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Developing a Frame Design for Airport Pavements Maintenance Management System

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Abstract
Software that depends on available information provides answers, solutions, or diagnoses by following techniques that aim to imitate the mental processes and apply the knowledge of an expert in any particular subject. Using an expert system has a number of advantages over typical computerized models. Expert systems are successful at issue solving because they include a large number of experts. Human knowledge and thought are just too complicated to capture and use in an analytical technique. For the past 20 years, that expert system has been used in paving applications, mostly for highway networks. The number of expert systems created for airport pavement is still minimal.

This Paper describes the initial development and methodological method of developing and validating the motion test method using video and photography, which increases the degree of automatic detection of road stress; to develop a descriptive strategy for airport road maintenance strategies, adapted to the Baghdad international airport system, using modeling strategies to predict road performance and service definition and implementation standards; and to develop a software, then evaluated it by applying to an existing computer programs that can be used as a decision support tool.

Keywords: Airport, Airport networks, Artificial Intelligence (AI), Expert Systems, Maintenance, and Airport Pavement Maintenance.

1. Introduction

Airports are often separated into two sections: airside and landside. Airside comprises all controlled access zones as well as runways, taxiways, aprons, aircraft service areas, and air control facilities. Public access parts including the passenger terminal (before security check), parking lots, and other public service facilities are located on the airport's landside.

Regarding pavements at an airport there are three critical areas: the runway; the taxiway; and the apron as it is clear in figure (1). The runway takes place the landings and takeoffs. The taxiway has the function of connecting the runway to the apron. An apron is a place where the aircraft (parks), in this place, the aircraft are loaded and unloaded (with passengers, luggage, and cargo), and it is also the place where the aircraft is refueled. (Tamagusko, 2020**).**

Although the need for maintenance is widely recognized, it is still not getting adequately done. Many countries spend just 20-50 % of what they should be spending on maintenance of their road network. There are many reasons why this is so. The challenges include distinguishing maintenance from other types of road work; calculating how much maintenance will cost; where to get the money; and how to plan for it institutionally; and contracting maintenance work (Heggie, 1995).

The importance of airports pavements maintenance comes from four reasons as:

1. Roads in airports are among the most important public assets in many countries.
2. Postponing airport pavement maintenance results in high direct and indirect costs.
3. Delayed maintenance has indirect costs as well.
4. Countries require a central runway to carry around 80% of airport traffic, as well as enough access routes to airports and important roadways in metropolitan centers.

2. Pavement Distress

The state of a pavement surface in terms of its overall look is referred to as "pavement distress" (Hicks, 1981). A distressed pavement may be cracked, warped, or disintegrating in contrast to a flawless pavement, which is level and has a continuous, unbroken surface. These three fundamental types of distress can be further broken down (Hveem, 1955).

Most agencies use some measure of cracking in evaluating the condition of flexible pavements. The most common measures are transverse, longitudinal, and alligator

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cracks. Distortion is usually measured by determining the extent of rutting, and disintegration is measured by the amount of raveling. Typically, each agency has a procedural manual that defines each element of distress to be observed, with instructions as to how these are to be rated on a given point scale (Hass and Hudson, 1978).

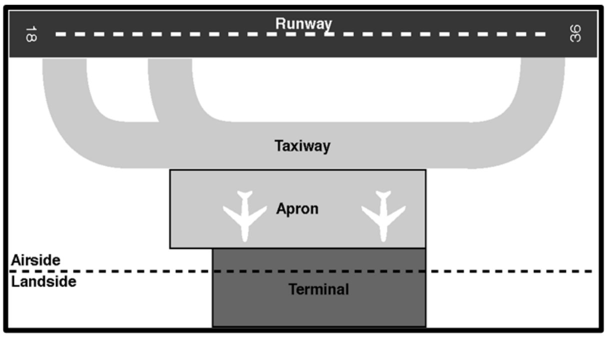

Figure 1: A Generic draft of an airport (Tamagusko, 2020).

