

Full Length Research Paper

An integrated graphical user interface for pavement deterioration modeling

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Flexible pavements deteriorate under traffic loads and climate effects. In this study, an integrated graphical user interface was developed to model, analyze and predict future pavement deterioration in highways. State highways in Turkey were chosen as a case study. A large database was built and connected to a user interface. This database included climate data obtained from the State Meteorological Service, traffic volumes for all state highway road sections and previous ride number measurements obtained from General directorate of highways. The created interface can analyze the traffic and climate data together for modeling purposes. In this study, a model was developed which can predict the future ride number value for any chosen state highway within Turkey. Thus, predicting the approximate timeline for probable maintenance needs of a flexible pavement section became possible.

Key words: Graphical user interface, flexible pavements, deterioration modeling, multiple regression.

INTRODUCTION

Since computers took place in our lives, the role of user friendly software interface became indispensable for fast and accurate decision making process. A well designed graphical user interface can be crucial when minimal error rates are concerned.

Traffic loads and climate effects cause flexible pavements to deteriorate in time. In Turkey, General directorate of highways conducts pavement maintenance and rehabilitation studies. In 2010, general directorate of highways (KGM) was responsible for a road network over 64000 kilometers (KGM, 2010). To measure the deterioration data for this network requires expensive tools and equipment. This expensive and time consuming measurement process requires the need for special software to analyze and predict future deterioration. In this study, a user interface was developed to model and analyze the traffic volumes and climate data to predict pavement deterioration that a road section might have in future.

Flexible pavements are layered systems constructed of

bituminous and granular mixtures. Bituminous materials possess both elastic and viscous properties (Saltan and Terzi, 2004). Pavements deteriorate under traffic loads effecting the pavement surface and environmental conditions (Ongel and Harvey, 2004). Flexible pavements deflect under traffic loads and some of this deflection is irreversible. Temperature and moisture affect the level of deflection in flexible pavements (SHRP, 1993). Seasonal and daily temperature differences cause distresses at the pavement which are named "climatological distresses" (Kirbas and Gursoy, 2010).

Roughness is a direct measure of the unevenness for the longitudinal section of a road pavement (Hunt and Bunker, 2003). In the 1980s, National Cooperative Highway Research Program sponsored two research projects. Based on the analysis of the data collected in these projects, University of Michigan Transportation Research Institute developed a method to calculate the ride number. Ride number uses a scale from 0 to 5 in which high values stand for smooth and low values stand for rough pavement surface (Perera et al., 2005). In Turkey, general directorate of highways is responsible for measuring roughness for all state highways. These measurements are conducted by using special equipment called road profilometer and results are

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PAVEMENT DETERIORATION MODELING INTERFACE

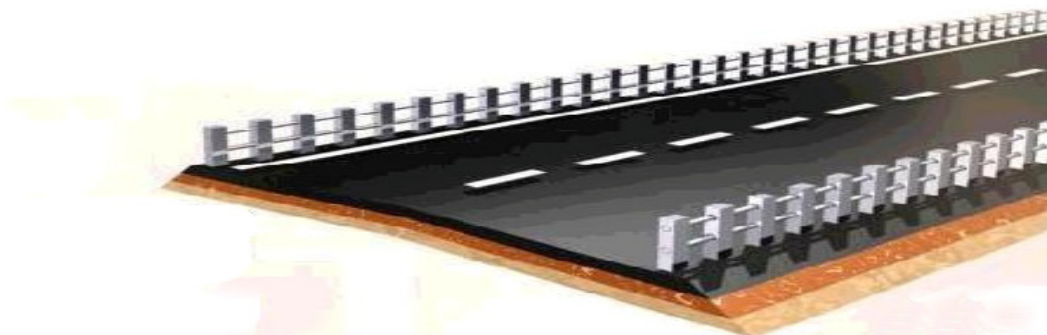


Figure 1. Interface splash screen.

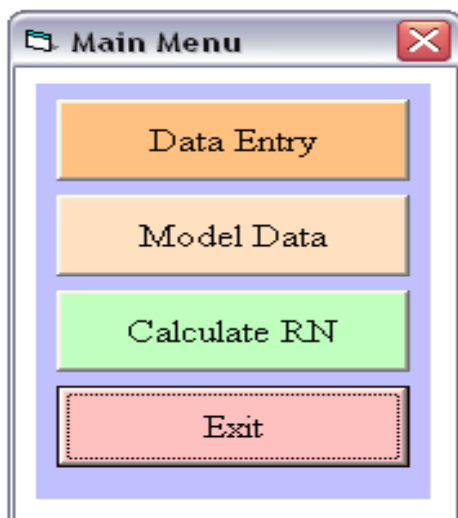


Figure 2. Main menu screen.

