Civil and Environmental Research
ISSN 2224-5790 (Paper) ISSN 2225-0514 (Online)
Vol.7, No.5, 2015

Pavement maintenance management systems

Hamad Al-Ajami

Member of Training Authority ,Public Authority for Applied Education and Training, Kuwait
* E-mail of the corresponding author: h.alasidan@hotmail.com

ABSTRACT:
Many countries have implemented a pavement maintenance management system(PMMS), in which this system will help the decision makers such as pavement engineers to apply the best technique for pavement rehabilitation at perfect time, so the maximal use of available funds were done. Each system requires a procedure to prioritize maintenance processes, in which the effectiveness of each prioritization will direct affect the obtainable funds efficiency. The analysis of priority concentrated on establishing the most appropriate list of road section ranking for rehabilitation depending on multiple factors .The Riyadh city pavement maintenance management system (PMMS) performs an inclusive assessment procedure of pavement situation for the whole road network before implementing any program of pavement maintenance. The main factors that this assessment process depends on are distress kinds, severity and their density. The evaluation process of the pavement condition is considered as a key part due to its ability to realize the effectiveness of the PMMS components.

Keywords: Pavement maintenance management system, Pavement condition, Evaluation processes

1. Introduction:

According to the continuously increasing rates of economical and developmental activities in several countries, traffic loads increased and caused roads devastation. Allocated funding resources and infrastructure requirements are generally considered inappropriate with highly growing maintenance demands, which in turn caused a large deterioration in roads pavement. So, pavement management system (PMMS) considered as an essential strategy to minimize the roads deterioration rates, protect road user's safety, elongate pavement life, and increase efficiently in addition to utilize recourses in best ways(Shafik and Mehar, 2005).
A system of pavement management is a management device, in which it represents the deterioration of pavement, especially surface deterioration, and these deteriorations depend on environmental and traffic factors, and this system concentrates on deciding the proper time and technique to accomplish the repairing process.
In any system of management of pavement maintenance, the prioritization for the procedures that are utilized to accomplish the maintenance process is also implemented. One method is often used to decide the priority of maintenance procedures in the priority index form is the priority model which depends on numerical terms (Abiola, 2010).

1.1 Importance of the study:

Generally, the funds allocated to complete the pavement rehabilitation processes is often Less than required, and according to inaccuracy in some tools that are utilized to predict road condition , such as visual assessment , this could cause the Misuse of these restricted recourses. All of that discuss the need for controlling system that decides the best technique to solve pavement issues at the right time and with utilizing available resources in best way which is called the pavement maintenance management system. The maintenance priority ranking is the procedure that utilized to manage the road enhancement and maintenance processes (Shareef E., 1991).
In any PMMS, the first step is to realize the relations through the type of distresses that appeared in pavement, and their acceptability stages. These acceptability stages in some cases do not represent the pavement situation in actual way, so engineers develop a model of distress index that give an indication for the whole pavement situation, and in some cases , it is also essential to create a model that depends on cost to manage the pavement maintenance procedure with focusing on the existing funds.

2. Pavement Maintenance Management System:

The procedure of pavement maintenance is considered as an approach of a cost-effective rehabilitation and treatment to a specific pavement system of roads(FAA,2006) .There are two levels that any system of pavement management can be implemented which are: project level in addition to network level. The first level focuses on a particular region that determined to apply rehabilitation procedures, while the network level concentrates on utilizing the available funds in the best effective way to maintain the overall network.
Each system of pavement maintenance aims to increase the efficiency of repairing and treatment of pavements through utilizing the existing funds in their maximum benefits. Generally, each management system of pavement maintenance includes: (the inventory of road network, the evaluation of the situation of pavement, for performance forecasting, method of planning) (Shahin, 1994).