Typically, distress data are obtained by trained observers who make subjective judgments about pavement condition based on predetermined factors. Often photographs are used for making judgments. Although some agencies use full sampling, pavement sections of about 300 ft often are randomly selected to represent each mile of road. Measurements are usually made on a regular schedule about every 1-3 yr. After the data are recorded, the results are condensed into a single number, called a distress (or defect) rating (DR). A perfect pavement usually is given a score of 100; if distress is observed, points are subtracted (Garber and Hoel, 2020). The general equation is:

$$\mathrm{DR} = 100 - \Sigma \mathrm{D_i W} \qquad \ldots(1)$$

where:

Di = the number of points assigned to distress type i for a given severity and frequency.

W = relative weight of distress type i.

One of the major problems with condition or distress surveys is the variability in results due to the subjective procedures used. Other causes of error are variability in condition of the highway segment observed, changes in evaluation procedure, and changes in observed location from year to year. Other concerns are related to safety of pavement surveyors (Garber and Hoel, 2020).

3. Airport Pavement Maintenance and Rehabilitation Design

Pavement Maintenance means every pavement, no matter how well-designed/constructed, will degrade with time due to the combined impacts of traffic loads and the environment. We utilize maintenance and rehabilitation to halt or stop the deteriorating process. Maintenance procedures such as crack sealing, joint sealing, fog seals, and patching assist decrease the pace of deterioration by detecting and correcting particular pavement flaws that contribute to overall degradation. The act of fixing areas of an existing pavement to restart the deteriorating process is known as rehabilitation. Removing and replacing the wearing course in a pavement, for example, gives new wearing course material on which the degradation process might begin again. Rehabilitation is defined as: "Measures to modify, reinforce, or salvage existing problematic piers in order to keep them in operation with minimal routine maintenance." Defective piers cause suffering that is beyond the scope of ordinary maintenance."

In other words, while pavement repair can delay the pace of deterioration, it cannot halt it. As a result, the effects of deterioration must eventually be reversed by adding or replacing components in the current pavement structure. This is referred to as rehabilitation. Options for rehabilitation are determined by local conditions and the kind of pavement narrowness. Airport networks have become one of the most essential assets in a country, requiring a significant expenditure of public cash. To obtain a fair return on investment, networks must be maintained and kept in excellent working order by employing the most cost-effective techniques of maintenance and rehabilitation. This is not only costly monetarily, but also in terms of human resources. (Kareem and Ibraheem, 2022).

The Expert System is likely the most effective application for engineers and decision makers since it replicates human experience and judgment by defining solution methods using logic and symbolic reasoning. APMS enables airport authorities to manage cost-effective decisions connected to specific Maintenance and Rehabilitation programs, tailoring optimal timing and understanding the long-term consequences of such decisions integrated with budget allocation (Demetrios, 2006).

3.1 Surface Condition Evaluation

The pavement's present status or performance is assessed using both functional and structural criteria. Consequently, the pavement has two kinds of criteria for evaluation which are:

1- The structural capacity or structural adequacy of pavement is the basis for structural evaluation.

2- The functional evaluation is based on field measurements of the following characteristics:

- Riding comfort or roughness safety.
- Surface distress.
- The potential for Foreign Object Damage (FOD) to aircraft, which is only applicable to APMS.

These characteristics are then assessed and given as a quality index. Surface roughness is used to assess a pavement's ride quality for riding comfort (Bouzid, 2007).

The Riding Comfort Index (RCI), Riding Comfort Rating (RCR), or International Roughness Index (IRI) all reflect it in (IRI) (Piryonesi, 2020). The mentioned concepts in chapter two, which are Present Serviceability Index (PSI) and Present Serviceability Rating (PSR) (Al-Omari, 1994), directly depend on the value of (IRI) and proportion, with (PSI) and (PSR) being direct proportion and exponential proportion, respectively. The following equations show the relationship between (IRI) and (PSI), (PSR):

$$Flexible \rightarrow PSI = 5.671 - 1.714\sqrt{IRI} \quad \textbf{... (2)}$$

$$Rigid \rightarrow PSI = 5.769 - 1.589\sqrt{IRI} \quad \textbf{... (3)}$$

$$PSR = 5e^{-0.26(IRI)} \quad \textbf{... (4)}$$

On the other hand, safety is determined by surface friction, the Surface Distress Index (SDI), Distress Manifestation Index (DMI), or Pavement Condition Index (PCI) represents the visual evaluation (type, severity, and quantity) of pavement surface condition (PCI). Most aviation organizations use PCI technique to assess the state of the pavement for APMS, which ranks the pavement from 0 (failed) to 100 (excellent).

