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DEVELOPMENT OF IMPROVED PAVEMENT PERFORMANCE PREDICTION MODELS FOR THE INDIANA PAVEMENT MANAGEMENT SYSTEM

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16. Abstract

The Indiana Department of Transportation (INDOT) is increasingly committed to the Pavement Management System. For this reason, updated simple pavement performance prediction models with the least number of explanatory (independent) variables are required to predict the performance of various pavement types for future planning of rehabilitation or replacement. In Indiana, the two main pavement types are jointed concrete pavement (JCP) and bituminous pavement (BIT).

1999 and 2000 year data were used to develop regression models for different pavement types for the Interstate and Non-Interstate Roads systems. The International Roughness Index (IRI), in inches per mile, was mainly used for dependent variables while the age (AGE) of pavement and the current average annual daily traffic (AADT) were used as independent variables in best model searching.

The data from the road test sections, which were randomly selected for this study, did not yield statistically strong pavement performance prediction models more probably due to non-uniform construction and foundation of the test sections. However, a few f the following regression models with R^2 close or higher than 0.50 were obtained and listed in the text for use by the INDOT.

IRI=43+1.8*AGE+0.0004*AADT for Flexible pavements on Interstate Roads, R^2 =0.70.
IRI=65+1.9*AGE+0.0003*AADT for Jointed Concrete pavements (JCP) on Interstate Roads, R^2 =0.50.
IRI=37+10.4*AGE+0.0002*AADT for Thin Overlay pavements on Interstate Roads, R^2 =0.34.
IRI=65+8.1*AGE+0.0009*AADT for Overlay pavements on Non-Interstate Roads, R^2 =0.90.
IRI=93+1.1*AGE+0.0012*AADT for Jointed Concrete pavements (JCP) on Non-Interstate Roads, R^2 =0.27.
IRI=64+4.0*AGE+0.0008*AADT for asphalt pavements on Non-Interstate Roads, R^2 =0.30.

The rutting is recommended to be used as safety factors along with the pavement prediction models

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INDOT Research

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Development of Improved Performance Prediction Models for the Indiana Pavement Management System

Introduction

The Indiana Department of Transportation (INDOT) is increasingly committed to the Pavement Management System. For this reason, simple pavement performance prediction models with the least number of explanatory (independent) variables are required to predict the performance of various pavement types for future planning of rehabilitation or replacement. In Indiana, the two main pavement types are jointed concrete (JCP) and bituminous pavement (BIT).

The ability to accurately predict pavement performance, in terms of pavement roughness, rutting, and other measurements, is essential for a pavement management system. The quality of pavement performance prediction models is greatly affected by the available data. Prediction models for Indiana pavement conditions were previously developed with limited available data. When developing these models, it was realized that these models should be updated and improved at a later time with additional data. Since then INDOT has obtained large amount of additional data of pavement conditions, including International Roughness Index, rutting and traffic volumes. It is therefore proposed to develop improved pavement performance prediction models with the collected data.

Findings

The following conclusions and recommendations were made on the basis of this study:

1. The IRI and RUT data obtained in 1999 yielded more consistent IRI and RUT data.

2. The following prediction models would predict IRI for the Interstate Roads for the indicated pavement types:

   Equation 2:
   *IRI=43+1.8*AGE+0.0004*AADT*
   for FLEXIBLE Pavements.

   Equation 4:
   IRI=65+1.9*AGE+0.0003*AADT
   for JCP Pavements.

   Equation 5:
   IRI=37+10.4*AGE+0.0002*AADT
   for THIN Overlay.

   Equation 6:
   RUT=0.08+0.0087*AGE
   for THIN Overlay.

3. The following prediction models would predict IRI for the Non-Interstate Roads for the indicated pavement types:

   Equation 17:
   IRI=64+4.0*AGE+0.0008*AADT
   for ASPHALT Pavements.

   Equation 19:
   IRI=93+1.1*AGE+0.0012*AADT
   for JCP Pavements.

