Jurnal
Teknologi

Full Paper

A REVIEW OF WEB BASED EXPERT SYSTEMS FOR FLEXIBLE PAVEMENT MAINTENANCE

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Article history
Received
8 June 2015
Received in revised form
4 November 2015
Accepted
15 May 2016

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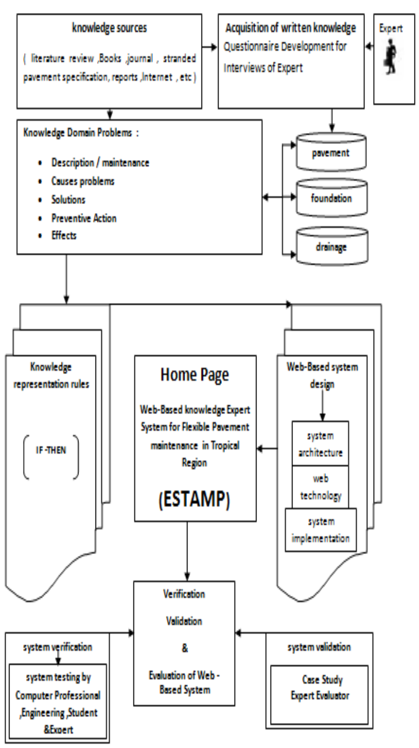
Graphical abstract



Abstract

This paper reviews the application of expert systems in a flexible pavement (ESFP). It involves a brief introduction to expert systems explaining how technology plays a role in the creation of latest approaches to highway engineering, development, and maintenance. The paper provides an outline for possibilities of future researches. The purpose of this paper is to summarise the latest outcomes of researches related to the process of engineering, developing and implementing an expert scheme for flexible pavement construction. Moreover, the paper shows the necessity to develop an expert system that can help to control damage in tropical regions. The current expert system does not accommodate the needs for damages and repairs for tropical climates. The tropical region's highway's flexible pavements are based on the knowledge of experts who analysed and maintained highway pavements. This system enables the performance engineers to analyse, determine and customise information to help relevant parties during decision-making processes.

Keywords: Flexible Pavement, Maintenance of Pavement, Expert System, Tropical Environmental Impacts, Deterioration Pavement

Abstrak

Kajian ini mengulas penggunaan sistem pakar bagi turapan boleh lentur (ESFP). Ia melibatkan pengenalan ringkas sistem pakar bagaimana teknologi ini berperanan dalam menghasilkan pendekatan terkini dalam kejuruteraan lebuhraya, pembangunan dan penyeleggaraan. Kajian ini menyediakan garis panduan untuk kajian di masa akan datang. Tujuan kajian ini adalah untuk meringkaskan hasil dapatan terkini berkaitan dengan proses kejuruteraan, pembangunan dan perlaksanaan skim pakar untuk pembinaan turapan boleh lentur. Sistem pakar sedia ada tidak memenuhi keperluan untuk kerosakan dan pembaikan bagi kawasan beriklim tropika. Turapan boleh lentur lebuh raya kawasan tropika adalah berdasarkan kepada pengetahuan pakar yang menganalisa dan menyeleggara turapan jalan raya tersebut. Sistem ini membolehkan jurutera menganalisa, menentukan dan menyesuaikan maklumat untuk membantu pihak-pihak yang terlibat dalam proses membuat keputusan.

Kata kunci: Turapan boleh lentur, penyelenggaraan turapan, sistem pakar, kesan alam sekitar beriklim tropika, kemorosotan turapan

1.0 INTRODUCTION

The application of expert system in highway has evolved from computer science's many branches and informally recognized as artificial intelligence (AI). The expert system can be developed for procedures such as diagnosis, prediction, consultation and others [1]. Moreover, the computer program is an expert system manipulating both knowledge and reference procedures that resolve issues deemed complicated for humans to solve [2]. In other words, expert systems are computer programs created to imitate the thought and reasoning processes that any expert humans can do. Expert systems encompass various applications in the field of transportation engineering [3].