Based on above the relationship between IRI and PCI is inverse proportion as a linear regression model and represented in the following equations (Adeli, 2021):

$$When\ R^2 = 30.2\% \rightarrow IRI = -0.012 * PCI + 2.064 \quad ...(\mathbf{5})$$

$$When\ R^2 = 53\% \rightarrow IRI = -0.0171 * PCI + 2.6163 \quad \mathbf{(6)}$$

$$When\ R^2 = 66\% \rightarrow IRI = 2.079 * \left(Log\frac{87.098}{PCI}\right) \quad \textbf{... (7)}$$

$$When\ R^2 = 69.7\% \rightarrow IRI = -0.045 * PCI + 5.024 \quad \textbf{... (8)}$$

Consequently, according to the values of the coefficient of determination represented in R^2, IRI will be evaluated. The value of the coefficient of determination has a meaning and that meaning relies on the range of it "R^2". If R^2 is high, that means the variations are explained; otherwise, that means the variations are not explained well according to its equation:

$$R^2 = \frac{explained\ variations}{total\ variations} = 1 - \frac{unexplained\ variations}{total\ variations} \quad ...(\mathbf{9})$$

Figure (2) shows the relationship between (PCI) and (IRI).

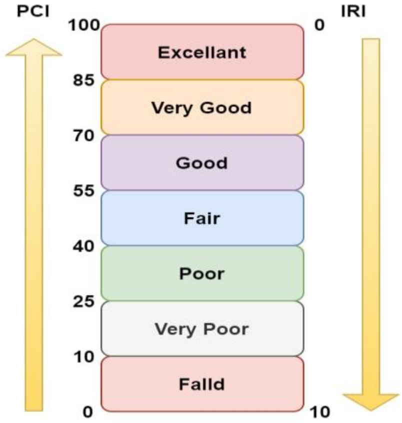

Figure 2: The inverse proportion between (PCI) and (IRI) (AASHTO,1986)

3.2. The Structural Adequacy Index

(SAI) measures a pavement's ability to accommodate traffic without causing significant structural strain, or, in other words, a pavement's load-bearing capabilities. The goal of a structural evaluation is to evaluate a pavement's permissible load, forecast the pavement's future service life in relation to the traffic using it, and examine the existing pavement's strength. To record pavement load-carrying capability, most aviation authorities use the International Civil Aviation Organization's Aircraft Classification Number to Pavement Classification Number (ACN/PCN) system (ICAO). The current pavement conditions are used to create deterioration models that predict future pavement performance (Nathan, 2009).

3.3 Airport Pavement Maintenance Expert Systems

Software that depending on available information provide answers, solutions, or diagnoses by following techniques that aim to imitate the mental processes and apply the knowledge of an expert in any particular subject. Using an expert system has a number of advantages over typical computerized models. Expert systems are successful at issue solving because they include a large number of experts. Human knowledge and thought are just too complicated to capture and use in an analytical technique. For the past 20 years, that expert system has been used in paving applications, mostly for highway networks.

The number of expert systems created for airport pavement is still minimal. This is mostly due to a lack of agreement among experts, as well as a lack of methods and instruments to describe Domain knowledge. In airports, an expert system method can make the choice to repair the berth. Pavement conditions, in particular, have progressively improved with the deployment of APMS (Airport Pavement Management System) with correct database creation throughout several U.S. states. APMS has a methodical and documented technical foundation for assessing M&R (Maintenance and Rehabilitation) needs, which includes taking into account future operating requirements for airport development projects. It uses a life cycle cost study of M&R, evaluating the influence on the pavement, and documenting current and future conditions. Furthermore, it can identify financial needs and propose the best M&R strategies within that budget (Bramer, 1993).

Micro Paver software could have tedious data collection procedures for the implementation of pavement management system. Moreover, it requires professional expertise from end-users. The situation of pavement management system would be rather complicated especially for big cites of huge roads' networks (kheder, 2002). Data from Micro PAVER and PMMS enables for the entry of unit costs for each treatment type, which will be useful in calculating maintenance costs for each area (Shafik, 2005).

