

Prediction the Effect of Maintenance Alternative on Pavement Performance Indicators

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Abstract
A road pavement continues to deteriorate under the combined actions of traffic loading and the environment. The ability of the road to satisfy the demands of traffic and the environment over its design life is known as performance. The most common indicators of pavement performance are: pavement condition index (PCI), riding quality or (IRI) and skid resistance or (IFI). Understanding the maintenance effects can benefit pavement maintenance decision-making. Accordingly, this research presents the effect of maintenance alternative on pavment performance indicators.Using the right maintenance treatment at the right time will help to get the maximum benefit and keeping the pavement performance indicator's values in a good level.
Keywords: pavement performance, pavement performance indicators, maintenance alternative, multi-objective optimization.

1. Introduction
Performance is a general term for how pavements change their condition with time. Performance can be simply and more broadly defined as the history of pavement with regard to general serviceability, roughness or international roughness index, surface distress and safety in terms of skid resistance. Pavement deteriorates with time, means decrease in pavement serviceability levels and / or an increase in pavement surface distresses with time [Ningyuan Li,1997].

One goal all maintenance activities have in common is extending the life of the pavement.

Pavement preservation activities employing to enhance pavement performance extend pavement life and improve safety. Preventive maintenance is one of the biggest components of a pavement preservation program, while other types of maintenance may not be considered preservation. An important aspect for cost-effective maintenance over the pavement life cycle is the selection and timing of maintenance activities.

1.1 Objective of this Research
Prediction the effect of maintenance alternative on pavement performance indicators such as; Pavement Condition Index (PCI), International Roughness Index (IRI) and International Friction Index (IFI).

2. Background
2.1 Pavement Performance
According to the American Association of State Highway Officials (AASHO), pavement performance is defined as the serviceability trend of the pavement over a design period of time, where serviceability indicates the ability of the pavement to serve the demand of the traffic in the existing condition [American Association of State Highways Officials, AASHO (1962)]. In other words, pavement performance can be obtained by observing or predicting the serviceability of a pavement from its initial service time to the desired evaluation time. Usually, pavement condition can be evaluated according to four aspects or evaluation measurements: roughness, surface distress, structural capacity, and skid resistance. Various indices have been developed to measure pavement performance in terms of either these individual aspects or a combination of them [Zhang, Z., N. Singh, and W.R. Hudson, (1993)].

3. Case Study
The study area is a part of section R/4Bwhich starts at station 49+000 Km and ends at station 53+500 Km, the total length of the study area is 4.5 km which is located at the beginning of section R/4B at AL-Latifiya city. Plate (1) shows the location of section R4.

Plate (1) Location of Section R4/Expressway No.1 in Iraq

4. Field Measurements

The following factors were obtained by the aid of field measurements to evaluate pavement;

1- Pavement condition index (PCI): a numerical rating of the pavement condition that ranges from 0 to 100 whereas, 0 being the worst possible condition and 100 being the best possible condition (ASTM D6433) as shown in Figure (1).

