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Research Article

MODEL DEVELOPMENT OF URBAN ROAD MAINTENANCE

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ABSTRACT
The accurate prediction of pavement performance is important for efficient management of surface transportation infrastructure. By reducing the error of the pavement deterioration, prediction agencies can obtain sufficient budget savings through timely intervention and accurate planning. The goal of this research is to develop a methodology for the purpose of assessment of pavement performance. The methodology describes the development of the Pavement prediction model with the help of which pavement authorities will be able to predict the deterioration of pavements, Priorities of repair of pavements, prediction of time of maintenance or rehabilitation and also estimating the funds of repair. The loss of riding quality of pavement was selected as performance indicator and acceptable riding quality is important for both the road user and the goods being transported. The vehicle operating cost and cost of transportation increases as the riding quality decreases.

Key Words: *Rut Measurement, Distress Condition, Model Analysis and Model Preparation*

INTRODUCTION
Hot mix asphalt refers to the bound layers of a flexible pavement structure. The HMA is also known as asphalt concrete which is a mixture of coarse aggregate, fine aggregate and asphalt binder(DIAZ and RIGGINS,1985).Recycled asphaltis a material in pavement construction a bitumen obtained from deteriorated pavement material by the recycling effort to preserve environment, reduce waste and cost effective material. Plain cement concrete is a material for construction of a rigid pavement in road infrastructure. This consists cement, fine aggregate, coarse aggregate and water. Rut measurement tool as laser profilographis the very important tool of rut measurement. The laser beams are sent into ruts and the depth, width and other details are displayed (Pajagopal and Lim, 1989).

Road pavement profilometers (aka profilograph as used in the famous 1958-1960 AASHO road test use a distance measuring laser (suspended approximately 30 cm from the pavement) in combination with an odometer and an inertial unit (normally an accelerometer to detect vehicle movement in the vertical plane) that establishes a moving reference plane to which the laser distances are integrated. (Pajagopal and Lim, 1996). The inertial compensation makes the profile data more or less independent of what speed the profilometer vehicle had during the measurements, with the assumption that the vehicle does not make large speed variations and the speed is kept above 25 km/h or 15 mph. The profilometer system collects data at normal highway speeds, sampling the surface elevations at intervals of 2–15 cm (1–6 inch), and requires a high speed data acquisition system capable of obtaining measurements in the kilohertz range.

The data collected by a profilometer is used to calculate the International Roughness Index (IRI) which is expressed in units of inches/mile or mm/m. IRI values range from 0 (equivalent to driving on a plate of glass) upwards to several hundred in/mi (a very rough road). The IRI value is used for road management to monitor road safety and quality is P).

Many road profilers also measure the pavement's cross slope, curvature, longitudinal gradient and rutting. Some profilers take digital photos or videos while profiling the road. Most profilers also record the position, using GPS technology. Another quite common measurement option is cracks. Some profilometer systems include a ground penetrating radar, used to record asphalt layer thickness (Hudsen and Zajewaskij, 1994).

Another type of profilometer is for measuring the surface texture of a road and how it relates to the coefficient of friction and thus to skid resistance. Pavement texture is divided into three categories: megatexture (roads), macrotexture, and micro texture. Microtexture cannot currently be measured directly, except in a laboratory. Megatexture is measured using a similar profiling method as when obtaining IRI values, while macrotexture is the measurement of the individual variations (Hjaekj and Brodbury, 1996).

Crack measurement tools as ROMDAS LASER crack measuring tool. The LCMS system employs high speed cameras, custom optics, and laser line projectors to acquire 2D images and high resolution 3D profiles of road surfaces that allow for automatic detection of cracks and the evaluation of macro-texture and other road surface features. Designed for both day and nighttime operation in all types of lighting conditions, the system is immune to sun and shadows and is capable of measuring pavement types ranging from concrete to dark asphalt. The LCMS can be operated at speeds of up to 100km/h on roads as wide as 4 m. Collected data is processed with INO's automated analysis software. Distress analysis results can then be used in association with a PMS to take appropriate rehabilitative action.

Figure1: Weathering and Raveling Measurement Tool Taken from Aasho Road Test
(*Source: www.aasho.com*)

The RWIS is composed of four components: collection (Environmental Sensor Station - ESS), processing (remote processing unit - RPU), disseminating, and transmitting. The ESS is composed of an array of three categories of environmental sensors: atmospheric, surface/sub-surface, and water/snow level. The RPU collects and processes ESS sensor measurements. The RPU also provides the ESS observation to that communications device (phone lines, wireless radios, communication network and internet) that transmits the data to a central server using a communication protocol standard. Agency personnel access the real-time pavement and weather data via computer workstations at the maintenance

Real-time information enhances the ADOT and PF's ability to conduct road maintenance operations in a safe and efficient manner. This and other weather information allow the ADOT and PF to schedule maintenance personnel and equipment based on current and forecast weather and pavement surface conditions.

Real-time weather information:

- Improves timeliness of maintenance actions
- Increases winter maintenance efficiency
- Minimizes the traveling public's exposure to hazardous weather related roadway conditions

Figure 2: Wind speed/direction sensor (top), precipitation gauge (middle), and fixed-zoom camera (bottom) *(Source: ALASKA'S road weather information system.www.alaska.gov)*

Figure3: Road Weather Information System *(Source: ALASKA'S road weather information system. www.alaska.gov)*

MATERIALS AND METHODS

The preparation of the pavement prediction model is the main work of this paper. The pavement prediction model gives guidelines to fix the priorities of roads to be repair and the estimated consumed time.