2.1 The inventory of Network:
Each network mainly consists of branches which could be divided into smaller parts which are known as sections. While choosing the best technique for rehabilitation of pavement, sections is considered as the smallest part of this management system. This division process will depends on multiple factors which are: the structure of pavement, traffic volume, the manner of the existing pavement and the history of construction. This could help in the process of collecting data and analyzing roads information. So generally each pavement network contains the following definitions (UFC, 2004):

- **Branch:** a branch is considered as a section in the pavement network and also considered as a single structure and owns a specific role (such as; Individual roads, parking lots).
- **Section:** Section is considered as a part of a branch; it owns regular properties over the whole length or area for each section. Figure (1) illustrates an example of branch divided into several sections.
- **Sample Unit:** In any pavement network; Sample unit is the smaller unit in this roads network.

2.2 Evaluation of Pavement condition:
The main purpose of this procedure generally is to realize the actual situation or performance of the pavement and mainly this evaluation is divided into a structural and functional evaluation. The structural evaluation considered as a quantitative assessment of structural pavement effectiveness for treatment, whereas functional evaluation is qualitative equipment which handles with the whole performance and the serviceability act of a pavement which depends on the measurement that are collected in the field according to several properties such as; roughness, safety, distresses of surface (Haas, 1997).The previous mentioned quality index is used to evaluate these properties. For example; riding comfort index (RCI) is utilized to measure the roughness of the surface. Another measurement utilized to represent the comfort level of riding is International Roughness Index (IRI).According to friction of surface, road safety could be measured. And the main index that is utilized to represent the surface distress is Pavement condition index (PCI), in which this index gives an indication of distress kind and how the distress will spread; figure (2) illustrates the rating method of pavement condition index.
This process started with distinguishing the kind of distresses existed in the pavement and their severities, plate (1) express the main kinds of distresses occurred in pavement surfaces , and the step that follows distinguishing the kind of distress, is to realize the severity of these distresses. Generally there are three descriptions for severity levels which are (Low, Meduim, High), and the most often used criteria to distinguish distress severity with relating to the kind of this distresses is the (IF-Then) rule, which represented in figure (3).

2.3 Models for performance forecasting:
These models are often used in each project and network level in order to realize the best maintenance technique according to pavement condition. For network level, these models utilized to distinguish the pavement condition, to plan funds, and delimitation of required works, and at the project level these models are utilized to predict the probable level of road traffic in addition to predict the common climate situation in order to select the most effective reparation process. Another reason to utilize these models at the project level is to compare between the options available for maintenance and reparation processes through creating a cost examination for the pavement life-cycle. In order to develop new models for pavement deterioration, several strategies were utilized such as; indication of straight line, abatement, markovian and mechanical-experimental techniques, etc (Shahin, 1994). Zimmerman propose an expert modeling technique which utilized for the cases when there are a shortage in available data which in turn limit the ability to generate a suitable model of deterioration(Zimmerman,1999).

2.4 Methods of planning:
These methods can help the competent managerial authorities to select the most appropriate treatment technique, through determining the present and the expected pavement situation. Several programs could be designed by pavement engineers such as; Program of planning for the recent and incoming maintenance techniques to preserve enhancement of pavement situation.

3. Pavement maintenance treatment decisions and prioritization of maintenance processes:
According to the roughness and structural pavement situation, in addition to several factors such as; the kind of distress, to what extent these distresses existed and their severity, all of these will affect the selection criteria for the best repairing technique of the pavement. Furthermore, the familiarity of the distress existence controls the selection for the suitable maintenance technique. For example, each kind of distress will require a specific kind of treatment procedure. According to pavement selected (OhioDOT-1999).
Generally, the decision taken from the collected information as mentioned before could be divided to six categories with reference to circumstance that surround distresses which are; (Nothing to do, fill the cracks and

sealing, cobbling, Milling, apply an overlay of thin hot mix, and repair Shoulder).Each rehabilitation technique has a direct effect on pavement cycle-life as shown in table (1).
Processes of maintenance and repairing must be arranged due to their necessity, value or depending on costs and advantages derived from implementing these processes.
Mainly there are four methods utilized to prioritize maintenance procedures in best manner which are (Washington State Department of Transportation, 1994);