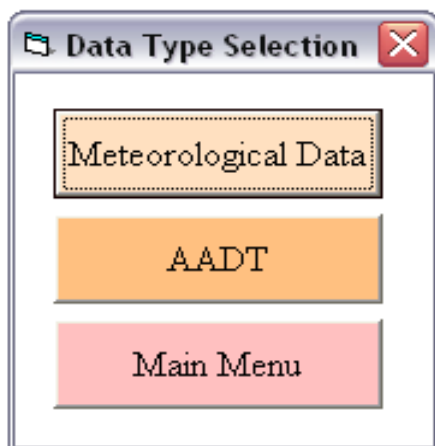


Figure 3. Data type selection sub menu screen

calculated as ride number. The directorate applies a maintenance method incase the ride number measurement value drops below 2.5 (KGM, 2000).

MATERIALS AND METHODS

There are three main data types used with the program interface. These are meteorological data, previous ride number measurement values and traffic volumes for vehicle types, car, bus, truck and tractor-trailer. The meteorological data obtained from Turkish state meteorological service contained monthly average temperature, average humidity, maximum temperature, minimum temperature, solar strength, total rain, cloud cover, snow height and ground temperature valuesfor a period of twenty years. Ride number measurements and traffic volumes for all vehicle types were gathered from annual reports and publicationsof the general directorate of highways.

MySQL database management system was usedwith the relational database formed. The meteorological data was entered on monthly basis for each year and city in Turkey. City codes were the common fieldof all tables. Traffic volumes for all road sections along with the previous ride number values were also entered into this database.

Visual basic programming language was used for the interface design and coding. When the user runs the program the splash screen appears (Figure 1). The main menu automatically replaces the splash screen (Figure 2) after a period of 5 s. The main menu displays "data entry", "model data", "calculate RN" and "exit" buttons.

The data entry button is designed for new entries and data update purposes, such that there are different data entry options for meteorological data and annual average daily traffic (AADT). The user has to select which data type he/she wants to work with by using the data entry sub menu (Figure 3). When the user selects the meteorological button, the interface displays the meteorological data entry and manipulation screen (Figure 4).

The interface automatically queries the database and displays the year, city names and related datain their respective textboxes. The user may update numeric data by entering and pressing the update button. The program requests confirmation to make changes in the database (Figure 5). Thus, the interface may counteract undesirable changes. Future data entry years up to 2017 were predefined.

Year	City	Data Type
2006	ISTANBUL	AVERAGE HUMIDITY

JANUARY	73.9	JULY	68.7
FEBRUARY	70.5	AUGUST	71.1
MARCH	72.2	SEPTEMBER	66.9
APRIL	67.8	OCTOBER	78.7
MAY	67.9	NOVEMBER	74.4
JUNE	64	DECEMBER	81.4

Figure 4. Meteorological data entry and manipulation screen.

Data Update Confirmation

The database will be updated. Do you confirm?

Tamam Iptal

Figure 5. Meteorological data update confirmation request screen.

If the user wishes to view any data for a different year, city or data type, he/she has to make a new selection from its respective field. The data will then be automatically queried and displayed in its textboxes. To return to the main menu the user has to select "Main Menu" button.

When the user selects the "AADT" button, the annual average daily traffic screen is displayed. There are three main sections in this screen (Figure 6). The equivalence factors are displayed on the left of the screen. These coefficients are automatically multiplied with their vehicle types' traffic value and the total forms the equivalent single axle load value.

All state highways in Turkey and their annual average daily traffic volumes are entered to the database along with their calculated equivalent single axle load values. The new calculated values will be automatically updated within the database when the user enters a new data or updates the recent one. The traffic changes in previous three years are displayed on the right side of the screen. Thus, possible illogical values can be ignored and user oriented

data entry errors can be minimized in case of an update. When the user wishes to change the equivalence factors, the system will inspect the new value and warn if an extreme value is detected (Figure 7).

After completing the data entry and returning to the main menu, the user may select "model data" button from the main menu which displays the model data preparation screen (Figure 8). Pressing the "prepare data" button would prepare the data for the multiple regression analysis.