   Equation 20:
   IRI=52+8.1*AGE+0.0009*AADT
   for OVERLAY.

   Equation 21:
   RUT=0.0007+0.03*AGE+0.000002*
   AADT
   for OVERLAY.

4. The following prediction models would predict IRI for the Non-Interstate Roads for National or Non-National Highways:
   Equation 26:
   IRI=65+4*AGE+0.00097*AADT
   could be used for ASPH Pavements for Non-Interstate for both NHS and Non-NHS.

5. The RUT values are recommended to be used in association with pavement performance prediction models as safety factors.

6. The data from the road test sections, which were randomly selected for this study, did not yield statistically strong pavement performance prediction models more probably due to non-uniform construction and foundation of the test sections.

7. Improved recording of pavement cross sections is needed to provide information for study.

8. Improved quality control of all data collection is needed.

Implementation

Based on this research, the following implementation steps are recommended:

1. The program Development Division will implement the findings of this study.

2. The recommended pavement performance prediction models along with the others could be used for INDOT's road systems.

3. The yearly or latest available friction numbers and RUT data could be used with the pavement performance prediction models.

4. As part of the implementation, a computer program was developed aiming at providing a friendly user interface for accessing, analyzing the pavement condition data and for using the prediction model. The designed program integrates an intuitive graphic user interface, GIS technology, and the INDOT pavement condition database. The program allows IRI, RUT and PCR data to be retrieved and displayed either in a map or a tabular form. The program also allows the users to select pavement condition data according to location (i.e. district, county, road type, road number, etc), year of testing, contract number, as well as threshold of data value, etc.

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I. INTRODUCTION

The Indiana Department of Transportation (INDOT) is increasingly committed to the Pavement Management System. For this reason, simple pavement performance prediction models with the least number of explanatory (independent) variables are required to predict the performance of various pavement types for future planning of rehabilitation or replacement. In Indiana, the two main pavement types are jointed concrete (JCP) and bituminous pavement (BIT).

Desirable pavement performance prediction models should relate various pavement measurements, such as International Roughness Index (IRI) or Pavement Serviceability Index (PSI), friction number, pavement condition rating, pavement age, traffic (including trucks) and pavement type, if possible.

The Pavement Serviceability Index can be obtained from the International Roughness Index. The models were developed by the research study entitled "***Correlation of Pavement Serviceability Rating with International Roughness Index"***[(1)]**.** These models have already been implemented by the Program Development Division , INDOT, to obtain PSI values from the corresponding IRI values since January 1993.

Practical limited pavement prediction models were developed by the research study entitled "***Practical Pavements Performance Prediction Models for Indiana Roads"***[(2)]**,** HPR-2095, in 1998**.** The Program Development Division has implemented some prediction models from this study.

The ability to accurately predict pavement performance, in terms of pavement roughness, friction, rutting, and other measurements, is essential for a pavement management system. The quality of pavement performance prediction models is greatly affected by the available data. Prediction models for Indiana pavement conditions were previously developed with limited available data. When developing these models, it was realized that these models should be updated and improved at a later time with additional data. Since then INDOT has obtained large amount of additional data of pavement conditions, including International Roughness Index, rutting and traffic volumes. It is therefore proposed to develop improved pavement performance prediction models with the collected data.

II. OBJECTIVE

The main objective of this study was to update pavement performance prediction models

III. SCOPE

In order to address the major independent variables (i.e., age, traffic and pavement type), the design of this research study contained the entire population of Indiana State Highways. Each road was subdivided into contract sections of the last major surface change. This provided uniform age (AGE), material, construction and pavement segments for analysis.

IV. DATA COLLECTION

The following data were collected on all available roads for this research study:

1. IRI Data
   1999 by Pathway*
   2000 by Pathway

2. Average Annual Daily Traffic (AADT)
   1999- by Program Development Division

3. Rutting Survey Data (RUT)
   1999 by Pathway
   2000 by Pathway

* Pathway Services, Inc.
  Noble, Oklahoma.