Evaluation of Pavement Condition is modeled by using Visual Basic language as a software named (EPCM) (Evaluation of Pavement Condition Model) by (Gani, 2008). The process of designing a pavement management system requires numerous tests and vistas for long periods of time and may take several years until knowledge of the behavior of the road (its disposal over time) depend upon road type, its environment, and know the effectiveness of maintenance activities on this behavior. The proposed model assesses the situation of asphalt pavement and the choice of appropriate effective maintenance.

4. Case Study: Baghdad International Airport (BIA)

located in a suburb of 16 km (9.9 mi) west of downtown Baghdad in the Baghdad Governorate, the area of the airport is estimated by acres as 35 which is equal to 141640 m^2, it was constructed from 1979 to 1982 by French and British Companies, and the coordinates of BIA are 33°15′45″N 44°14′04″E. It is the home base for Iraq's national airline, Iraqi Airways. The first design of Baghdad International Airport was supposed to be with four lounges for travelers, and each of which is its own color: (Or / Red, Greater / Blue, Babylon / Green, Nineveh / Yellow) and each room has its own character and the significance of the historical name of the two rivers civilization in Iraq and also to enjoy travelers from and to Iraq brunch and the beauty of these lights and give it a special aesthetic character for each era from the history and civilization of Iraq:

1. The lounge is in red "Ur": and is an emergency in southern Iraq, which was called the country of Rafidain, showing the most important landmarks of the Ur. That is the names of Somers' kings such as Kish and Orock.
2. The Language of the ... The Language of Walls is: and represents a mixture between a fortress or a lot of a lot of carbacism, and the minified city in Samarra, and the two represent the era of Abbasid. A wonderful era for the history of Iraq, but now it is called the Hall of Masarra.
3. The airline is in green "Babylon": This lounge is rich in the definition while carrying from the most important and wonderful what he knew the history of mankind Ishtar.
4. A hall in yellow “Nineveh”: It represents the Assyrian civilization in the north of Mesopotamia and its inscriptions are the kings of the Assyrian civilization, including Shalmaneser and Sennacherib, as well as inscriptions and drawings of the legendary winged bull that is well known because it carries a card.
5. Six gates are available at each lounge to convey guests to and from the aircraft. The lounges have excellent designs and connections to Concertinas as well. However, because to its high cost and the fact that Iraq was at war, the passenger hall "Ur," which serves as the building's initial gateway, has not yet been constructed Instead, the choice to make it into the final design as shown in Figures 3 and 4 was made at the same time.

5. Inspection processes for the Case Study

Pavement conditions surveys from the core part of pavement management. The overall good of pavement management is to ensure efficient use of resources by assisting management in making informed decisions. In other word PM reduces the level of subjective in decisions making. Condition surveys have three main aspects namely:

1- Data collection
2- Condition rating
3- Quality management

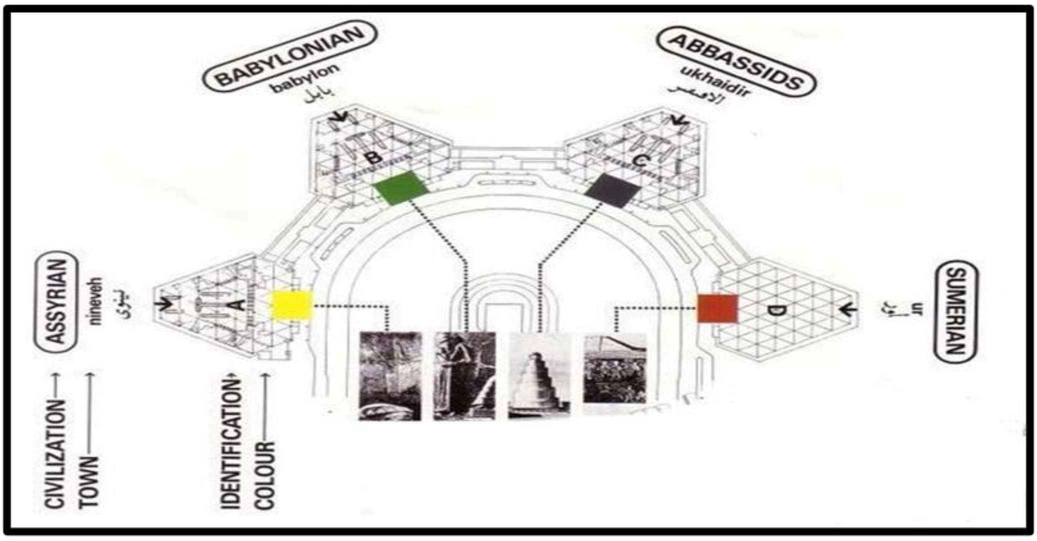

Figure 3: Design for passenger halls for Baghdad International Airport.