RESULTS

Using multiple regression analysis, different combinations of the data were analyzed to determine the independent variables. Stepwise method was also applied and results revealed that the best combination of all independent

The screenshot shows the 'AADT Data Entry' window with the following data:

Equivalence Factors	
Car	0.0006
Bus	3.9
Truck	2.8
Trailer	4.4

Road Sections	
Road Number	200-07-2
Year	07
CITY NAME: BILECIK	
Car	9998
Bus	567
Truck	3943
Trailer	1595
ESAL	20276

Traffic Change in Previous Three Years			
	3 Years Ago	2 Years Ago	Last Year
Car	5653	8389	9375
Bus	539	561	567
Truck	3225	3354	3669
Trailer	880	977	1254
ESAL	15009	15883	18008

Figure 6. Annual average daily traffic data entry screen.

The screenshot shows the 'AADT Data Entry' window with an error dialog box. The data is as follows:

Equivalence Factors	
Car	0.0006
Bus	11
Truck	2.8
Trailer	4.4

Road Sections	
Road Number	200-07-2
Year	07
CITY NAME: BILECIK	
Car	9998
Bus	567
Truck	TEZ
Trailer	
ESAL	

Traffic Change in Previous Three Years			
	3 Years Ago	2 Years Ago	Last Year
Car	6653	8389	9375
Bus	539	561	567
Truck	3225	3354	3669
Trailer	880	977	1254
ESAL	15883	18008	

The error dialog box contains the text: "The value you've entered is over the logical limit. Please correct..." and a "Tamam" button.

Figure 7. Extreme equivalence value detection screen.

variables that would explain the dependent variable were cumulative standard axel load (CSAL), minimum temperature ($Temp_{min}$), solar strength and total rain

height.

The equation to predict the ride number was:

$$\hat{RN} = 4.983 - 1.92310^8 CSAL - 0.094 Temp_{min} - 99.075 SolarStrength + 41.92 TotalRain$$

(1)

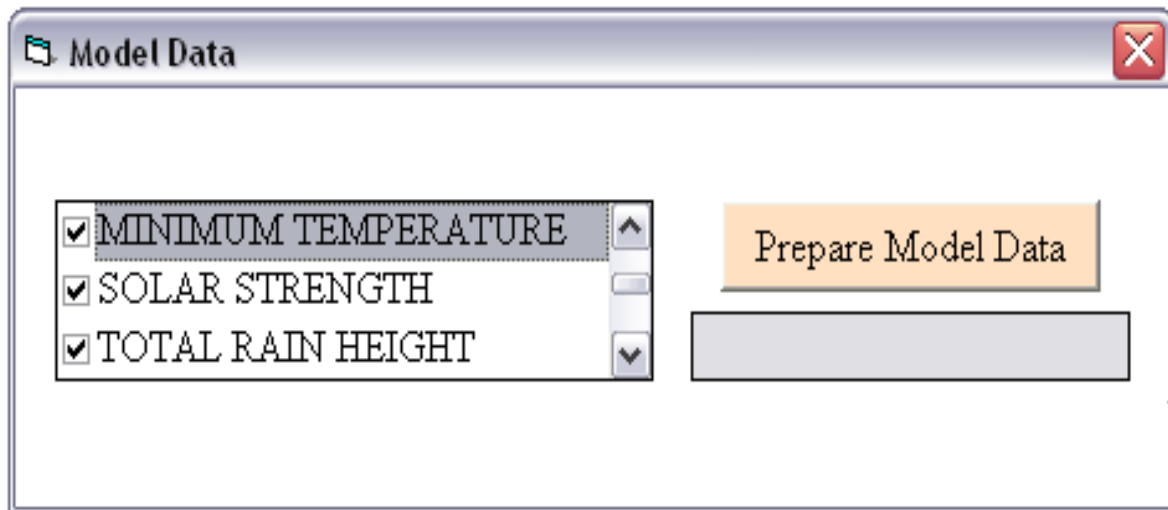


Figure 8. Model data preparation screen.

Table 1. Multiple regression analysis results.

Regression analysis				
R		0.870		
R ²		0.757		
Adjusted R ²		0.729		
Standard error of estimate		0.19526		
		Sum of squares	Df	F
Regression		4.157	4	27.259
Residual		1.334	35	
Total		5.491	39	
		Coefficients	Standard error	Sig.
Model				
Constant		4.983	0.224	0.000
CSAL		-1.923E-08	0.000	0.000
Temp _{min}		-0.094	0.015	0.000
Solar strength		-99.075	16.206	0.000
Total rain height		-41.920	7.350	0.000

Multiple regression analysis results as seen in Table 1 showed that the independent variables used had enough power to predict the ride number. The “significance” (Sig.) result in Table 1 was smaller than the chosen level 0.05 which proved that the model was valid.