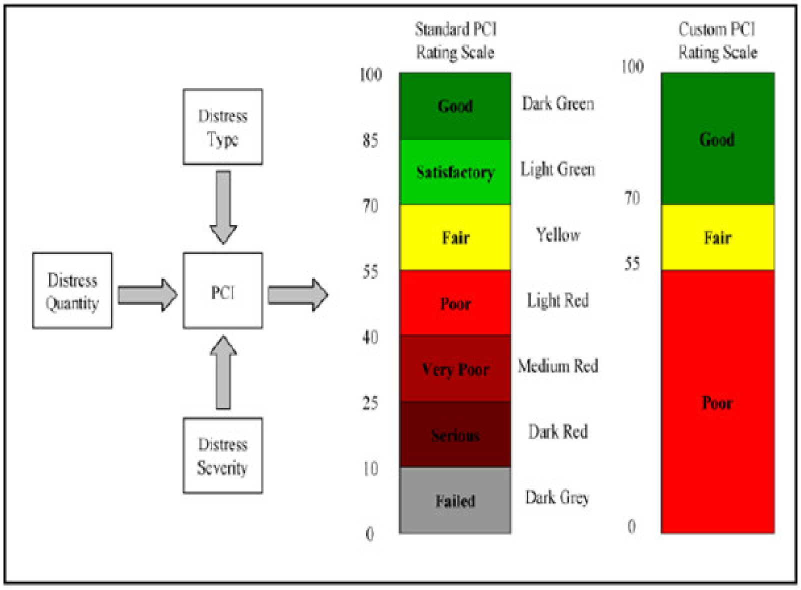

Figure (1) Pavement Condition Index (PCI) Ranges [U.S. Army Corps of Engineers-USACE, (2012)].

2- International Friction Index (IFI):

Skid resistance was assessed based on (IFI) (International Friction Index). A scale ranging (0.0-0.6) as shown in Figure (2), IFI of 0.6 indicates that the pavement seems to be in a good texture.

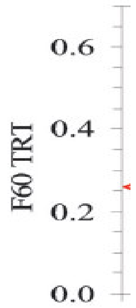

Figure (2) F60 Scale [McDaniel, R. S., and K. J. Kowalski, (2012)].

3-International Roughness Index (IRI):

The longitudinal profile is measured to identify the deformations that affect user comfort and safety. The quality indicator generally used for ride quality is the International Roughness Index (IRI). Scale rating can be shown in Figure (3).

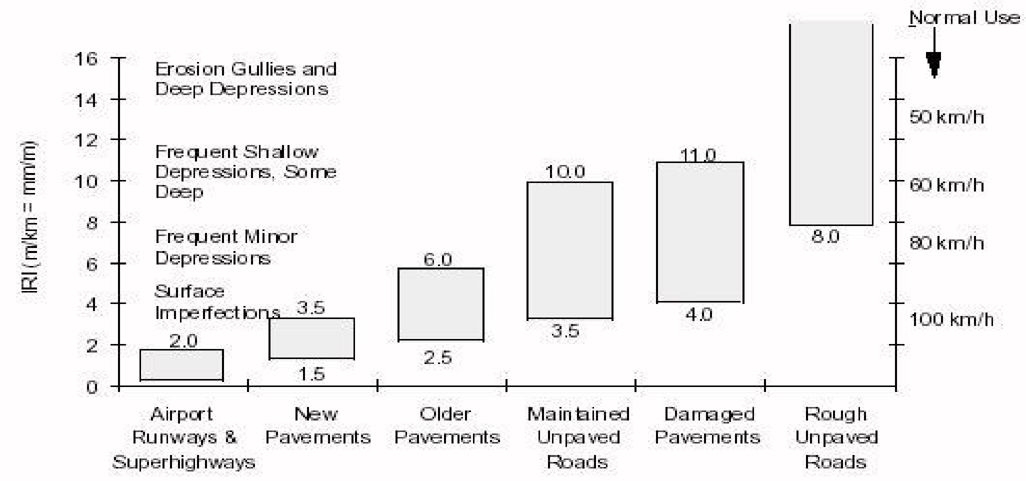

Figure (3) IRI Roughness Scale, [Sayers, M. W et al., (1986)].

5. Pavement Maintenance strategies and Repair Technique

Pavement maintenance is broadly identified as work accomplished to preserve or extend the pavement's service life until major rehabilitation or complete reconstruction performed [Prithvi S. Kandhal , Mary Stroup-Gardiner (1998)] .

There are three types of pavement maintenance strategies:

1. Preventive Maintenance: Pavement preventive maintenance treatments preserve, rather than improve, the structural capacity of the pavement structure Thus; preventive maintenance treatments are limited to pavements in sound structural condition. In addition, in order to be effective, preventive maintenance should be applied before pavements display significant amounts of environmental distress such as raveling, oxidation, and block cracking. To be cost-effective, pavement preventive maintenance treatments should be applied before most engineers, or project decision-makers, would normally consider their use. Timely treatments prove to be most cost effective [Mamlouk MS, ZaniewskiJP (1999)].