Figure 4: Design of final passengers for Baghdad International Airport.

The processes that are going to be applied in this paper are shown in the following flowchart:

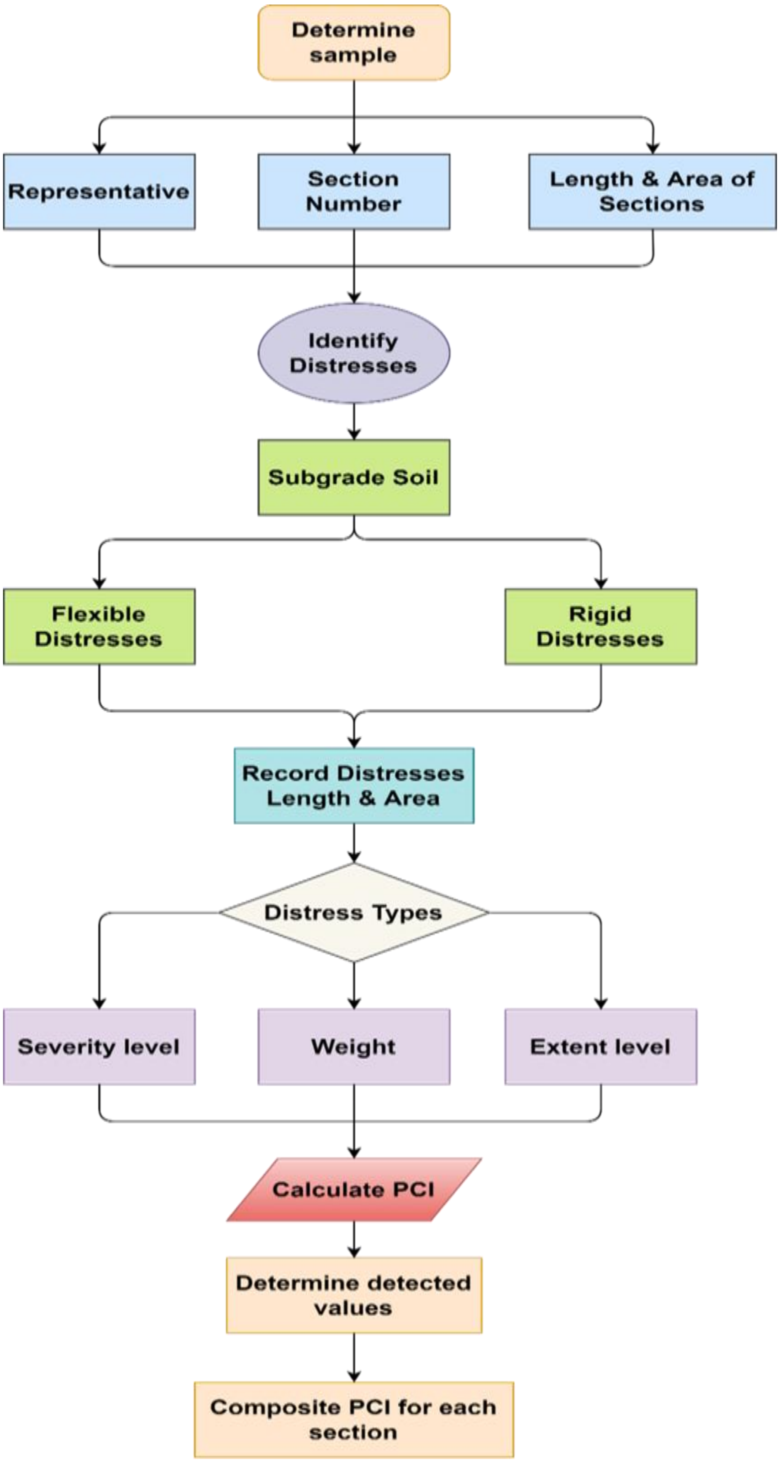

Figure 5: Flowchart of calculating PCI.