- **The matrix method:** this method may depend on various factors such as: situation and traffic, in more details the priority always given to the worst state of the pavements and to roads with heavy volume traffic.
- **Method of condition index:** This method depends on relative results ranged from zero which is considered as the worst case to 100 that is the best pavement state. In order to generate a latest list of projects, a combination between state score and other factors such as traffic volume can be done.
- **The process that depending on the benefit-cost ratio:** Generally, sections that own a highest ratio of Benefit-cost always own the highest priority. This ratio may offer high priorities to start with poor pavement state than initializing with pavements with worst cases.
- **The method of cost-effectiveness**: This criterion is considered as the same as the procedure of benefit-cost ratio, but the main role of this procedure is to increase the segment act with reference to cost.

In some cases, PCI could be considered as an indicator of maintenance priority, where when obtaining a highest value of PCI then the state of the road will be better and that causes delaying of its maintenance priority.
Priority Rank order presents an order of pavement maintenance strategies for different road segments with related to restricted recourses. The model of priority ranking determines the budget availability with connecting it to overall cost need for enhancement, figure (4) illustrates the general schematic flow of priority ranking model.

4. Case study:

PMMS in KSA: Municipality of Riyadh city, has applied Distinctive pavement management maintenance system which was depend on roughness measurements, visual surveying of the pavements condition, skid resistance to assesses the state of the pavement. Riyadh Municipality also performs an inclusive assessment of pavement situation before implementing any program of rehabilitation and repairing. The assessment procedure concentrated on realizing the type, density and the severity of pavement distresses. An index for pavement condition were utilized to represent the data which is called index of urban distress (UDI) in which is composed of fifteen kinds of pavement distresses existed in pavement maintenance management system of Riyadh, in addition to the fact that UDI is considered as a numerical leveling method for different distresses and this rating procedure is depending on the numerical index ranging from 0-100 , where 100 symbolize excellent condition of pavements. The measurement of UDI depended on the kind of distresses, density and distress severity for each section of Riyadh network as mentioned before, and with reference to the UDI system, there are four main situation of pavement existed which are; excellent, good, fair and poor (Al-Swailmi et al., 1999), table (2) illustrates the main four ratings of pavement condition for the UDI in Riyadh PMMS.
The data accumulated from the system were divided into two main categories: segments of main road and segments of secondary road. In which data in Secondary Street included state of pavement, types of distress in addition to the IRI for each road segment. Generally, there are multiple kinds of rehabilitation procedures depending on the value of UDI and FN (skid resistance) value in Riyadh PMMS as discussed in figure (5), (6),(7) .
The outputs from this pavement maintenance management system in Riyadh presented that there are a great relation between IRI and specific types of distresses such as cracking, depression, raveling and patching**.**

5. Conclusions:

This paper has created a comprehensive review for the pavement maintenance management system (PMMS), especially in Riyadh city, where pavement management maintenance system is considered as a systemic method that aids in assessing the pavement performance and condition of existing and future pavement. Evaluation of pavement condition is considered as a main component of any pavement maintenance management system, and depending on the condition of the pavement; the treatment needs, funds and ranking of priority will be specified. So, PMMS is considered as an extra technique to enhance the performance of existing pavement and to utilize the allocated funds for such projects to best advantage.

References:

Abiola, O.S. Pavement Performance Models for Lagos-Ibadan Express Road. Unpublished PhD Thesis, University of Agriculture, Abeokuta, Nigeria, 2010.

Al- Swailmi, S., Al-Mansour, A., and et al "Developing Urban Distress Index for Riyadh PMMS", Fifth Saudi Engineering Conference, UmmAl-Qura University, 1999.

FAA, 2006. Airport Pavement Management Program, Advisory Circular AC 150/5380-7A, FAA Washington, D.C.

Haas R, 1997. "Pavement Design and Management Guide". Transportation Associate of Canada. ISBN 1-55187-114-9.

Ohio DOT. "Pavement design and rehabilitation manual" January-1999.

Shafik, J and A.H. Mehar. Development of Pavement maintenance Management System (PMMS) for Gaza City. Journal of the Islamic University of Gaza (Series of Natural Studies & Engineering) Vol.13, No.1, 2005, pp. 119-138.