Expert systems offer assistance in managing the multifarious problems in institutions [4] by improving both the analysis and counseling. The foreground of the establishment of an expert system is to assist designers in the pavement design structural systems of flexible pavement. In the area of highway engineering design, [5] point out that the core of an expert system called (PAVE) should be able to determine the reasons why flexible pavements fail. The flexibility of pavement design's overlay in Expert System (EXSPAV) is utilised in the design and overlay, to predict the pavements' ages. Pavement rehabilitation expert system, or PARES, is a system facilitating civil engineers to measure the condition of flexible pavements [6]. Knowledge production depicts an important phase of the expert systems' growth. This particular stage is complex and time-consuming [7] as expert systems necessitate specific inquiry approaches [8]. A developed highway expert engineering system designed to assist when selecting design road [9].

Roads maintenance programs are important and necessary after the establishment of the roads. Maintenance is needed in order to secure a safe and comfortable passage. Thorough evaluation of the roads to detect defects and the causes of these defects in order to determine the best maintenance techniques to be used to extend the lifespan of the pavement and prevention of delays in the reconstruction project cost. In recent years, Libya's road maintenance is considered excellent and has been used to describe safety components related to accidents, government insurance cost and provisions occurred from Bleeding & Flushing (Excess Surface Asphalt), Fatigue (Alligator) Cracking, Longitudinal Cracking, Potholes, Raveling, Reflective Cracking, Rutting, Shoving and Pushing, Transverse (Thermal) Cracking. Road maintenance and rehabilitation of pavement models have been developed throughout the world, where an expert system is adapted to sustain the pavement maker of choice. Prediction of future pavement performance of a road network is a crucial step in a pavement management system equipped with a corresponding annual budget. Researchers used soft computing, i.e., fuzzy logic, neural network, and so on in enhancing the pavement management systems [10], [11], [12] and modeling pavement deterioration [13].

2.0 COMPUTER BASED SYSTEMS IN PAVEMENT

There are various pavement expert systems utilised by present highway departments in recent years. Several knowledge expert systems are enhanced within the area of pavement engineering. The following subsections have summarised each of the existing systems developed to be applied to a particular area under certain climatic conditions and with regards to specific distress and maintenance types.

2.1 PAVE

Kuprenas have come up with PAVE which is a microcomputer-based expert system used to look for typical reasons why asphalt concrete pavements failed when the forward chaining inference method is used [14].

2.2 PMAS

Hanna has improved on KBES named Pavement Management Advisory System (PMAS); a system which is used to select some suitable strategies to maintain pavements' in cold areas' flexibility and rigidity. Surface distresses in the system are divided into three types, i.e. alligator crack, transverse crack, and rut. The system manipulates several factors such as surface condition, riding comfort index, and a few others to sort out and suggest restoration approaches [15].

2.3 PARES

Ross developed New Mexico State Highway and Transportation Department's Pavement Rehabilitation Expert System (PARES) to help highway engineers to assess and develop restoration structures for flexibility in pavements. The system adopts an important system to determine the sections for rehabilitation centered on the areas' condition study and traffic capacity. Depending on the importance of the assignment, the early approximation cost and accessible funds to rehabilitate together with the amount and degree of projects' considered to be rehabilitated are decided. Certain factors are put into consideration when selecting. The processes are the complete pavement assessment value, individual distress category, severances of distress and extent, normal daily traffic, and roughness. The knowledge used in this system is taken from the state highway experts' experiences. The system employs 278 rules in two key groups, which are classifying distress and selecting suitable rehabilitation strategies [16].

2.4 PAVEDKB

Goh built an expert system's advisory prototype named Pavement Design Knowledge Base (PAVEDKB) for flexibility in pavement designs. The system attempts in imitating the pavement engineering specialists' design process that looks for the most suitable design decision from many probabilities of pavement material types and traffic data groupings that rely most on empirical correlation, which is distinguishable from each other. The PABEDKB's knowledge territory are built on the design method developed from NAASRA (National Association of Australian State Road Authorities) [17].

2.5 PDS

Lan improved Pavement Diagnosis System (PDS), which identifies, and diagnoses the flexible pavement distresses. Its knowledge base is made up of experiential rules extracted from interviews carried out with senior pavement engineers [18].

2.6 PMDSS

DeCabooter established Pavement Management Decision Support System (PMDSS), a rule-based system for the Wisconsin Department of Transportation to offer some rational and dependable resolutions to problems with regards to maintaining and rehabilitating pavement. PMDSS has more than 1200 decision rules for aspects of distress assessment, problem recognition, and rehabilitation commendation. Based on the field observation, PMDSS allocates the entire degrees of seriousness (minor, modest, or major) for individual distress. It then shows the pavement's nature of the problem and the seriousness before suggesting suitable treatments realistic for each problem [19].