The following tables are illustrated some of the distresses type, location, possible causes, the treatment which represents the maintenance decision process and the value of PCI after showing the impact of severity and extent levels for rigid and flexible pavements:

Table 1: Rigid Pavement (Runway).

Location	Description	Classification of Distresses	Possible Causes
Touchdown direct zone Area (Runway) **SR1**	It reflects the deterioration of the concrete within 2 feet on either side of a joint. Breaking or chipping of the pavement joints usually results in fragments with feathered edges.	Joint Load Transfer System Deterioration.	Overloading. Thermal expansion (freeze-thaw). Lack of support at joint due to pumping action and voids (causes corner cracks). Expansive internal pressure due to alkali-aggregate reactivity between the cement and aggregates. Expansive internal pressure due to corrosion and deterioration of dowel bars (causes spalling).
Runway **SR2**	In severe circumstances, roughness and moisture intrusion might be a safety problem.	Blowup (Buckling)	Cold weather causes PCC slabs to compress, resulting in bigger joint holes. High compressive pressures may result from later PCC slab expansion during warmer seasons (such as spring and summer) if these gaps are filled with incompressible material (such as rocks or soil). If the tensions are too strong, the slabs may crack and buckle, relieving the pressure.
safe zone area (The end of the runway). **SR3**	It refers to occasional to extensive interconnected cracks that may appear anywhere within a panel but do not extend throughout the entire depth of the slab.	Linear cracking	Usually, a result of a combination of loss of support, moisture stresses, temperature gradient curling, and traffic pressure.
Runway **SR4**	It is the scaling, spalling, chipping or disintegration of the concrete wearing surface that leads to roughness and poor durability. It is measured in square feet per panel but does not include any distresses within 2 feet of the joint.	Durability cracking	Poor materials or construction (e.g., Too much water, overworking of surface, etc.), Thermal and moisture stresses ˝(freeze-thaw), Corrosion of reinforcing steel - Reinforcing steel too close to surface

Table 2: Rigid Pavement (Taxiway).

Location	Description	Classification of Distresses	Possible Causes
Taxiway **ST1**	It is a different vertical displacement to a joint or crack. Faulting may be either longitudinal or transverse and creates a "step" deformation of the pavement surface. Faulting commonly Occurs in transverse joints of Portland cement concrete pavements that do not have load transfer devices (dowels). Usually the "upstream" slab is higher than the "downstream" slab.	Faulting	Uneven roadbed support. Thermal and moisture stresses (frost action). - Pumping of slabs due to lack of load transfer (dowel) devices. Insufficient pavement structure.

Table 3: Rigid Pavement (Apron),

Location	Description	Classification of Distresses	Possible Causes
Apron **SA1**	It is used to describe any unplanned longitudinal or diagonal structural crack(s) that extend through the depth of slab.	Corner break	Overloading. Long joint -spacing - shallow or late joint sawing. Pumping of the subgrade. Curling or warping of slab. Culvert or utility trench subsidence.

Table 4: Flexible Pavement (Parking Way).

Location	Description	Classification of Distresses	Possible Causes
Free parking **SP1**	It is the progressive wearing away of the pavement from the surface downward caused by the loss of asphalt binder and the dislodging of aggregate particles.	Raveling/ Weathering	Poor mixture quality - Asphalt hardening due to aging. Insufficient asphalt content – Improper construction methods.
Exit port for travelers parking **SP2**	It’s also called flushing, is used to describe a free film of asphalt on the surface of the pavement that creates a smooth, shiny, greasy, and reflective surface it is usually found in the wheel paths and becomes quite sticky when hot.	Bleeding	Mixture problems (bad oil, stripping aggregate, low air voids, high AC.concrete, etc.). Improper construction practices. Paving over excess asphalt.
starts and stops points. **SP3**	Corrugation and Shoving type of plastic action that moves the pavement surface in ripples (corrugation) or sudden waves (shoving). The distortion is parallel to the flow of traffic. often happens at intersections where traffic begins and ends.	Corrugation and Shoving	It is caused by a combination of contaminants. Inadequate mix design. HMA. manufacture is substandard. Subgrade dampness is severe.

Table 5: Flexible Pavement (Entrance Way).