In order to achieve the objectives proposed in this paper, it was found necessary to select a sufficient number of pavement sections for study of road management in New Delhi metro city covering the range of possible conditions (good, fair and poor).

Three sections of the road network in the New Delhi metro city were selected.

The first section of the road was from New Delhi railway station to Najafgarh. The second section of road was selected from Uttamnagar to Palam colony and the third pavement section was selected from Uttamnagar to Tilaknagar via Vikaspuri.

The pavement conditions of these three sections of road were studied. The distress conditions were examined to prepare the distress model for maintenance and rehabilitation of the pavement in future.

In order to obtain the specified objectives roughness of roads of these sections had to be measured, first using profilometer and then rod and level (Machine for evaluating roughness).

The surface integrity had to be established using condition survey of the pavement)

The second step in this regard was data collection on these sections of roads.

The data includes as

1. Pavement roughness (RQI)=2,Where RQI is ride quality index
2. Pavement distress (SR)=4 Where SR is surface rating of the pavement
3. Pavement quality=GOOD……..

The data for second section of road section are as follows

1. Pavement roughness=3
2. Pavement distress=3.5
3. Pavment quality=…Very poor….

The data for third section of road are as follows

1. Pavement roughness=2.9
2. Pavement distress=1.8

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3. Rutting data=4.5
4. Pavement quality=Average……..

The pavement quality index was calculated from RQI and SR as PSI=√RQI×√SR
These calculated values are compared with standard ones given in the table below

Table1: Pavement Performance Table

Index name	Pavement attributed measured by index	Rating scale
Ride quality index(RQI)	Pavement roughness	0---5
Surface rating(SR)	Pavement unevness	0--4
Pavement quality index(PSI)	Overall pavement quality	0---4.5

After collection of RQI data of given road sections, its distress condition can be predicted. The type and severity of the distress of pavement provide a neat insight into what its future maintenance or rehabilitation needs will be.
Distress models are then prepared for the future rehabilitation and maintenance.
The percentage of each distress in 500 ft sample was determined and multiplied by a weighted factor to give a weighted percentage.
The weighted percentage are higher for higher severity levels of same distress and higher for distress types that indicate more serious problem in roadway such as alligator cracking and broken pavement.
Once all of the weighted percentage are calculated to give the total distress TWD. The SR of the road section was then calculated as
SR=e (1.386--.045×TWD)(Hudson, et al., 1979)

Rutting Description

Rutting is a longitudinal surface depression in the wheel path.
Severity Levels
LOW
Ruts with a measured depth ≥ 0.20” and ≤ 0.49”
MED
Ruts with a measured depth ≥ 0.50” and ≤ 0.99”
HIGH
Ruts with a measured depth ≥ 1.00”
Ruts < 0.20” are not included in the distress calculation:
Note: All index formulas listed below contain MAE applicable to 0.02 mile (105.6 feet) interval.

Alligator Crack Index

AC_INDEX = 100 – 40 * [(%LOW / 70) + (%MED / 30) + (%HI / 10)](11. Hudson W, Hass R and Darly R 1979, 'Pavement Management System Development', NCHRP report 215.)
Where The values %LOW, %MED and %HI report the percentage of the observed pavement(0.02 mile, primary lane) that contains alligator cracking within the respective severities.
These values range from ≥ 0 to ≤ 100.
%LOW = Percent of total area (primary lane, 0.02 in length), low severity
%MED = Percent of total area (primary lane, 0.02 in length), medium severity
%HI = Percent of total area (primary lane, 0.02 in length), high severity
Percent of total area is computed as:
square foot area of alligator crack severity 0.02 mile * lane width
In AC_INDEX, the denominators 70, 30, and 10 are the Maximum Allowable Extents (MAE) for each severity. In other words, we will allow up to 70% of low severity alligator cracking for a 0.02 interval before failure, 30% for medium severity, and so on.
As you can see, if any single severity reaches MAE the resulting index value is 60, or failure.