2.7 EXSPAV and EGYPAV

Khedr and Mikhai developed EXSPAV to be used in flexible pavement and overlay design. It encourages knowledge being transferred amongst experts and the research's outcomes and preparation to less knowledgeable design engineers. It integrates an adaptable design approach facilitating the forecast of the pavements' structural presentation. EXSPAV was advanced in the EXSYS environment and conforms to the Ohio State University's analytical program of flexible pavement structural performance. It owns an overlay design module. EGYPAV is a program that is based on knowledge of the pavement design that trails EXSPAV structure. Its knowledge base was shaped on consultations with experts from the Roads and Bridges Authority, resident universities, and construction companies. The base replicates Egypt's experience, data, and research outcomes on traffic, environmental situations, pavements, and material classification. It contains recommended designs for pavement structures, using different design parameters combinations. The program user may inspect the recommended design and locate its structural performance through the inference engine-deterministic model interaction of the EGYPAV itself [20].

2.8 ES-DFIVIP

Syamsunur and Atiq improved KBES or Expert System for Design Module in Flexible Pavement (ES-DFMP) for flexibility in pavement design. Using Kappa-Pc, this tool contains a graphic display. ES-DFMP replicates AASHTO design standards to specify each structural layer's minimal thickness. Many different results are obtainable from this method, as the results are dependent on the input data. A user can alter the each layers thickness as he changes the proposed materials or the number of layers properties. ES-DFMP is tried out, and its results are compared with the results attained using manual design. The outcomes are identical [21].

2.9 EXDAW

Dhitivara enhanced a KBES hybrid called Expert System for Designing Asphalt Concrete Mixture Containing Waste Materials and By-products (EXDAW). It is beneficial when used to design asphalt concrete mixtures which contain reclaimed asphalt pavement, recycled cumulative material, crumb rubber convertor, mineral filler, and conservative asphalt concrete mixture. EXDAW is established based on the Marshall Hot Mix Asphalt (HMA) mixture's design concept. Statistical contrasts between real HMA mixture design data and test outcomes of the expert system showed low percentage error, indicating that the expert system can accomplish efficiently compared to human experts. Besides, the development of expert system is user-friendly, thus enabling use and learning. The end product showed important assistances to both expert and skilled design engineers who want an improved HMA mixture design efficiency [22].

2.10 SCEPTRE

Ritchie technologically developed an expert system called Surface Condition Expert System for Pavement Treatment and Rehabilitation (SCEPTRE) as an advisory device to evaluate flexible pavement surface conditions and recommend rehabilitation approaches at the project level. The system's knowledge base is built from the experiences of two pavement rehabilitation specialists from Washington and Texas. Only four types of surface distress are reflected in the system: alligator cracking in wheel paths, transverse cracking, longitudinal cracking in wheel paths, and rutting distress. This system has approximately 140 production rules; is advanced based on the expert system shell program EXSYS and written in LISP for IBM PC and compatible microcomputers [23].

2.11 OVERDRIVE

Ritchie enhanced the first prototype expert system called OVERDRIVE, (Overlay Design Heuristic Adviser) facilitating the local engineers as they design the asphalt concrete pavement overlays structural thickness. This system handles numerous main tasks formulating the ideas for the new overlay. A commanding trait in OVERDRIVE is the users' capability at the end of a design session to detect and change any of the inputs for the overlay (Ritchie 1987; Ritchie & Mahoney 1989) [23].

2.12 ROSE

Hajek worked on an expert system called ROSE which suggested the selection of appropriate treatment for cracks in asphalt concrete pavements in cold areas. ROSE integrates data transmission of 41 variables such as pavement serviceability, age, and type of pavement distress, and a few others [24].

2.13 PERSERVER

Haas proposes the single most cost-effective treatment to maintain each road segment and chooses treatments that resolve more than one distress in the segment. Three types of distress are in consideration, explicitly alligator cracking, progressive edge cracking, and distortion. The system's knowledge base is guarded to those assumed by the Pavement Maintenance Guideline Manual of the Ontario Ministry of Transportation and Communications, with rules collected from experts who were interviewed. This system depends on user's information on the road section and distress' types identified earlier to the purpose of all probable treatments for each condition of distress. The equal yearly cost for each treatment is considered and applied to be chosen as the best treatment. PRESERVER's construction uses OPSS representation languages on a VAX mainframe [25].