V. DATA ANALYSIS

Regression models for the dependent variables IRI and RUT were searched for the Interstate and other roads in Indiana. The data for 1999 and 2000 were used in the model development separately in order to eliminate[3] any systematic calibration errors of the IRI and RUT instruments used by two different contractors. The independent variables used in the model search are age (AGE) and average annual daily traffic (AADT) and their interaction. The following models only show those independent variables, which significantly contributed, to the best model obtained.

RUT is the average rut depth of the right and left wheel path in inches. AGE is the difference between the last major surface work and the year of data collection in years. IRI is the International Roughness Index, the average of the left and right wheel path readings in inches per mile. Each dependent variable (IRI and RUT) was a weighted average by distance over variable length of the contract segments. The AADT was a weighted average by distance over the same contract segments.

A. For Interstate System

The regression models were obtained using 1999 and 2000 data and listed in Table 1.

Table 1. Regression Models for Interstate Roads

No.	SURFACE	DATA Year	N	R^2	REGRESSION MODEL
1	C&S	1999	46	0.24	IRI=42+2.3*AGE+0.0002*AADT
2	FLEX	1999	12	0.70	IRI=43+1.8*AGE+0.0004*AADT
3	FLEX	1999	12	0.10	RUT=0.22+0.002*AGE-0.0000008*AADT
4	JCP	1999	40	0.50	IRI=65+1.9*AGE+0.0003*AADT
5	THIN	1999	5	0.34	IRI=37+10.4*AGE+0.0002*AADT
6	THIN	1999	5	0.66	RUT=0.08+0.0087*AGE+0.0000005*AADT
7	OVERLAY	1999	95	0.15	IRI=55+1.2*AGE+0.00015*AADT
8	ASPH	2000	20	0.38	RUT=0.20-0.001*AGE-0.00001*AADT
9	C&S	2000	60	0.08	IRI=32+2.2*AGE+0.0003AADT
10	FLEX	2000	10	0.90	IRI=15+9.0*AGE+0.0014*AADT
11	FLEX	2000	10	0.17	RUT=0.27-0.006*AGE–0.0000075*AADT
12	JCP	2000	45	0.33	IRI=67+1.8*AGE+0.0004*AADT
13	OVERLAY	2000	114	0.18	IRI=45+1.5*AGE+0.0002*AADT
14	OVERLAY	2000	114	0.16	RUT=0.12-0.067*AGE-0.000002*AADT
15	THIN	2000	6	0.29	IRI=40+10.7*AGE+0.00001*AADT
16	THIN	2000	6	0.47	RUT=0.12+0.0058*AGE-0.0000012*AADT

Where: C&S = Crack and Seated Pavement
FLEX = Flexible Pavements
JCP = Jointed Concrete Pavement
THIN = 1 ¼ inches thick asphalt overlay over existing asphalt pavement
OVERLAY = Asphalt overlay over existing concrete pavement
N = Number of observations (contract segments)
R^2 = Correlation of Determination, in other words, percent of information for the dependent variable that could be obtained from the regression model

B. For Non-Interstate Roads

The regression models were obtained using 1999 and 2000 data and listed in Table 2.

Table 2. Regression Models for Non-Interstate Roads

Equation No.	SURFACE	DATA Year	N	R^2	REGRESSION MODEL
17	ASPH	1999	1375	0.30	IRI=64+4.0*AGE+0.0008*AADT
18	ASPH	1999	1375	0.26	RUT=0.098+0.008*AGE-0.0000008*AADT
19	JCP	1999	46	0.27	IRI=93+1.1*AGE+0.0012*AADT
20	OVERLAY	1999	6	0.90	IRI=52+8.1*AGE+0.0009*AADT
21	OVERLAY	1999	6	0.99	RUT=-0.0007+0.026*AGE+0.000002*AADT
22	ASPH	2000	1738	0.13	IRI=74+2.3*AGE+0.000005*AADT
23	ASPH	2000	1738	0.14	RUT=0.145+0.005*AGE-0.0000009*AADT
24	JCP	2000	75	0.18	IRI=90+0.9*AGE+0.00095*AADT
25	OVERLAY	2000	25	0.15	IRI=61+2.67*AGE+0.00095*AADT

The regression models were also computed for the Non-National Highway System (NHS) Roads using 1999 year data for National Highway System and Non-National System Roads separately. The results were tabulated in Table 3 and Table 4.