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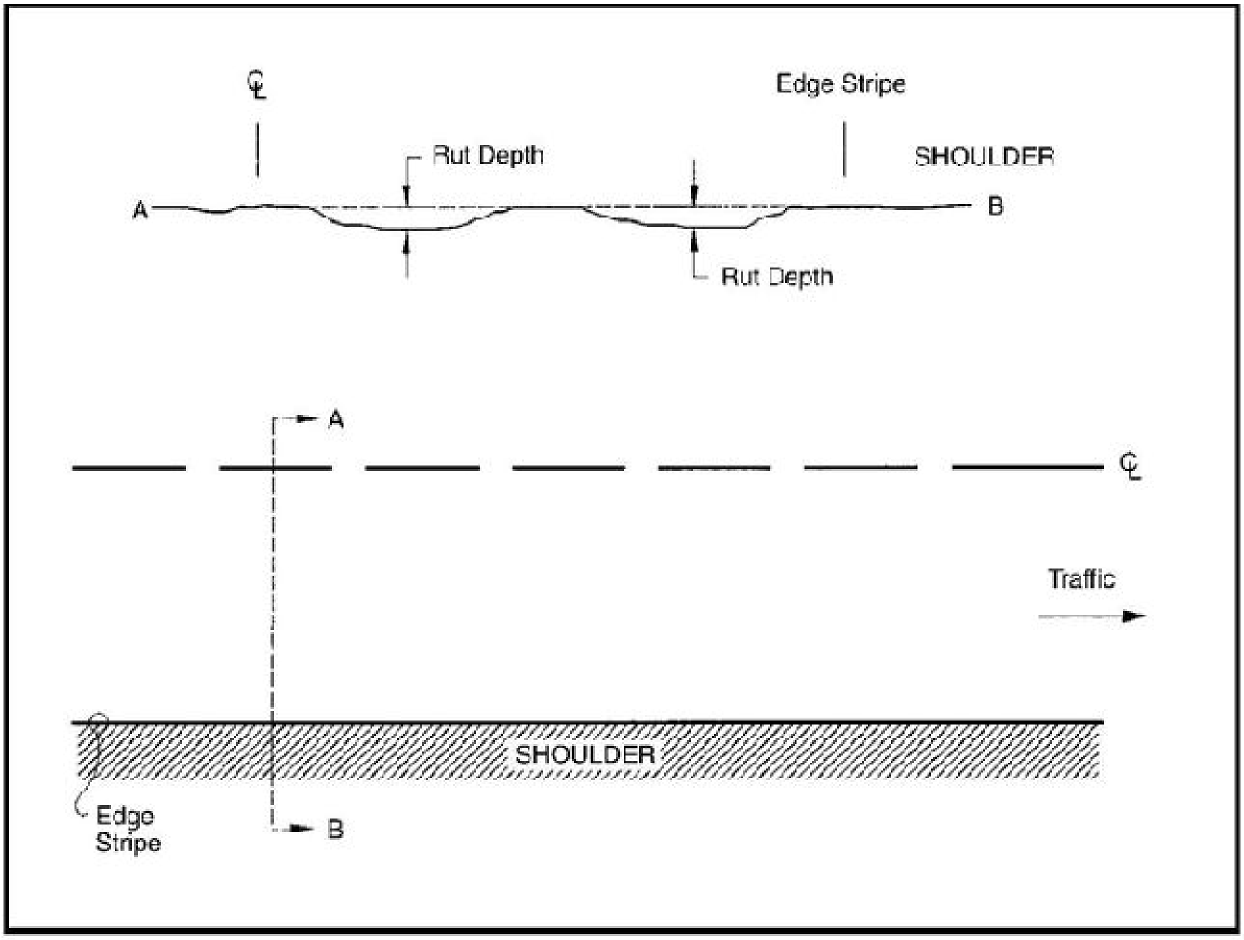

Figure 4: Rut development profile figure index formulas

Longitudinal Crack Index
LC_INDEX = 100 – 40 * [(%LOW / 350) + (%MED / 200) + (%HI / 75)]
Where:
The values %LOW, %MED, and %HI report the length of longitudinal cracking within each severity as a percent of the section length (0.02 mile, primary lane).
These values are ≥ 0 and can exceed 100.
%LOW = Percent of interval length (primary lane, 0.02 in length), low severity
%MED = Percent of interval length (primary lane, 0.02 in length), medium severity
%HI = Percent of interval length (primary lane, 0.02 in length), high severity
Percent of interval length is computed as:
Length of respective longitudinal cracking
0.02 mile (105.6 feet)
In LC_INDEX, the denominators 350, 200, and 75 are the Maximum Allowable Extents (MAE) for each severity. In other words, we will allow up to 350% of low severity alligator cracking for a 0.02 interval before failure, 200% for medium severity, and so on. As you can see, if any single severity reaches MAE the resulting index value is 60, or failure.
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Transverse Crack Index

TC_INDEX = 100 – {[20 * ((LOW / 15.1) + (MED / 7.5))] + [40 * (HI / 1.9)]}13. Huang, H 1993, ‘Pavement Analysis and Design’, Prentice Hall, New Jersey.

Where:

The values LOW, MED and HI report a count of the total number of transverse cracks (reported to three decimals) within each severity level, where one transverse crack is equal to the lane width. These values are ≥ 0.

LOW = Number of cracks in interval (primary lane, 0.02 in length), low severity

MED = Number of cracks in interval (primary lane, 0.02 in length), medium severity

HI = Number of cracks in interval (primary lane, 0.02 in length), high severity

Number of cracks is computed as: Total length of transverse cracks

Lane width In TC_INDEX, the denominators 15.1, 7.5, and 1.9 are the Maximum Allowable Extents (MAE) for each severity. In other words, we will allow up to 15.0 low severity transverse cracks for a 0.02 interval before failure, 7.5 cracks for medium severity, and soon. As you can see, if any single severity reaches MAE the resulting index value is 60, or failure.

Patching Index

PATCH_INDEX = 100 – 40 * (%PATCHING / 80)(1Huang,1993)

Where:

The value %PATCHING reports the percentage of the observed pavement (0.02 mile, primary lane) that contains patching/potholes. This value ranges from ≥ 0 to ≤ 100.