2.14 ERASME

Allies constructed an expert system based on knowledge called ERASME (French acronym for "highway maintenance aided by a multi-expert system") for the Directorate of Roads in France to assist in the process of making a conclusion on to maintain pavement. The system aids the user who needs to choose suitable pavement maintenance and rehabilitation strategies utilizing the respective parameters: pavement structure, deflection, nature and date of previous pavement repairs, and surface conditions. Numerous pavement rehabilitation methods are suggested, and each solution is evaluated based on service life, serviceability, cost, and construction period of the treatment. This prototype system contains 210 rules and 50 decisions [26].

2. 15 RC-MSS

Teh came up with Road Construction Material Selection System (RC-MSS) expert system prototype using Microsoft Visual Basic 6.0. It also uses interviews with pavement experts about the suitable material for each pavement layer under precise design conditions. Expected traffic loading, soil condition, type of terrain, and geometric features are the main factors for consideration in the pavement material selection [27].

2.16 ORAGE and SEVADER

Christory and Laye have built an expert system that became part of the streets' design and maintenance. The usage of both systems give the end user the benefits when a thorough management system is used, particularly since ORAGE gives a relational database tool to keep tab of the structure's background. Data are collected and kept in ORAGE and it allows the user to create significances based on deteriorating pavement surfaces, bearing capacity of pavement structures loading, the conditions of gutters and curbs and pedestrians. This information can then be handled by working engineers to mediate with SEVADER, comprising reasoning (rules and logic). The information on SEVADER includes choices of surface to overlay and grind, the viability of geometrical factors, durability and costs. Users may also set the important elements for six different pavement management decision-making aspects for features like durability, environment, comfort, maintenance, economy, safety. The SEVADER's information domain is systematised into three special areas- The ESCOP expert system shell program that is written in LISP is used in the development of SEVADER. Currently, the system has approximately 15,000 computer code lines and 600 rules. ORACLE relational database management system is used in the development of ORAGE and both system's components' are improved by the Association of Engineers of French Cities (AIVF) [28].

3.0 COMPARISON AMONG THE BASED SYSTEMS

A comparative analysis of the present expert systems used in maintaining and designing for flexible pavements is included in Table 1 and Table 2. The tables show that expert system submissions for flexible pavements are highly restricted compared to the highway pavements. Most systems are improved for flexible highway pavements and the surface distress conditions were utilized to attain information when drawing conclusions and offering proper recommendations. . The development of sixteen existing systems for the flexible pavements, including ROSE, SCEPTRE, PERSERVER, ERASME, PARES, PMAS, PMDSS, PAVEDKB, PDS, PAVE, EXSPAV, RC-MSS, ES-DMFP and DFPRDLS.

Table 1 Summary of Expert System in Flexible Pavement

Expert System	Facility2	T2	P2	PCV3	Hardware	Development tools	Number of Rules	Operation3
ROSE	H	S	F	SD	IBM-PC	EXSYS	360	P
SCEPTRE	H	M	F	SD	IBM-PC	EXSYS	140	P
PERSERVER	H	S	F	SD	VAX Mainframe	OPSS	Unavailable	P
ERASME	H	M	F	SD	IBM-PC	French Shell insight+2	210	P
PARES	H	M	F	SD	IBM-PC	Unavailable	278	F
PAVER	H	M	F,R	SD	IBM-PC	Mainframe	Unavailable	F
PMAS	H	M	F	SD,RQ	Macintosh IBM-PC	EXSYS Expert plus	I170 II250	P
PMDSS	H	M	F	SD,RQ	IBM-PC	Unavailable	1200	P
PAVEDKB	H	D	F	NA	IBM-PC	FORTRAN	Unavailable	P
PDS	H	M	F	DD	Unavailable	Unavailable	Unavailable	P
PAVE	H	M	F	NA	IBM-PC	Unavailable	Unavailable	P
EXSPAV	H	M	F	NA	Unavailable	Unavailable	Unavailable	P
RC-MSS	H	S	F	NA	Unavailable	Visual Basic	Unavailable	P
ES-DMFP	H	D	F	NA	Unavailable	KAPPA-PC	Unavailable	P
DFPRD	H	M	F	NA	IBM-PC	PROLOG	Unavailable	F
ORAGE& SEVADER	H	M	F	NA	Unavailable	ESCOP	600	F