Shahin, M.Y., 1994. "Pavement Management For Airport, Roads, and Parking Lots". Chapman & Hall, New York. ISBN 0-412-99201-9.

Shareef Essam A., " Ranking versus simple optimization in setting pavement maintenance priorities: A case study', Transportation research record No.1397, Washington D.C., 1991. UNIFIED FACILITIES CRITERIA (UFC), 2004. "PAVEMENT MAINTENANCE MANAGEMENT". UFC 3-270-08, 16 January 2004.

Washington State Department of Transportation, "A Guide for Local Agency Pavement Managers", TransAid Service Center, Olympia, December 1994.

Zimmerman, K., and Broten, M., 1999. "Development of Performance Models for Pavement Management System". Presented at 24th International Air Transportation Conference, ASCE.

H. Al Ajami, Hamad Mohammed Amer Alasidan Al-Ajami, born in Kuwait, 13 May, 1973. The author earned a PHD degree in Civil Engineering Field in Kuwait in 2011 & a Master degree of Public Works Engineering, Kuwait, 2008, etc .This author became a member of in a training organization of public authority for Applied Education and Training in 2002 until now. The author also published a scientific research about "Drafting and dissemination of public policy (decision-making and his theories)" in 2004, in addition to a scientific research published in the same year about" Decision-making in crisis situations".

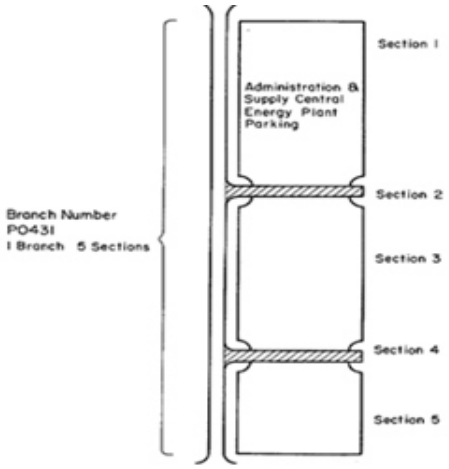

Figure (1): example of branches and sections

\

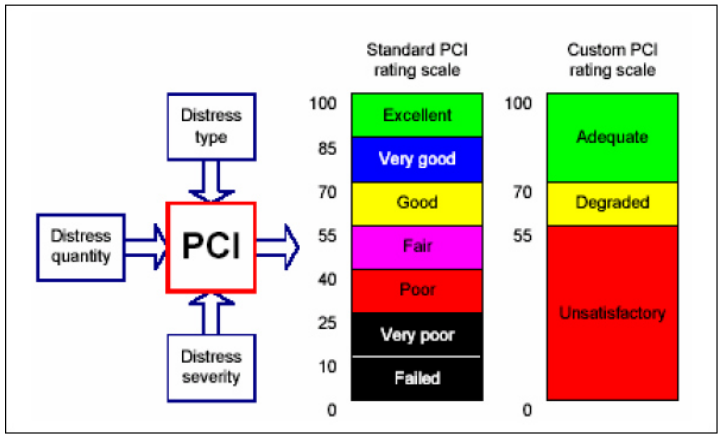

Figure (2): Pavement Condition Index (PCI) Rating Criteria

Treatment strategy	Expected increase in pavement life (years)
Crack filling and sealing	3-5
Patching	3-5
Milling	1-4
Hot mix Overlay application	8-15

Table (1): predictable increase level in Life-cycle of pavement according to rehabilitation technique

Pavement Condition	UDI
Excellent	100 – 90
Good	89 – 60
Fear	59 - 40
Poor	≤ 39

Table (2): ratings of pavement condition for the UDI in Riyadh PMMS

Block Cracking :

IF crack mean width ≤ 6mm, THEN severity is low.
IF crack mean width > 6mm and ≤ 19mm, THEN severity is moderate.
IF crack mean width > 19mm, THEN severity is high.
Record square meters of affected area at each severity level.