%PATCHING = Percent of total area (primary lane, 0.02 in length)

Percent of total area is computed as:

square foot area of patching/potholes

0.02 mile * lane width

There are no severity levels for patching. It either exists or does not.

In PATCH_INDEX, the denominator 80 is the Maximum Allowable Extent (MAE) for each severity. In other words, we will allow up to 80% patching for a 0.02 interval before failure. As you can see, if patching/potholes reaches MAE the resulting index value is 60, or failure.

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Rutting Index

RUT_INDEX = 100 – 40 * [(%LOW / 160) + (%MED / 80) + (%HI / 40)]

Where: 10 ARAN rut depth measurements are taken per 0.02 interval for each of 2 wheel paths (left and right), resulting in a total of 20 measurements taken for both wheel paths. The values% LOW, %MED and %HI report the percentage of the 20 measurements within that severity. These values range from ≥ 0 to ≤ 200.%LOW = Percent of ARAN-measured ruts in both wheel paths (20) within a single wheel path, low severity

%MED = Percent of ARAN-measured ruts in both wheel paths (20) within a single Wheel path, medium severity

%HI = (Percent of ARAN-measured ruts in both wheel paths (20) within a single Wheel path, high severity

Percent of rut measurements within each severity is computed as:

Number of ruts within each severity

10 * 100

In RUT_INDEX, the denominators 160, 80, and 40 are the Maximum Allowable Extents for each severity. In other words, we will allow up to 160% low severity ruts for a 0.02 interval before failure. As you can see, if any single severity reaches MAE the resulting index value is 60, or failure.

Roughness Condition Index
RCI = 32 * [5 * (2.718282 ^ (-0.0041 * AVG IRI))]
Where:
The value AVG IRI reports the average value of the Left IRI and Right IRI measurements for the interval (0.02 mile, primary lane). This value can range from approximately 40 to
over 1000.Average IRI is computed as:
Left wheel path IRI + Right wheel path IRI
2
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Surface Condition Rating Index
SCR = 100 - [(100 - AC_INDEX) + (100 - LC_INDEX) + (100 - TC_INDEX) + (100 -PATCH_INDEX) + (100 - RUT_INDEX)]
Where:
See above for determinations of AC_INDEX, LC_INDEX, TC_INDEX,
PATCH_INDEX and RUT_INDEX.
The threshold for failure for this index is SCR = 60.
Pavement Condition Rating Index
PCR = (0.60 * SCR) + (0.40 * RCI)
Where:
See above for determinations of SCR and RCI.
The values 0.60 and 0.40 function as weights within the formula.
Note: If SCR equals zero (which means that the road surface condition is very poor), then the formula simply reduces to: PCR = 0.40 * RCI.
If RCI equals zero (which means that this value was not available for some reason), then
the formula becomes: PCR = SCR.
The threshold for failure for this index is PCR = 60.

Table 2: Pavement Rating Table

Rating category	**IrI value**	**Rcp value**
Excellent	<=127	95—100
Good	128—154	85---94
Fair	155---240	61---84
Poor	>240	<=60

The modeler begins with concepts, experience and ideas to select the appropriate model to suit the specific problem. The modeler needs information about variables.
After gathering information about data in terms of conceptual approach we have to collect the data of problem and then it is presented in a clear and useful way then we build together the both knowledge and data to start building a model.
Once the proposed model has been found then the modeler thinks to feed the set of data into specified models.

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RESULTS

Table 3: Models Comparison

Models	Advantage	Disadvantage
Regression	• Microcomputer software packages are now widely available for analysis which makes modelling easy and less time consuming. • These models can be easily installed in a PMS. • Models take less time and storage to run.	• Needs large database for a better model. • Works only within the range of input data. • Faulty data sometimes get mixed up and induces poor prediction. Needs data censorship. Selection of proper form is difficult and time taking.
Survivor Curve	• Comparatively easy to develop. • It is simpler as it gives only the probability of failure corresponding to pavement age.	• Considerable error may be expected if small group of units are used.
Amrkov	• A convenient way to incorporate and Provides data feedback. • Linear trends • Reflects performance trends regardless of non.	• Easy to perform •Performance has no influence Past • It does not provide guidance on physical factors which No read made software is available. Contribute to change. • Needs large computer storage and time.
Semi-Markov	• A solely on subjective inputs. • Needs much less field data.	• No armed made software is available. • Needs large
	• Provides a convenient way to incorporate data feedback. • Past performance can be used	• Computer storage and time.
Mechanistic-empirical	• Easy to work with the final empirical model. • Needs less computer power and time.	• Depends on field data for the development of empirical model. • Does not lend itself to subjective inputs. • Works within a fixed domain of independent variable. • Generally works with large number of input variables (material properties, environment conditions, geometric elements, etc.) which are often not available in a PMS.

Once a proposed model that gives a good description of the process has been identified, and assessed then result appears reasonable then it can be adopted.

Modelling of pavement performance is a necessary asset of pavement management level.

There are many types of performances of the pavements and corresponding there are different types of performance models

These models provide the tool for analyse , Design, Planning and allocating costs.