Location	Description	Classification of Distresses	Possible Causes
The way to enter passenger’s buildings **SE1**	It's similar to alligator cracking only located within 1 to 2 feet of the edge of the pavement. Failure begins at the edge of the pavement and progresses toward the wheel path.	Edge Cracks	Traffic Loading. Environmental. Construction Related. Low Shoulder. High Shoulder. Holding Water.
The start of the airport's main entry road. **SE2**	Transverse cracks are those considered to extend three fourths of the width of the pavement or more, generally perpendicular to centerline.	Transverse cracks	Environmental (thermal) - Swelling or shrinkage of the subgrade. Reflection cracks - Settlement (trench, backfill).

Table 6: Flexible Pavement (Maintenance way).

Location	Description	Classification of Distresses	Possible Causes
Maintenance way for Runway, Taxiway & Apron **SM1**	The weakening of the binding between aggregates and asphalt binder, which normally occurs at the bottom of the HMA layer and goes upward.	Stripping	Surface chemistry properties of aggregates is deficient. Moisture damage triggered by water in the HMA. These overlays have a tendency to strip when placed over an existing open-graded surface course.

6. Proposed Expert System Design

The proposed expert system has been built to assess the condition of the pavement based on PCI. As it's known PCI can be calculated by knowing the whole distresses value then it will be subtracted from 100. The following equation shows the how the value of PCI can be extracted:

$$PCI = 100 - \sum D\,V \quad \ldots (\mathbf{10})$$

On the other hand, the distresses exist in the Flexible and Rigid pavements and each one has its value relies on the defect that is caused to the pavement and the difficulty of treating that defect. Besides its value, it should consider the level of distress itself from two sides which are the Severity and Extent levels. According to the standards utilized in states with conditions comparable to Iraq's, and a survey of experienced and skilled road builders the proposed expert system has been built.

Based on above, the software is named as Rating of Pavement Condition (RPC) has been initiated and coded by Visual Basic .NET (VB.net) in order to serve the purpose of the study. Rating of Pavement condition in short (RPC) figure (6) shows the interface of the software:

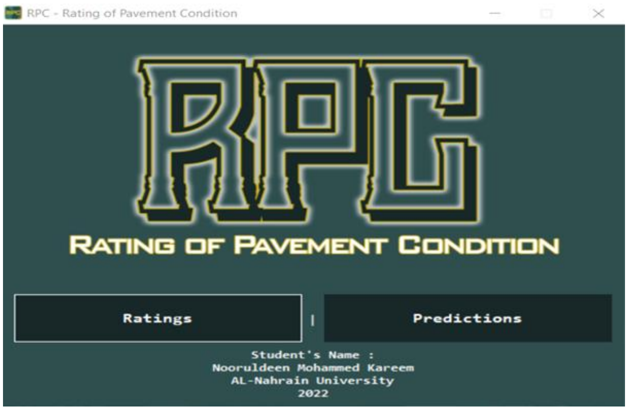

Figure 6: The interface of RPC software.

The following flowchart (figure 7) shows how the program works.

6. Validation of RPC Software

The same samples that have been detected where compared with two software already existed as it's mentioned previously for both rigid and flexible pavement as shown in sections below.

6.1. Rigid Pavement

Table 7 shows the computation for the value of PCI average relying on the sections, which are (Runway, Taxiway & Apron) among the expert systems.