Longitudinal, reflection and transverse cracking :

IF crack mean width ≤ 6mm, THEN severity is low.
IF crack mean width > 6mm and ≤ 19mm, THEN severity is moderate.
IF crack mean width > 19mm, THEN severity is high.

Potholes :

IF pothole depth < 25mm, THEN severity is low.
IF pothole depth > 25mm and < 50mm, THEN severity is moderate.
IF pothole depth > 50mm, THEN severity is high.

Fatigue Cracking :

IF an area of cracks with few fine parallel cracks connected, THEN severity is low.
IF interconnected cracks forming alligator pattern, THEN severity is moderate
IF interconnected cracks forming alligator pattern with spalling and distortion, THEN severity is high

Patching :

IF patch shows no visual distress, THEN severity is low.
IF patch shows medium distress with notable roughness, THEN severity is moderate.
IF patch shows high distress with distinct roughness, THEN severity is high.

Edge Cracking :

IF cracks are light with no breakup or loss of material, THEN severity is low.
IF cracks are well defined with some breakup and loss of material, THEN severity is moderate.
IF cracks are well developed with significant breakup and loss of material, THEN severity is high.

Rutting, bleeding, raveling, polished aggregate and shoving :

Record maximum rut depth in millimeters, and number of occurrences and square meters of affected area, severity level is not applicable.

Transverse Cracking:

IF crack spacing > 15 m, THEN extent is low.
IF crack spacing > 7.5 m and < 15 m, THEN extent is moderate.
IF crack spacing < 7.5 m, THEN extent is high.

Fatigue Cracking :

IF crack is 1% to 9% of wheel path, THEN extent is low.
IF crack is 10% to 24% of wheel path, THEN extent is moderate.
IF crack is 25% to 49% of wheel path, THEN extent is high.

Patching :

IF Patching is 1% to 9% of section, THEN extent is low
IF patching is 10% to 24% of section, THEN extent is moderate.
IF patching is 25% to 49% of section, THEN extent is high.

Block Cracking :

IF cracking is 1% to 9% of section, THEN extent is low.
IF cracking is 10% to 49% of section, THEN extent is moderate.
IF cracking is > 49% of section, THEN extent is high.