Modeling the performances of pavement is an absolutely essential activity of the pavement management system. Many highway agencies have developed a variety of pavement of pavement performances model for use in their pavement activities

This paper gives a brief to have a comprehensive idea of different types of pavement performances and accordingly different types of pavement performances prediction model.
The accurate prediction of the pavement performance is a vital thing for the efficient management of road infra structure
This pavement performance prediction is essential for national budget and resource allocation
Several performances model have been proposed over the years.
Most of the models Developed are empirical in the sense that they fit for the prediction under the particular traffic and climatic condition.
The result is normally presented as bearing capacity in tons calculated using program from KUAB based on constant derived empirically in India. The program produces values for the bearing capacity of road subsections which will result in a standard amount of deterioration.
This method uses the D0 and D20 seismometer values. It uses the following formula to calculate a type of elasticity modulus:
D20))-(D0x(D0K1xP=E (22)
With a given heavy traffic density and a given E modulus, the road will deteriorate to a certain degree in a unit period of time. This Calculation compares the calculated elasticity with a reference value (normally this value is 200MPa), and the actual heavy traffic volume with the reference volume (50 per day) to calculate what the axle load should be to produce the same amount of road deterioration as in the standard case.
This axle load is referred to as the bearing capacity of the road (BEi) calculated by following formula:
ADTT50x (] 200) D20)-D0x(D0110xP(11x[=BE0.0720.6i(Jackson et al., 1996)
Where P is the tire pressure and ADTT is the actual heavy traffic volume (annual daily heavy vehicle traffic).

Table 4: Severity Levels' Deduct points for Main Sections

Distress Names	Code	Low severity	Medium Severity	High Severity
Block Cracks	D2	2.00	2.50	4.00
Longitudinal and Transverse	D3	2.00	2.50	4.00
Cracking				
Patching	D4	1.00	2.40	2.80
Potholes	D5	4.00	4.50	5.00
Depression	D6	2.00	3.00	4.00
Weathering and Raveling	D11	2.00	2.50	4.00
Cracking	D12	2.00	3.00	

The constants in equation 22 were calculated by the INDIANS. Thus in a given case where there are 100 heavy vehicles a day and the program calculates a bearing capacity of 6 tons, to keep the deterioration of the road to the standard amount, the axle load should be restricted to 6 ton.

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Result Regarding Roughness Measurement
Cracking, potholes and patching, weathering and raveling.
Evaluation of road roughness by measuring IRI value was obtained and a graphical sketch was plotted. The table and the figure below show roughness measurement of the road.

