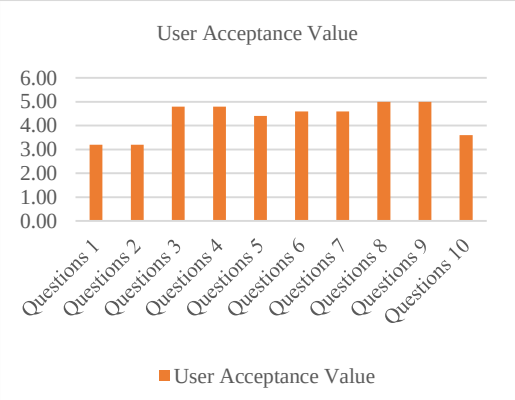


Figure 4. Graph of User Acceptance Value

No.	Feature	User Accepatance Value	Utility Level
1	I think I would like to use this expert system frequently.	3.20	Good
2	I thought this system was accessible.	3.20	Good
3	I could easily understand the instruction of the system.	4.80	Excellent
4	I thought this system was easy to use.	4.80	Excellent
5	I thought the system was able to provide optimum solution.	4.40	Excellent
6	I found the solutions provided were explainable.	4.60	Excellent
7	I thought the system was consistent.	4.60	Excellent
8	I could understand the pictures in system.	5.00	Excellent
9	I could read clearly the letter in this system.	5.00	Excellent
10	I felth that the colour design of the system was comfortable viewing.	3.60	Good

Figure 5. Usability Level for Each Attribute

For validation, ES-RPDM was mainly focused on ascertaining the completeness and accuracy of the system. The result of solution comparison between ES-RPDM and domain expert were shown in Figure 6. There were 10 rigid pavement distresses in the expert system. As can be seen from Figure 6, the strategy suggested by ES-RPDM for pumping was full-depth patch while domain expert suggested partial depth patch. Therefore, the discrepancy of strategy provided by ES-RPDM and domain expert was only 10% with 90% similarity as shown in Figure 7. This proved that the accuracy of ES-RPDM was high and reliable.

Comparison of Solution between ES-RPDM and Domain Expert			
Rigid Pavement Distress		Solution	
		ES-RPDM	Domain Expert
1	Blowup	Full-depth patch	Full-depth patch
2	Corner Break	Full-depth patch	Full-depth patch
3	Faulting (<12.5mm)	Dowel bar retrofit	Dowel bar retrofit
4	Faulting (>12.5mm)	Reconstruction	Reconstruction
5	Linear Cracking	Full-depth patch	Full-depth patch
6	Polished Aggregate	Diamond grinding	Diamond grinding
7	Pumping	Full-depth patch	Partial-depth patch
8	Punchout	Full-depth patch	Full-depth patch
9	Spalling (< 75mm)	Partial-depth patch	Partial-depth patch
10	Spalling (>75mm)	Full-depth patch	Full-depth patch

Figure 6. Solution Comparison between ES-RPDM and Domain Expert

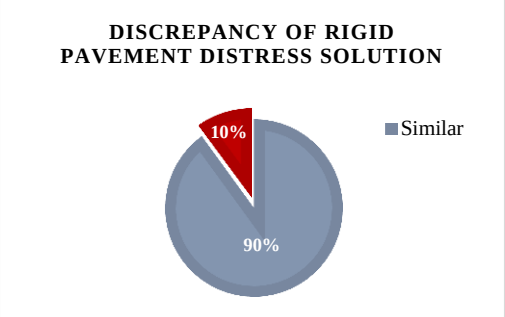


Figure 7. Rigid Pavement Distress Solution Discrepancy Pie Chart

In this study, respondents are crucial in evaluation and validation of ES-RPDM to provide information about the usability of the system. Based on the results from evaluation and validation, ES-RPDM is an effective, user-friendly and consistent expert system. This is beneficial and educational for civil engineering students as well as novice engineers who require guidance in pavement distress management.

4. Conclusion

In conclusion, road pavement distress will cause road death, endanger road users and poor pavement distress management will lead to costly maintenance fees especially rigid pavement. Therefore, a proper pavement distress management expert system play an important role to tackle this issue. Besides, expert system as a computer system also capable to resolve the inaccessibility of human expert. However, maintenance of expert system is necessary to ensure the pavement distress management knowledge is updated with the latest technology. Technology will not sit still and thus continuous effort to upgrade the expert systems is a required such as collecting feedback from end-users and re-test the system once latest changes have been made. Lastly, ES-RPDM are successfully produced as the results from evaluation and validation show that it is a reliable, consistent and efficient expert system. Thus, objectives of study have been achieved.

References

Allen Kent. (1994). *Encyclopedia of Computer Science and Technology.* New York: Marcel Dekker Inc.

Fares H, Shahata K, Elwakil E. (2010). Modelling the effect of various factors on the condition of pavement marking in cold weather conditions. *Structure and Infrastructure Engineering* , 1067-1079.

Group, O. B. (2014). *The Report: Malaysia 2014.* Oxford Business Group.

Janet Finlay, Alan Dix. (1996). *An Introduction To Artificial Intelligence.* London: Routledge.

Liebowitz, J. (1986). *Useful Approach for Evaluating Expert Systems in Expert System*, 3 (2), 86-92.

Malaysia Institute of Road Safety. (2016). Retrieved from ASEAN Road Safety Centre: https://www.miros.gov.my/1/page.php?id=17

Thomas D. McFarland, Reese Parker. (1990). *Expert Systems in Education and Training.* New Jersey: Educational Technology Publications.

Wee S.Y., R.A@R.B Chan, Teo H.W. (2009). Potential Modeling Of Pavement Deterioration Rate Due To Cracking. *Unimas E-Journal of Civil Engineering Volume 1*, 6.