H=Highway ; T2=system specialization type; P2=pavement type; F= flexible; R=rigid; M= maintenance and rehabilitation; S=selection; D=design; SD= surface distress; RQ= riding quality; DD= diagnosis distressed; FP= failure in pavements; NA =Not Applicable

Table 2 Comparison among Expert Systems in Flexible Pavement

Applications	Year [Developer]	Consideration surface distress	Dependent variables	Strategies function
ROSE	1987[Hajek]	All cracks except alligator cracking	• Type and the degree of seriousness of crack •Pavement serviceability • Pavement structure of the existence of •pavement distress • Availability of maintenance treatment	Maintenance • Routing and sealing
SCEPTRE	1987[Rithchie]	Alligator cracking, Longitudinal cracking, transverse cracking and	•Type, amount and severity of surface distress • Existing pavement performance,	Rehabilitation • No action taken • Fill cracks • Fog seal

Applications	Year [Developer]	Consideration surface distress	Dependent variables	Strategies function
		rutting	• Traffic levels • Climate	• Friction course • Chip seal • Double chip seal •AC overlay (thin, medium or thick) • Mill and replace
PERSERVER	1987[Hass&Shen]	Alligator cracking, Progressive edge cracking, and Distortion	• Type, severity and density of surface distress • Section size cost	Not available
ERASME	1988[Allez]	Not available	• Pavement structure • Deflection Nature and data of pavement repair • Surface condition	Rehabilitation
PARES	1990[Ross]	Not available	• Overall pavement rating value (PMV) • Individual distress type, severity and extension • ADT • Roughness	Rehabilitation
PAVER	1990[Shahin]	• 19 distresses for AC-surfaced road • 19 distress for PCC-surfaced Road • 16 distresses for AC-surfaced	•Type, severity and extent of surface distress • History of pavement condition • Pavement age	Routine Maintenance • No action taken • Cracks sealing
PMAS	1993[Hanna]	• Alligator cracking • Transverse cracking • Rutting	• Type, severity, and density of surface distress • Riding Comfort Index (RCI) • Traffic Volume • Climate • Cost comparison	• No action taken • Cracks sealing • Pothole patching • Rout and seal •Surface replacement •Hot mix recycled patching •Hot mix patching •Cold mix patching • Reconstruction
PAVEDKB	1993[Goh]	Suitable design of pavement material types	•Pavement material •Types of traffic data •Heavy reliance on empirical correlation	Design
PDS	1993[Lan]			
PMDSS	1994[Decabooter]	•Distress evaluation •Problem identification	•Overall severity (minor, moderate, or severe) for each distress	Rehabilitation
PAVE	1995[Kuprenas]	Common causes of failures in asphalt pavement	unavailable	Maintenance
EXPAV& EGYPAV	1996[Khedr]		•Traffic •Environmental •Conditions • Pavements • Material	Rehabilitation
RC-MSS	2005[Teh]	•Suitable material for each pavement layer under certain design conditions	•Anticipated traffic loading • Soil condition • Type of terrain, and	Not available
PAVEMENT EXPERT	1989[A1-Shawi]	12 states of distress in 4 categories • Surface deterioration • Patching • Pumping joint spalling • Cracking	Incidence, severity, and the degree of distress	Not available

Applications	Year [Developer]	Consideration surface distress	Dependent variables	Strategies function
ORAGE& SEVADER	1991 [Christory & Laye]	•Pavement surface deterioration •Bearing capacity of pavement structures •Loading •Conditions of gutters and curbs •Condition of sidewalks.	•Durability •Environment • Comfort •Maintenance •Economy •Safety	Not available

Notably, the above limitations were observed by looking into the published literature. Other limitations which include the input/output and accuracy of the data base also exist. According to the above mentioned, a new system is required, one that is more appropriate to conditions in tropical areas.

4.0 LIMITATIONS OF THE EXISTING SYSTEMS FOR FLEXIBLE PAVEMENT

The design The design and development of each current system is applicable to a specific area under some prearranged climatic conditions, as well as distress and maintenance types. However, the current systems for flexible pavements are not applicable to tropical climates and activities linked to maintaining the pavements.