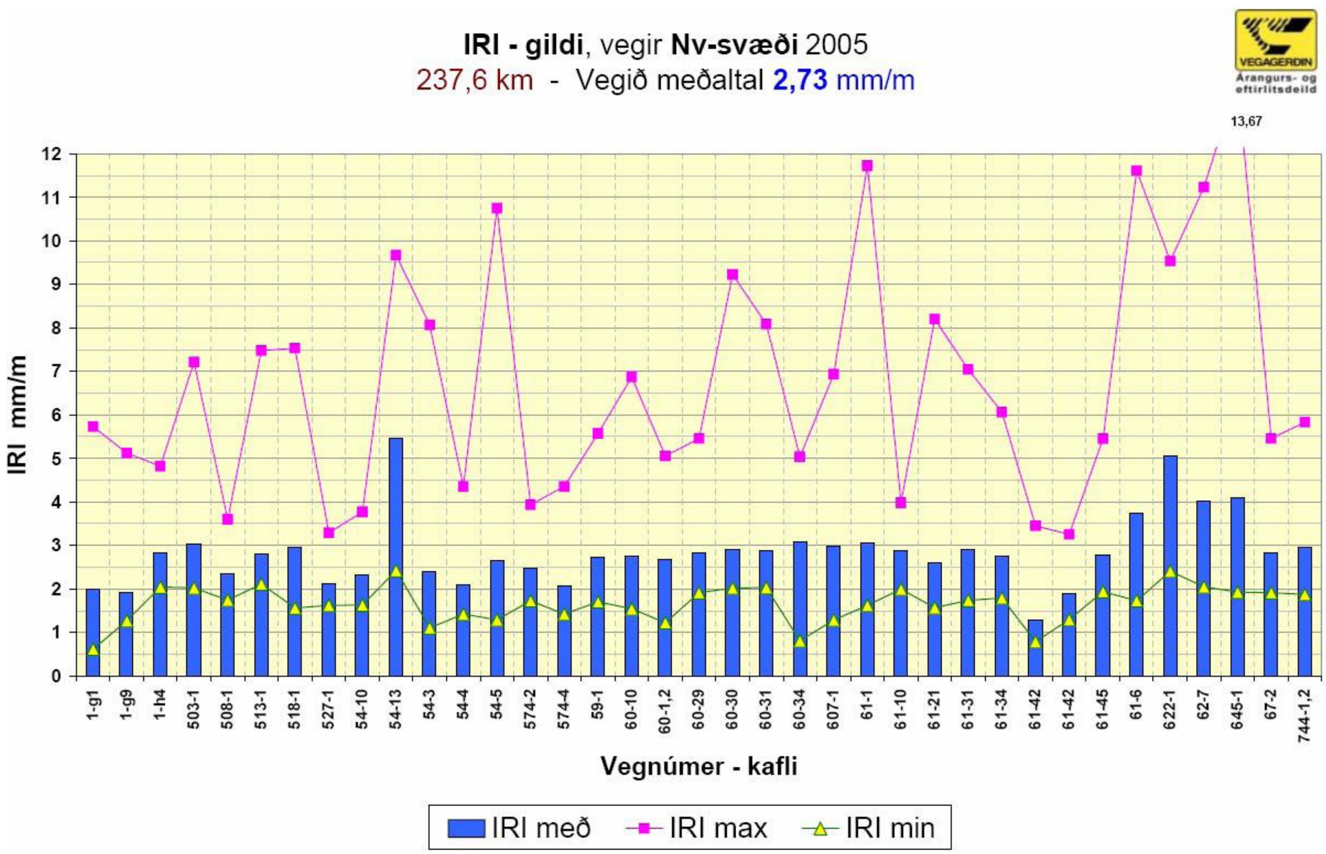

Figure 5: Photograph Taken From AASHTO Test

Rut Depth Measurement Result
Rut depth which is related to permanent deformation in asphalt layer. The measured rut depth is sum of ruts caused by permanent deformation and ruts caused by wear from studded tyre. The result obtained is from transverse profile beam apparatus.
Model Formulation Result
Objective Function (Distress Methodology for Predicting Pavement Performance')
The objective of this model is to minimize the cost of INDIAN roads to the public comprise both road user costs and maintenance costs, as the public fund maintenance through taxation paid to Central Government. The objective function in this formulation reflects this objective and contains four separate terms. The first term from the objective function computes the total discounted cost of road maintenance over the planning horizon. The second term calculates the discounted road user costs incurred by motorists when driving along road sections. The third term computes the discounted increase in road user costs that occur when maintenance is being performed. The final term in the objective function is the perpetuities of user costs, costs during maintenance and maintenance costs calculated in constraint seven.
With this objective in mind, the solution to this formulation may indicate to an appropriate level of annual maintenance funding. The level of funding may presently be too low, or alternatively too high. Whichever

case holds, a likely outcome is the improvement of road quality at the present budget level due to the formulation optimising road maintenance.

Maintenance State Change Constraint Set (Distress Methodology for Predicting Pavement Performance')

This set of constraints works by tracking the structural number and IRI value of road sections with similar characteristics over the duration of the planning horizon. The IRI of a road section can change in two ways. Firstly, if no maintenance is performed during a year, then the IRI on a road section increases by the parameter p. Secondly, if maintenance is performed on a road section, the IRI gets reduced to the IRI reset value of that specific maintenance type. The structural number can also change in two ways. Firstly, if no maintenance is carried out, then the structural number of a road section decreases by the parameter d. Secondly, when maintenance is performed, the structural number gets reset to the structural number reset associated with that maintenance type.

Budget constraint set (Hung H, 1993)The budget constraints ensure that the funds spent on maintenance during a year cannot exceed the funding available. As funds that are not required for use in a year can be placed in an account at the start of that year, interest is earned and the inflated amount will accrue to the next year when it can be used. Thus, the amount of funding available for road maintenance in an individual year is the annual budget plus any funds unused in previous years. These are equality constraints to ensure that when the funding available in a year exceeds the actual amount spent on maintenance, the remainder becomes unused funds which can then be utilised in following years.

Setting of Initial Area constraint set

This constraint set ensures that the area of all road sections of the same road type, IRI value and structural number at the start of the planning horizon equates to the summation of the equivalent ‘Area of Road’ decision variables in the first year regardless of their maintenance type.

IRI Target constraint set (Hunt, 2001).

For each road type with an IRI greater than a set limit in the final year of the planning horizon these constraints force the area of road, to be less than some fraction of the initial area of that road type. The target level for each road type’s IRI is taken as the 80th percentile of initial roughness values; that is, the IRI value lower than which 80% of the initial area of roads in a road type are. These values are different for all road types, ranging from just 2.8 for the high volume, high user cost Tertiary roads, to 6.4 for low volume Secondary roads. The target fraction that has been used in the base run is 20%. Thus, the constraint ensures that at the end of the planning horizon less than 20% of the area of a given road type can have an IRI equal to or exceeding the initial 80th percentile IRI value. This set of constraints have been included to prevent the dramatic reduction in road quality towards the end of the planning horizon that can be evident in solutions generated by Chong and Thompson with DTIMS.

Structural Number Target constraint set (Johnson, 1992)

This set of constraints acts in the same manner as the target constraints for IRI. They ensure that road sections within a road type with structural numbers equal to or less than the target have a combined area that is less than a certain percentage of the total area. Again, this is by no means a complete method. The problems that may have occurred with the IRI targets could again provide setbacks.

Due to the lack of structural data and the solver capacity (without decomposition) a full results set could not be attained.

Result Discussion

First Approach: Analytical Hierarchy Process (AHP) (Haugodegard *et al.*, 1994)

AHP can be used for critical assessment of the list of input and output variables. It enables us to find the relative importance of the factors affecting deterioration of the pavement. After listing the factors under examination (load,

traffic, minimum temperature, maximum temperature, and precipitation), a panel of expert decision makers from Virginia Transportation Research Center was formed to investigate the stated factors through pair wise comparisons. In this research, the ratio scales were utilized to represent the judgments of decision makers. Next, the judgements of the experts were combined in order to obtain a representative judgment for the group. Such a group judgment must satisfy the reciprocal requirement, meaning that combining the judgments of all individuals and then taking the Reciprocal must give the same result as taking the reciprocal of each person's judgment and then combining them gives a detailed proof that the geometric average is a proper way for obtaining group judgments while Preserving the reciprocal requirement. Having the final comparison matrix, the priority vector was obtained by Computing the normalized principal eigenvector of the matrix. The obtained weighting vector, presented in Table 1, Is used to combine the stated uncontrollable factors into one variable named "Environmental Harshness Factor".