2. Corrective Maintenance: Performed after a deficiency occurs in the pavement, such as moderate to severe rutting, raveling or extensive cracking. This may also be referred to as “reactive” maintenance. The differences between preventive and corrective maintenance occur in the timing and cost. Corrective maintenance is reactive, i.e., it is done after a road is in need of repair so the cost is greater. Delays in corrective maintenance result in even larger costs since defects and their severity continue to increase. Corrective maintenance treatments include structural overlays (3 inches or greater), milling, patching and crack repair [Robinson R. and Roberts P., (1982)].

3. Emergency Maintenance: Performed during an emergency situation, such as a blowup or severe pothole that needs repair immediately. This could also include temporary treatments that hold the surface together until a more permanent treatment can be performed. Emergency maintenance is often related to safety and time, with cost not being a primary consideration. Likewise, materials that may not be acceptable for preventive or corrective maintenance may be the best choice for emergency situations [Johanns M. and Craig J., (2002)].

The differences between preventive, corrective, and emergency repair is the condition of the pavement when the treatment is applied, rather than the type of treatment. [Mamlouk MS, ZaniewskiJP.,(1999)].

The types of repair techniques are illustrated below.

1. Crack Sealing: Crack sealing is the process of cleaning and sealing or resealing of cracks in AC pavement. This technique is used to fill longitudinal and transverse cracks, including joint reflection cracks from underlying PCC slabs, that are wider than 1/8 in. The primary purpose of crack sealing in AC pavement is to prevent surface water infiltration into the pavement foundation. It is more cost effective to use this technique as a preventative measure when the overall pavement condition is good or better. Sealing cracks in a deteriorated pavement is not cost effective [Shahin, M.Y., (2005)].
2. Patching: This technique involves replacing the full depth of the AC layer and may include replacement of the base and subbase layers. Full-depth patching is used to repair structural and material related distresses such as alligator cracking, rutting, and corrugation. In the case of slippage cracking where the failure may be limited to the top AC layer, the depth of the patch may be limited to the top AC layer if it can be removed easily [Shahin, M.Y., (2005)].
3. Overlay: This technique involves adding one or more AC layers to an existing AC or PCC pavement. It is used to correct or improve structural capacity or functional requirements such as skid resistance and ride quality. The use of an AC overlay is usually more economic when the existing pavement is still in good condition [Shahin, M.Y., (2005)].
4. Asphalt Seal-Coat: Asphalt seal coats are composed of a thin
layer of an asphalt material such as cutbacks, asphalt emulsions, or paving-grade asphalt cement. Modifiers are often added to the asphaltic liquid mixture and may include rubber, latex, polymers, and rejuvenators. Sand, aggregate, mineral and synthetic fillers, and rubber crumbs can be applied after the asphaltic mixture is applied to the pavement surface. Some seal coats such as slurry seals and microsurfacing incorporates the sand, aggregate, and fillers in the mixture before placing it on the roadway [Yamada A., (1999)].There are different types of surface treatments such as fog seal, sand seal, scrub seal, chip seal, multiple chip seals, slurry seal, cape seal, microsurfaceing and pavement dressing.

6. Effect of Maintenance Mode and the Type of Repair on PPI

6.1. Effect of Preventive Maintenance on the PPI

Preventive maintenance is defined as those activities that correct minor surface deficiencies of pavement in good condition.

Pavement preventive maintenance preserves, rather than improve, the structural capacity of the pavement structure and have little effect on the PPI that are in a fair level.

Pavement performance indicators of the selected case study indicate the condition of pavement in a poor state, so this type of maintenance is not appropriate.

6.2 Effect of Corrective Maintenance on the PPI

Corrective maintenance performed after a deficiency occurs in the pavement, such as loss of friction, moderate to severe rutting, raveling or extensive cracking to make the condition of pavement at a good level

The primarily differences between preventive and corrective maintenance in cost and timing. Corrective maintenance is reactive, means, carried out after a road is in need of repair, is therefore high costly. Delays in corrective maintenance result in even larger costs since defects and their severity continue to increase.

6.3 Effect of Emergency Maintenance on the PPI

Emergency maintenance is applied when an unexpected situation happens such as sever pothole that needs repair immediately, led to improve pavement condition.