DISCUSSION

The effects of individual variables within the model were evaluated. As shown in Figure 9, temperature increases pavement deterioration also increases. Pavements deteriorate faster under the influence of powerful solar

strength (Figure 10). Figure 11 clearly reveals that the amount of rain has an increasing effect on deterioration. When the user selects the “calculate RN”, enters any cumulative standard axel load, the interface will analyze, predict and display the future ride number estimation for the selected city (Figure 12). The measurements conducted by the directorate of highways were compared with values predicted by the interface (Figure 13).

Conclusions

In this study, a graphical user interface was created to

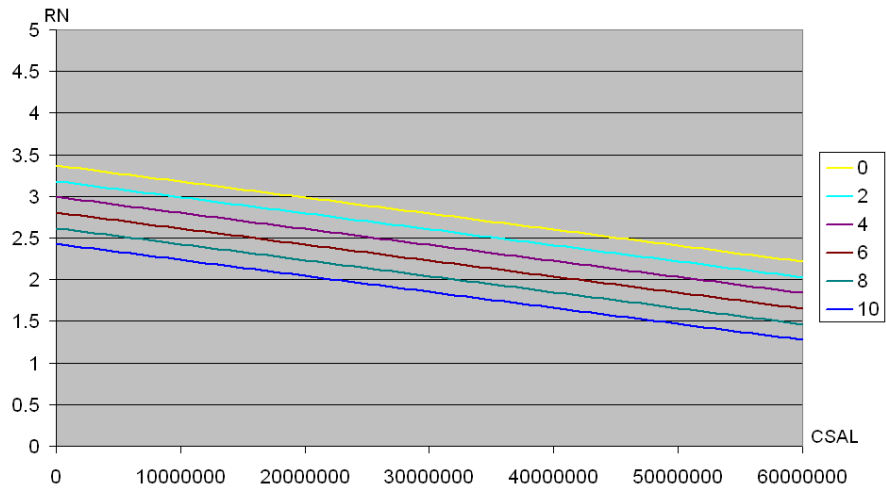


Figure 9. The effect of temperature on pavement deterioration.

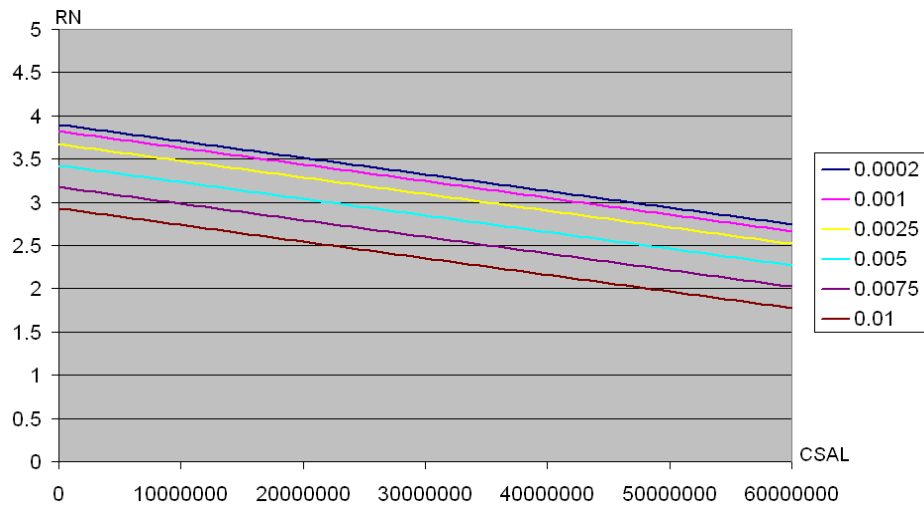


Figure 10. The effect of solar strength on pavement deterioration.