Table 4: The Weighting Vector Obtained Using the AHP Methodology

FACTOR	LOAD	TRAFFIC	PRECIPT	MIN TEMP	MAX TEM
WEIGHT	.38	.10	.29	.10	.13

RESULT AND REMARK OF AHP APPROACH

We note that the variables Load, Traffic, Precipitation, and Maximum Temperature are non-isotonic variables; meaning that as their values increase, the output variables decrease. The variable Minimum Temperature is an isotonic Variable, meaning that as the Minimum Temperature increases, the environmental condition gets better, leading to larger values for "Change in IRI" and "Change in CCI". In combining the stated variables into one variable using the weighting factors obtained by AHP method, one should make sure that the combined variable maintains the isotonic property. To do so, the inverse of the non-isotonic variables is used in constructing the "Environmental Harshness Factor". This is called the multiplicative inverse approach to address the non-isotonicity issue (Huang, 1993)

Second Approach: Regression Method (Haugodegard, 1994)

Regression analysis can be used to identify correlation between different input and output variables. The coefficients obtained from regressing the output variable on the set of uncontrollable inputs indicate the importance of the uncontrollable factors on the transformation process. Thus, by using the coefficients obtained from regression analysis as the weighting factors one can combine the controllable factors into one factor representing Fallah-Fini, Triantis, de la Garza environmental harshness. To do so, the output variable "change in CCI" was regressed on the set of uncontrollable variables. Considering all uncontrollable variables in one egression model resulted in a model with a low R-squred. Besides, most of the coefficients in the model turned out to be statistically insignificant or did not show the desired sign. In order to come up with a valid regression model, different subsets of uncontrollable variables were considered as the regressors and finally the model presented in Table 2 showed the desired behavior (statistically significant regression model and coefficients with desired signs). The coefficients of this model were used as the weighting factor for combining the uncontrollable variables into one variable, "Environmental Harshness Factor". "Change in CCI" was chosen as the response variable since it represents pavement deterioration due to both load related and non-load related factors. In addition, "Change in CCI" in comparison with the "Change in IRI" resulted in a better regression model in terms of significance of the coefficients and their corresponding signs.

Result of Regressing CCI on Uncontrollable Variables (desired significance level = 0.2)

Table 5: Coefficient T-Value P-Value

	Coefficient	**T Value**	**P Value**
LOAD	-.0028	-1.277	.201
SNOWFALL	2.7248	4.837	3.05
TEMPERATURE	2.7062	4.552	7.05

Result and Comment of Regression Method
As Table 2 shows, the coefficient of the variable "Load" has a negative sign. This is because an increase in the load imposed to the paved lanes causes more deterioration and thus less improvement in pavement condition (i.e. lower values for the variable "Change in CCI"). "Snowfall" and "Temperature Difference" have been used as the ordinal variables instead of interval variables. The values one to four were assigned to four different ranges of possible values for these variables such that "one" represents the worst climate condition and "four" represents the best climate condition. That's why the coefficients of these two variables show positive signs in the regression model.
Third Approach: Environmental Classification Method Developed by [Pavement Remaining Life', Transportation Research Board, TRR 1524, Washington, D.C
Using the climate and terrain condition data such as precipitation, temperature, etc. [15] proposes six environmental regions across the state of Virginia. Based on the obtained results, traffic data and the statistical techniques, (Hudson, Has and *et al.,* 1979) developes an environmental classification to measure the relative rate of deterioration of bridge parts in different(Helali, Kazmieroweski and *et al.*,1996)) regions of the state. Use the environmental region of each county, the AADT value for the respective fiscal year and findings of to assign a "Regional Effect Factor" to each of the counties at Virginia. Regional Effect Factor developed by basically shows the severity of deterioration due to climate/terrain condition and traffic at each county. It is used in the third approach to capture the effects of climate condition, traffic and load.
DEA Results and Discussion Table 3 Summarizes the DEA results for the three approaches. Due to missing pavement condition data for some of the counties at some fiscal years, the total number of DMUs under analysis is 33. As Table 3 shows, high standard deviation of efficiency scores, as well as observed values for minimum and maximum efficiency in all three methods confirm that the three methods used for increasing discrimination of DEA analysis while incorporating the effects of uncontrollable variables have been successful. Obtained results showed that out of 33 DMUs, 23 of them have the same efficiency scores in all three methods. Plus, the efficiency scores of the other 10 DMUs were very close and even the same in two of the three methods. More importantly, the efficiency trends were observed for the counties were very similar in all three methods. County A showed very high efficiency scores in the first two years and a considerable drop in its efficiency scores over the last three years. This may require maintenance managers of county A to investigate the changes in their policies and practices have happened in the last three years as a potential source for inefficient performance. Further analysis of the results declared that particular counties of concern are C and F whose efficiency scores have been very low over all years in all three methods. In addition, DMU's corresponding to these two counties never were referenced as a peer by any other DMU, as it was expected. By investigating operational and strategic policies of the set of peers corresponding to these two counties, maintenance managers can identify the changes needed to improve the performance of the stated counties. Summary Statistics for the Three Approaches are given in the following table as