Table 3. Regression Models for Non-NHS Roads

Equation No.	SURFACE	DATA Year	N	R^2	REGRESSION MODEL
26	ASPHALT	1999	1125	0.31	IRI=65+4*AGE+0.00097*AADT
27	ASPHALT	1999	1125	0.27	RUT=0.094+0.0082*AGE+0.00000076*AADT
28	JCP	1999	19	0.38	IRI=86+1.41*AGE+0.00127*AADT

Table 4. Regression Models for Non-Interstate Roads for National Highway System

Equation No.	SURFACE	DATA Year	N	R^2	REGRESSION MODEL
29	ASPHALT	1999	250	0.27	IRI=53+3.6*AGE+0.00095*AADT
30	ASPHALT	1999	250	0.24	RUT=0.124+0.0087*AGE-0.0000018*AADT
31	JCP	1999	27	0.21	IRI=98+0.545*AGE+0.0012*AADT

VI. DISCUSSION OF RESULTS

A good correlation (i.e., when the correlation of determination, $R^{2,}$, the percent of the information that could be obtained from the regression model for the dependent variable, is more than or equal to 0.50) could not be obtained between IRI/RUT and the other independent variables of AGE and AADT for most of the pavement types. The test sections (contracts) were randomly selected from various roads of variable cross section, layers, and structural foundations. This variability may account for the poor correlation of determination. In addition, there must be other independent variables that would increase the correlation between the dependent variable and the model.

It appears that the regression models obtained from the 1999 year data are more consistent and have higher R^2 values in general.

VII. CONCLUSIONS AND RECOMMENDATIONS

The following conclusions and recommendations were made on the basis of this study:

1- The IRI and RUT data obtained in 1999 yielded more consistent IRI and RUT data.

2- The following prediction models would predict IRI for the Interstate Roads for the indicated pavement types:

Equation 2:
IRI=43+1.8*AGE+0.0004*AADT **for FLEXIBLE Pavements.**

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IRI=65+1.9*AGE+0.0003*AADT **for JCP Pavements.**

Equation 5:
IRI=37+10.4*AGE+0.0002*AADT **for THIN Overlay.**

Equation 6:
RUT=0.08+0.0087*AGE+0.00000000*AADT for THIN Overlay.

3- The following prediction models would predict IRI for the Non-Interstate Roads for the indicated pavement types:

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4- The following prediction models would predict IRI for the Non-Interstate Roads for National or Non-National Highways:

Equation 26:
IRI=65+4*AGE+0.00097*AADT could be used for ASPH Pavements for Non-Interstate for both NHS and Non-NHS.

5- The RUT values are recommended to be used in association with pavement performance prediction models as safety factors.

6- The data from the road test sections, which were randomly selected for this study, did not yield statistically strong pavement performance prediction models more probably due to non-uniform construction and foundation of the test sections.

7- Improved recording of pavement cross sections is needed to provide information for study.

8- Improved quality control of all data collection is needed.

VIII. IMPLEMENTATION

Based on this research, the following implementation steps are recommended:

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2) The recommended pavement performance prediction models along with the others could be used for INDOT's road systems.

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4) As part of the implementation, a protocol of a computer program was developed aiming at providing a friendly user interface for accessing, analyzing the pavement condition data and for using the prediction model. The designed program integrates an intuitive graphic user interface, GIS technology, and the INDOT pavement condition database. The program allows IRI, RUT and PCR data to be retrieved and displayed either in a map or a tabular form. The program also allows the users to select pavement condition data according to location (i.e. district, county, road type, road number, etc), year of testing, contract number, as well as threshold of data value, etc.

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