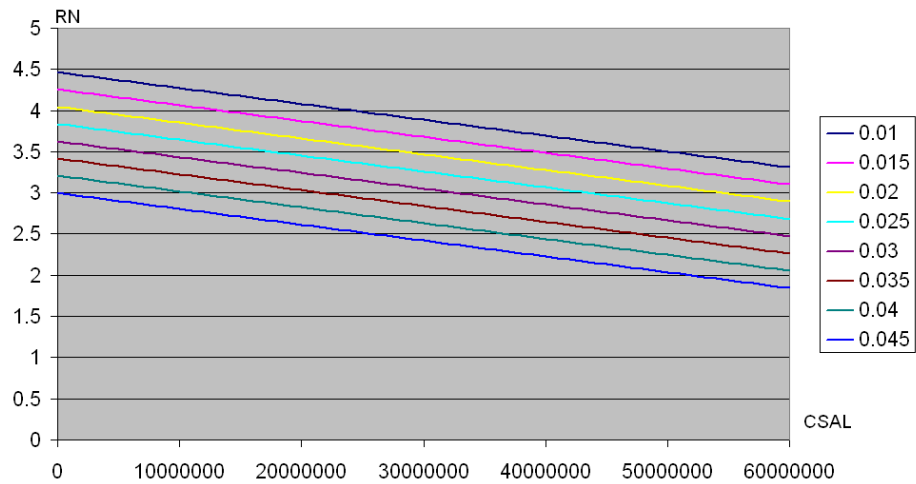


Figure 11. The effect of total rain on pavement deterioration.

The screenshot shows a software window titled "Ride Number Prediction". The interface has a yellow background and contains the following elements:

- A text label "Cumulative Standard Axle Load" above a text input field containing the value "15624829".
- A text label "City" above a dropdown menu currently displaying "ISTANBUL".
- An orange button labeled "Predict RN".
- A text label "Predicted RN" above a text output field containing the value "3.44".
- A pink button labeled "Main Menu".

Figure 12. Ride number prediction screen.

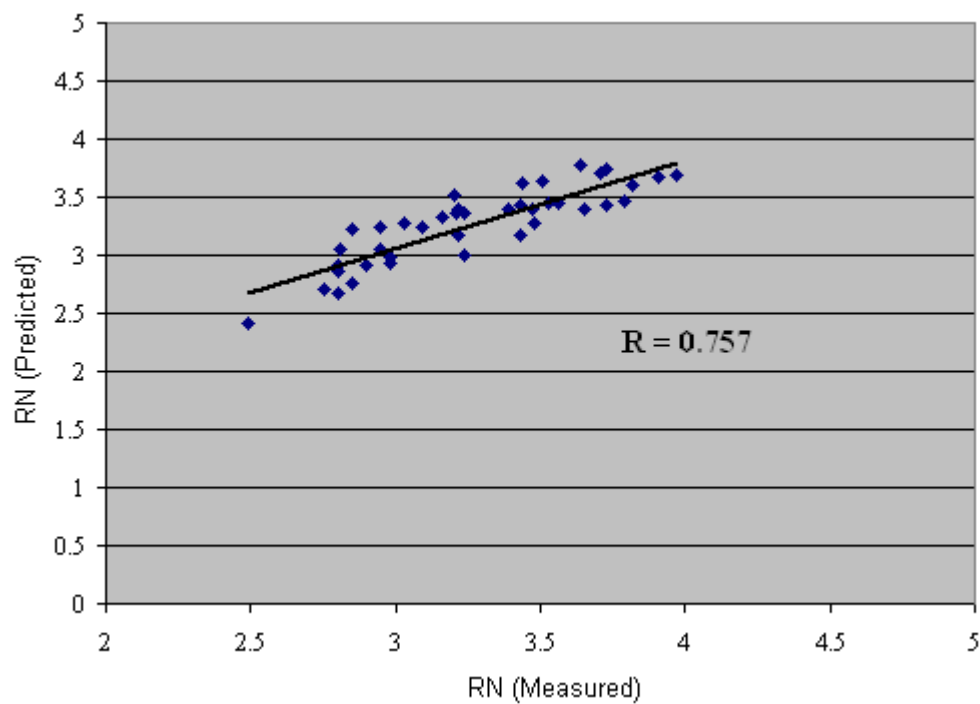


Figure 13. Comparison between the model and measured values.

model pavement deterioration using multiple regression analysis. With the use of this interface, large amount of data could be analyzed in short amount of time with minimal error. As the result of these analyses, a model equation was obtained to predict future pavement deterioration. Thus, it became possible to predict the highways that would need maintenance without conducting expensive and complex measurement techniques. Model results clearly reveal that when temperature, solar strength and total rain height increase deterioration also increases. The model outcomes were compared with the actual measurements conducted by the directorate of highways and the results revealed that the model was accurate.

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