Table 6: Result Comparison

	MEAN (%)	MEDIAN (%)	SD (%)	MIN (%)	MAX (%)	NO OF 100 % EFFICIENT
AHD	49.5	41.9	39.7	1.6	100	10
REGRESSION APPROACH	53.8	51.0	42.0	1.3	100	12
REGINOAL EFFECT FACTOR APPROACH	45.9	35.1	40.1	1.6	100	10

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Result Comment and Remark as a Whole

The observed efficiency trends, which are very similar in all three methods, need to be validated by the VDOT's decision makers before taking any action. Performance evaluation is not an once-in-a-lifetime analysis. The developed approach should be applied periodically through lifetime of a road section as historical data corresponding to maintenance operations and condition of the road is collected through time.

Figure 6: Photograph Taken from ASCE (*Source: www.asce.com*)

Findings of the Project

The model development for urban road maintenance is the main findings of this paper. There are many models available for urban road maintenance but no model is perfect. A particular model developed is suitable for a particular climate and for a specified area. A model developed for urban road maintenance in an area is not suitable as a prediction model in the road maintenance in the other area.

In this paper a generalized model has been developed which is suitable for all the climatic condition and for all the topographical areas except too arid and too cold areas.

This model utilizes the general concept of all the developed models (Hajek *et al.*, 1985)

Seven models have been developed for urban main pavement distress models (UMPDM) using the modified function equation 9. The models are; Block Cracking Model, Longitudinal and Transverse Mode, Patching Model, Potholes Model, Depressions Model, Weathering and Ravelling Model, and Cracking due to patching Model. Table section summarizes the calculated shape coefficients for each distress. It can be used for estimation or prediction. Figure 6.4 (a-g) shows the distress prediction models for each flexible pavement distress in the SAURN-UMS. Five curves are plotted in Figure 6.4a to Figure 6.4g. The first and the foremost is the solid line which is the predicted model for a distress type. The coefficients in Table 6.2 have been used to obtain the predicted model. The second and the third curves are the 95% upper and lower confidence limits of the predicted values from the model. These curves were developed by generating a confidence region based on the upper and lower limits of the estimated parameters of the model. This method called contour method as explained in. These curves are the longer dotted lines that are surrounding the predicted model. The fourth and the fifth curves are the 95% upper and lower confidence intervals of the measured data. These curves were developed by the asymptotic method. The asymptotic method is a practical and a reasonable representation for the confidence limits. The interpretation of this method in nonlinear regression analysis is valid only if the assumptions of nonlinear regression are true or at least not badly violated. The assumptions are investigated fully on the section of assessing the selected models (Residual analysis) in section 6.6.6.1 where it concluded that the assumptions were met the requirements. Therefore, the 95% CI is supposed to be an interval that has a 95% chance of containing the true valuation.

Seven for urban main pavement distress models (UMPDM); (Hjaek, and Bradbury, 1996)

• Block Cracking Model = (588.0)/752.13(100te)
• Longitudinal and Transverses Cracking Model = (640.1)/846.10(100te)
• Patching Model =(789.0)/317.6(100te)
• Potholes Model = (968.0)/388.14(100te)
• Depressions Model =(455.0)/896.36(100te)
• Weathering and Ravelling Model = (291.1)/116.7(100te)
• Cracking (due to patching) Model = (671.0)/665.14(100te)
• Six models for urban secondary pavement distress models (USPDM); Modelling Using Canadian Strategic Highway Research Program Bayesian Statistical Methodology', Transportation Research Record, TRR 1524, Washington, D.C.
• Block Cracking Model = (598.0)/768.27(100te)
• Longitudinal and Transverses Cracking Model = (491.0)/830.31(100te)
• Patching Model = (415.0)/179.14(100te)
• Potholes Model = (608.0)/543.33(100te)
• Depressions Model = (749.0)/407.30(100te)

Modeling Road Maintenance Management is a great deal of this research paper. Many models has been carried out over the past few decades into developing models for estimating road transport costs derived from maintenance investment policies. These existing models attempt to estimate the best investment strategy for fixed budgetary resources. However, they do not take into account the effects derived from work productivity increments arising from new contracting formulas. This paper describes a simulation model for estimating the overall benefit derived from the use of different systems for financing road maintenance as well as the productivity achieved in the management of the work. In order to validate the model, the paper ends with an application on a secondary road in India. The results of the simulation show that work productivity is extremely important to the optimal level of investment. Moreover, the simulation provides some relevant figure and data for all the important sections of roads.

Conclusion

The different types of pavement performances models are useful for management of the pavement at both project and also for network level with a view to technical assistance and economic requirements. The development of a particular model is done by applying a certain principle. The principle of statistics and mechanics should always be used because these two principles are the supporting pillars on which structure of pavement performance model rests.

The arbitrary selection of a model should not be done since arbitrary selection of a model affect cost, technical inefficiency, economy and equity. Also besides the cost allocation the poorly designed performance model make optimal pavement design which is not correct.

The pavement performance model developed on the scientific approach as described in this paper will has the user economy and technical efficiency.

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