Figure (3): (IF-Then) rule for distress severity level

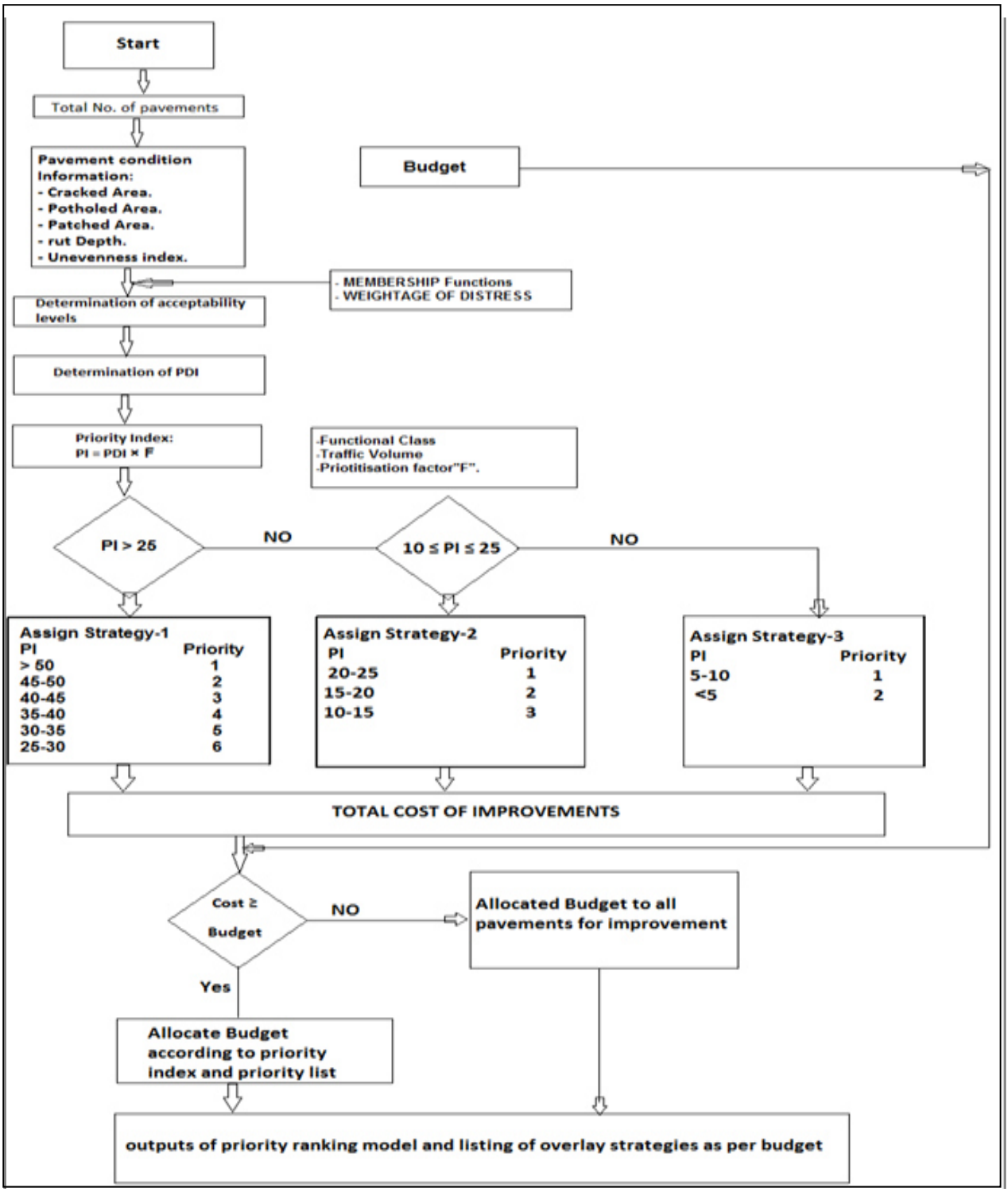

Figure (4): schematic flow of Priority ranking model

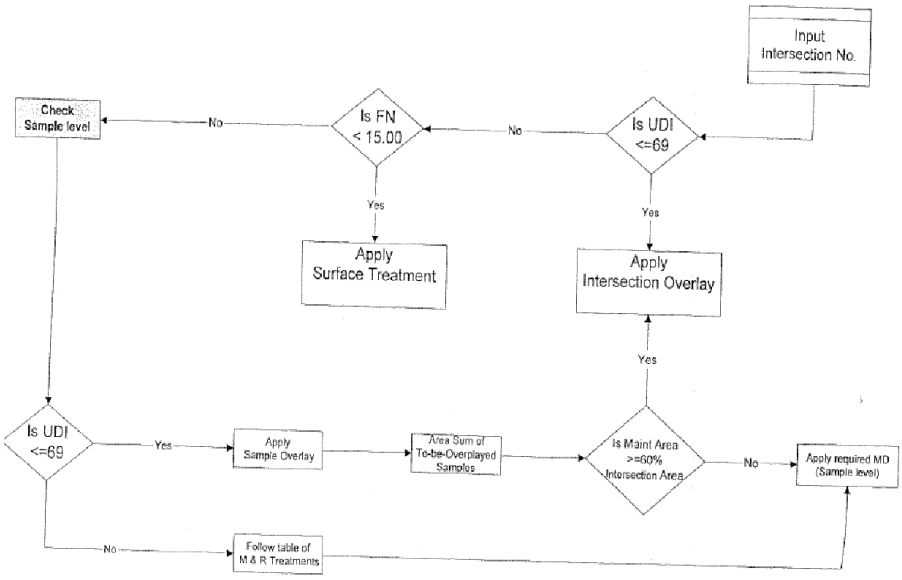

Figure (5): Decisions on maintenance for intersections

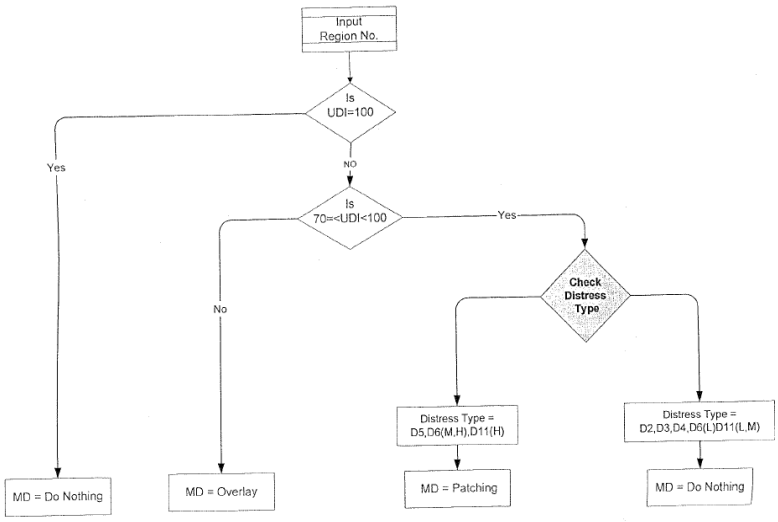

Figure (6): Decisions on maintenance for regions

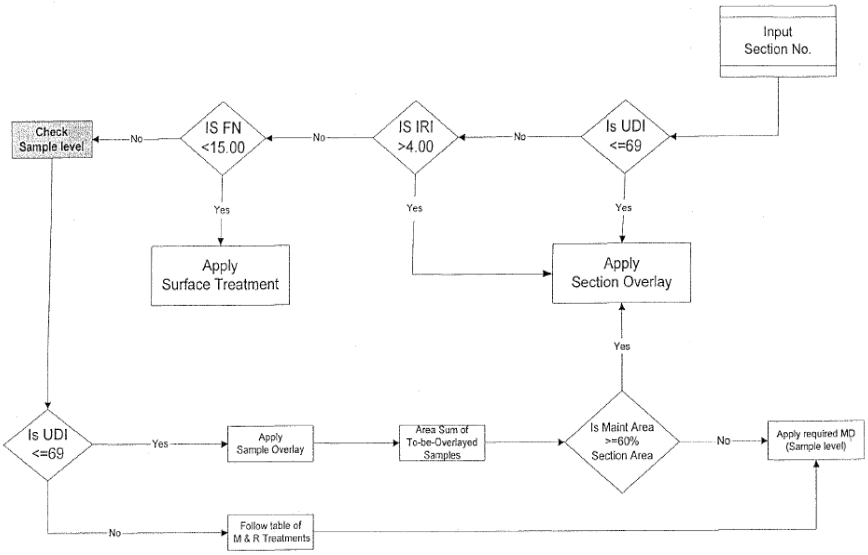

Figure (7): Decisions on maintenance for sections

Plate (1): Selected photographs of main kinds of surface pavement distresses

The IISTE is a pioneer in the Open-Access hosting service and academic event management. The aim of the firm is Accelerating Global Knowledge Sharing.

More information about the firm can be found on the homepage:
http://www.iiste.org

CALL FOR JOURNAL PAPERS

There are more than 30 peer-reviewed academic journals hosted under the hosting platform.

Prospective authors of journals can find the submission instruction on the following page: http://www.iiste.org/journals/ All the journals articles are available online to the readers all over the world without financial, legal, or technical barriers other than those inseparable from gaining access to the internet itself. Paper version of the journals is also available upon request of readers and authors.

MORE RESOURCES

Book publication information: http://www.iiste.org/book/

Academic conference: http://www.iiste.org/conference/upcoming-conferences-call-for-paper/

IISTE Knowledge Sharing Partners

EBSCO, Index Copernicus, Ulrich's Periodicals Directory, JournalTOCS, PKP Open Archives Harvester, Bielefeld Academic Search Engine, Elektronische Zeitschriftenbibliothek EZB, Open J-Gate, OCLC WorldCat, Universe Digtial Library , NewJour, Google Scholar