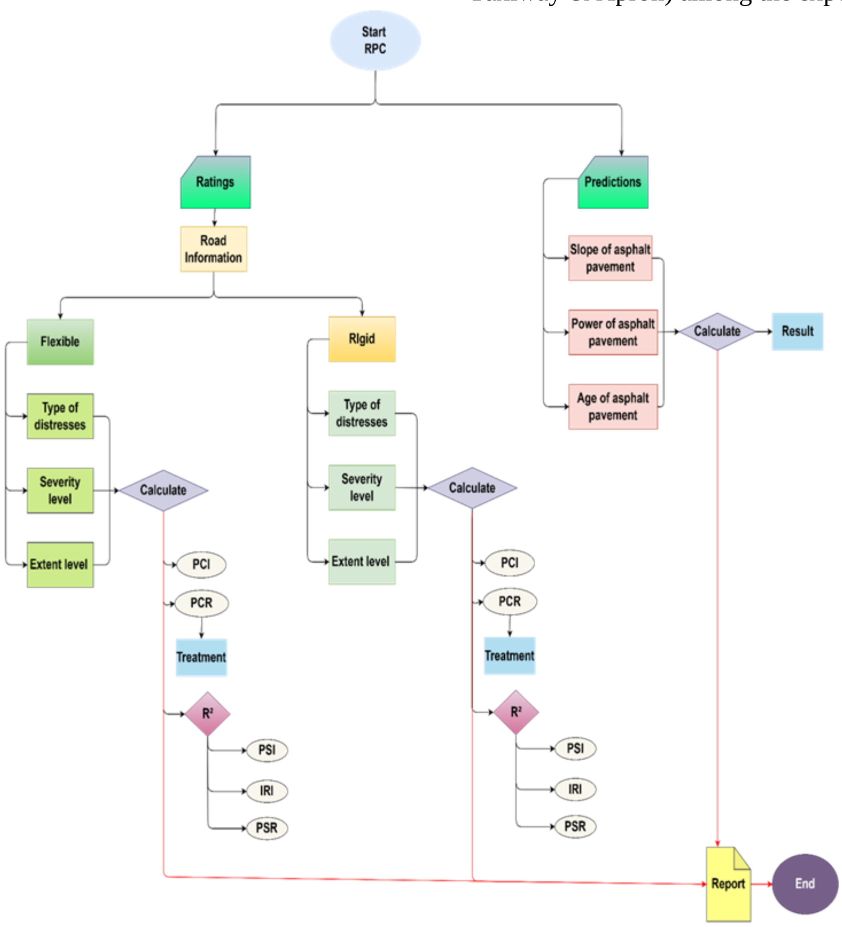

Figure 7: The flowchart of RPC software.

Table 7: Comparison PCI average values

Sections	PCI Average		
	RPC	Paver	EPCM
Runway	95.8	94.82	**No Values***
Taxiway	94.4	94.4	
Apron	94.4	94.07	

***Because EPCM is programmed for flexible pavement only.**

6.2. Flexible Pavement

Table 8 shows the computation for the value of PCI average relying on the sections, which are (Parking way, Entrance way & Maintenance way) among the expert systems.

Table 8: Comparison PCI average values.

Sections	PCI Average		
	RPC	Paver	EPCM
Parking way	94.73	95.29	94.73
Entrance way	96.05	96.43	96.05
Maintenance way	94.73	93.93	94.73

As a conclusion for above, the following bar chart presents the values of Pavement Condition Index (PCI) as an average for both Flexible and Rigid pavement:

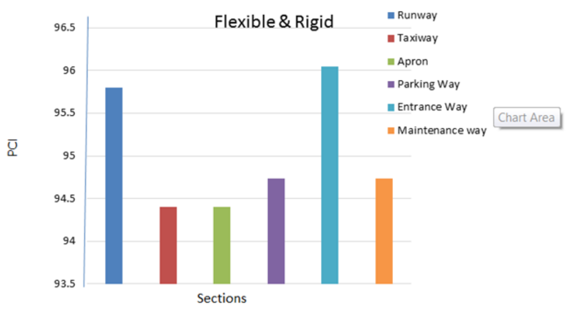

Figure 8: Average PCI for both flexible and rigid pavement.

7. Conclusions

The conclusions can be drawn from this paper can be summarized as follows:

1- Airport Pavement Management Program (APMP) provides a consistent, objective and systematic procedure for establishing facility policies, setting priorities and schedules, allocating resources, and budgeting for pavement maintenance and rehabilitation. APMP not only evaluates the present condition of a pavement, but also predicts its future condition through the use of pavement condition indicators.

2- The developed expert system RPC (Rating of Pavement Condition) is written in VBASIC language can evaluate pavement condition, determine the most appropriate maintenance activity, International Roughness Index (IRI), Present Serviceability Index (PSI) and Present Serviceability Rating (PSR) and predict pavement condition in the future.

3- The (RPC) software was successfully applied to Baghdad International Airport (BIA) and on most of the asphalt road areas and concrete for runway, taxiway, apron.... etc. Also the software was validated by comparing the results with two other software (Micro Paver 5.3.2) and (Evaluation of Pavement Condition Model - EPCM).

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