6.4 Effect of Overlay Repair Technique on the PPI

This technique used to correct or improve structural capacity or functional requirements such as skid resistance and ride quality, it is enhancing the smoothness, friction, and / or profile of the roadway, led to increase in PCI and IFI and decrease irregularities in longitudinal profile.

6.5 Effect of Crack Sealing Repair Technique on the PPI

This technique is used to fill longitudinal and transverse cracks. The primary purpose of crack sealing to prevent moisture intrusion in the pavement as well as minimizing the amount of incompressible materials in the cracks. Sealing cracks in a deteriorated pavement is not cost effective and with little impact on PPI.

6.6 Effect of Asphalt-seal Coat Repair Technique on the PPI

It is used to provide a surface seal or skid-resistant surface to structural sound pavement [Shahin, M.Y., (2005)].This technique suitable to low volume-roads and has little improvement in indicators.

6.7 Effect of Patching Repair Technique on the PPI
Patches restore a pavement's structural integrity and improve its ride.
This technique repair alligator cracking, rutting and corrugation this leads to improve PPI.

7. Formulation Multi-Objective Optimization Model

multi-objective optimization model is constructed as follow:

1- Objectives:

The objectives can be carried out as follows;
Minimize strategy cost =C
Maximize condition = (PCI+IFI-IRI)
Where
C: maintenance strategy cost
PCI: Pavement Condition Index
IFI: International Friction Index
IRI: International Roughness Index

2- Constraints

Table (1) shows the field measurements data at current year and previous years. Relate current data with available previous data for the same pavement section to develop the constraints.

Table (1) PCI, IFI, IRI for the Year 2012, 2014 and 2016

Year / indicators	2012	2014	2016 (current condition)
PCI	64	56.5	55
IFI	0.31538	0.28123	0.2668
IRI	1.68778	1.86472	2.008

1-Relate current data of PCI with previous data
(56.5/64)= (PCI next year/PCI current)
PCI next year= 0.88281*PCI current………………… (1)
2-Relate current data of IFI with previous data
(0.28123/0.31537) = (IFI next year /IFI current)
IFI next year= 0.89175* IFI current…………………... (2)
3-Relate current data of IRI with previous data
= (1.86472/1.68778)= (IRI next year /IRI current)
IRI next year= 1.10484*IRI current……………………. (3)
The pavement condition should be in a better state so at this state treatment needs to bring the pavement condition in to a better condition because all current indicators (PCI, IFI, and IRI) refer to pavement condition in faire state. So the equations should be limited as follow:
PCI next year= 0.88281*PCI current $\leq$ PCI after a specific type of maintenance
IFI next year= 0.89175* IFI current $\leq$ IFI after a specific type of maintenance
IRI next year= 1.10484*IRI current$\geq$ IRI after a specific type of maintenance
Note: PCI, IFI and IRI (after a specific type of maintenance) obtained from opinion experts.

8.Results

Implementation SOLVER V 2016-R2 software to solve multi-objective optimization model, the results can be shown in Table (2) and (3).

Table (2) Effect of Pavement Maintenance Strategy on PCI, IFI and IRI

maintenance strategy / indicators	Preventive strategy	Corrective strategy	Emergency strategy
PCI	74.7613	93.4516	80.9914
IFI	0.4009	0.3979	0.3979
IRI	1.3631	0.9996	1.2722

Table (3) Effect of Pavement Repair Techniques on PCI, IFI and IRI

Repair techniques / indicators	crack sealing	patching	overlay	asphalt seal-coat
PCI	77.8763	77.8763	84.1064	71.6462
IFI	0.3590	0.3590	0.41886	0.3590
IRI	1.5448	1.27222	1.18135	1.45397

9. Conclusions

As the pavement service life and the deterioration increase, the maintenance alternative changes. When the pavement performs in a good condition, inexpensive preventive maintenance treatments is applied while if the pavement reaches to the end of its design life, expensive reconstruction maintenance type will be necessary, so the appropriate maintenance alternative for the selected case study is corrective strategy and overlay repair technique.

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