The following list summarises the restriction involved in the present system including the weaknesses noted in the databases and the progress environment:

1- The present systems relate to certain local conditions that limit their usage to the areas. Local conditions may involve weather, dominant distress and maintenance types.

2- None of the current systems take into account the tropical region's distress based on two factors which are the climate and the pavement. Areas with wet climate that has recurrent rainfall are afflicted more by water induced problems than the dry regions. This significantly influences how appropriate maintenance decision is made. This process is vital as it is related to the level of urgency of a particular maintenance activity [31].

3-Most of the existing systems prefer to lean on a subjective platform when appropriate maintenance is considered. They have obviously not thought of any drainage systems in their maintenance strategies. For Singaporean and Malaysian roads, trench build-ups in existing pavements for utility installations or repairs are common. To worsen the situation, low quality backfill settlements normally contribute to unevenness and poor ride quality besides interrupting the subsurface drainage and joints that permit the flow of water and may cause the water to accumulate in pavement systems and further lead to the structural failure of the pavements.

4- No existing system has recommended any maintenance strategies for adoption in tropical regions (Malaysia, Singapore). While SCEPTRE, for instance includes ten basic rehabilitation strategies in its agenda, ROSE appears to favor the aspects of routing and sealing.

5- The user of the existing systems will find it difficult to identify and classify the existing distresses, therefore incorporating pictures of "real life" distress with the verbal description would be very helpful to the user. Having observed these limitations from established literature, we would like to add other limitations that may exist involving the input/output and accuracy of the database which further imply the need to develop a new appropriate measure to cater for tropical area conditions.

5.0 WEB BASED INFORMATION SYSTEM CONSTRUCTION

Users can access documents online, and bigger datasets are available in the intranets of organisations and can be accessed on web databases (the so-called Deep Web). Although the number of obtainable data grows continuously, it makes finding, organizing, accessing, and maintaining information difficult for the users. Transportation engineers, planners, and officials still lack a easily available system to access critical information with regards to flexible pavement maintenance technologies that can assist in deciding which technologies are potentially applicable to their projects.

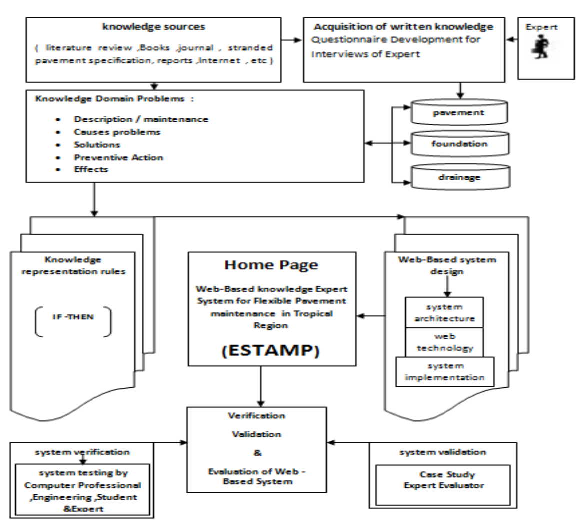


Figure 1 Web Based Information System Construction

6.0 CONCLUSION AND SUGGESTION

The paper reviewed the expansion and possibilities of expert system in flexible pavements built in tropical regions. It found that the expert systems are able to provide some important benefits over conservative computerised models. Expert systems can solve issues efficiently as they include wide-ranging expert knowledge and human intellectual that are too intricate to be represented and implemented analytically. Reviews on appropriate publication has demonstrated that despite the fact that the expert system is established since the 1970's in pavement applications, most of them tend to be concentrated on pavements for highways, using an approach that integrates human expert knowledge and analytical techniques with a user-friendly personal computer program. However, there is a lack of total expert systems improved for flexible pavements in tropical regions. This is due to the lack of agreement reached amongst experts and the insufficient number of procedures and tools which concern with the knowledge domain. Thus, a research on the possible application of a web based expert system for flexible pavement maintenance in wet tropical regions and an effective decision making technique is very much required.

Acknowledgement

I want to express my gratitude to the National University Malaysia (UKM) for supporting this project. I would also like to express my gratitude to Prof. Dato' Ir. Dr. Riza Atiq Abdullah O.K. Rahmatand Professor Noor Ezlin Ahmad Basri for their timely assistance and guidance.

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