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Review

Modeling of state highway pavement maintenance work

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A highway network is valuable for the society it serves, and should be maintained so as to keep this value at an optimum level. This study was performed to contribute to the planning of highway pavement maintenance work, associated with the Pavement Management System application in Turkish State Highways. In this study, pavement performance was modeled, taking into consideration traffic loads, environmental conditions, and the longitudinal evenness value which is accepted as the pavement performance indicator by the General Directorate of Highways in Turkey. Then, using this model, it is planned to estimate the total maintenance costs (per lane-km) of Turkish State Highways according to maintenance year and type.

Key words: Pavement management, maintenance, modeling, state highways.

INTRODUCTION

Many of the roads in the Turkish highway network were designed and constructed according to the demands of their times. Thus, today they have become unable to carry the increasing amount of traffic, especially heavy vehicle traffic. On the other hand, frequent overloading of heavy vehicle decreases the service life, which is estimated as 20 years, of the state highways significantly.

Total length of the Turkish highway network is 63.219 km in 2004, comprising 1.851 km of motorways, 31.318 km of state highway and 30.050 km of provincial roads. All of the motorways, 98% of the state highway and 87% of the provincial roads have bituminous pavement (ITU, 2005).

Maintenance and improvement costs of the Turkish highway network continuously increases as new state roads and motorways are added and significant management problems arise. Increase in trade traffic adds up to this; so, the need for new facilities and maintenance and improvement of present state highways become more important (TCK, 1994).

Determining the present state of the pavement, which carries the traffic loads on a state highway, and the necessary maintenance strategies are carried out by the pavement management system. Highways, in good condition just after construction, start to deteriorate because of traffic load and climatic conditions. These deteriorations are slow in the beginning and in order to protect the road's performance, only routine maintenance is necessary. However, as time passes the improvement to be made in time will be failed, structural deterioration that require expensive improvement alternatives occur. The Pavement Management System contributes to in time improvement programs, in order to avoid expensive repairs (Haas et al., 1994; Shahin, 2005; OECD, 1987; OECD, 1995).

In this study, which was carried out to make a contribution to state highway pavement maintenance work in Turkey, pavement longitudinal evenness values, traffic loads and climatic conditions of the regions were taken into account. Then, the variation of the pavement performance according to these parameters was modeled. After this, by using the model, the cost of the necessary structural maintenance according to its year and type (per lane-km) and other constant maintenance costs were determined.

PAVEMENT MANAGEMENT SYSTEM

The pavement management system is a set of tools or methods that can assists decision makers in finding cost effective strategies for providing, evaluating, and maintaining pavements in a serviceable condition. It

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provides the information necessary to make these decisions. The Pavement Management System consists of two basic components: A comprehensive database, which contains current and historical information on pavement present condition, pavement structure, and traffic. The second component is a set of tools that allows us to determine existing and future pavement conditions, predict financial needs, and identify and prioritize pavement preservation projects. The basic purpose of a pavement management system is to achieve the best value possible for the available public funds and to provide safe, comfortable and economic transportation.

Pavement management starts with the evaluation of the highway network. For this reason, all roads in the highway network are studied with regard to structural resistance, ride comfort, surface deteriorations and skid resistance. Collected data are analyzed sections by sections so as to display the present condition of the highway network. Then, it is estimated the road pavement performance in future, namely the variations of the existent road pavement performance over time. In this period, the roads which must be improved in the present situation and the future by years are determined. After this, the improving strategies are selected to form the optimum study program in the considered planning period (Paterson, 1987).

From engineering point of view, deterioration is any kind of deviation of the pavement from its original physical characteristics. Maintenance is the work that aims to maintain the pavement under normal traffic conditions and environmental effects as close to its initial conditions as possible with the possibility of deterioration because of climatic, traffic and ground water effects. Independence of the pavement type, in order to maintain an investment for a road, is possible only with an effective drainage system and a sufficient maintenance process.

Pavement maintenance covers two different activities, namely “Routine Maintenance” and “Structural Maintenance”. Routine maintenance is applied for preventing and covering for surface deterioration in order to maintain a constant level of service without changing the capacity of the road. Structural maintenance is applied to get rid of structural deficiencies and adapt the capacity of the road to traffic volume increases by supporting with an additive structural element or removing the causes of deterioration (Paterson, 1987).

MODELING MAINTENANCE WORK ON TURKISH STATE HIGHWAY PAVEMENTS

Pavement performance is the measurable sufficiency of the structural and the functional service, throughout a certain design period, of a pavement. The main performance indicators are recognisable deterioration, structural appropriateness (deflection), surface friction (skid resistance), and longitudinal evenness. Deteriorations, structural appropriateness and surface friction are the significant engineering indicators of a pavement’s condition, where the condition of a pavement is mainly defined by the driving quality (Ergun et al., 2005). Longitudinal evenness of pavement surface affects driving quality, safety, and vehicle maintenance cost negatively. Longitudinal evenness is defined as an index that is measured by one of the many relevant measurement configurations (NHI, 1994; AASHTO, 2001). The primary stage of the pavement management is to evaluate the highway network cautiously, accurate and sensitive data of the current performance should be collected from all the links of the highway network. Information on the current performance (state) of roads is not only used to determine the roads that are in bad condition but also used to determine the ones that are in intermediate or good condition.

AASHTO determined nearly the 90-95% of the information on highway pavement performance by road surface’s longitudinal evenness during experimental studies on roads. Longitudinal evenness (roughness) concept is the road surface disorder that the drivers and the passengers of a vehicle, using a road surface, perceive. Driving quality perception is an indicator of the acceptability of service that a road provides. Longitudinal evenness affects moving vehicle dynamics by stepping-up the wearing on the components of a vehicle and, hence, becomes effective on vehicle operating costs and safety and on comfort and cruise speed dominantly. Moreover, longitudinal evenness accelerates pavement deterioration by increasing the dynamic loads on road surface that vehicles cause. Longitudinal evenness can affect the surface drainage negatively by causing water accumulation on the road surface affecting both the pavement performance and the vehicle safety.

Longitudinal evenness is a property of the profile of road surface where wheels contact and is defined most accurately as the effect of a road on both its functional performance and structural performance. Longitudinal evenness is defined as the deviations of a road surface, affecting to vehicle dynamics, driving quality, dynamic loads and drainage, from a real plane surface that has characteristic dimensions.

The Turkish Road Authority assumes driving comfort index, obtained as a result of measurements on longitudinal evenness, as an indicator of pavement performance and in some regions; the Turkish Road Authority measured the riding number (RN), indicating longitudinal evenness values, on state highways by using a profilometer type instrument (T6500 K. J. Law Profilometer) to determine the pavement performance (TCK, 1994).

The measured RN values range from zero to 5, where zero indicates an unserviceable highway pavement and 5 indicates a perfect highway pavement. RN value is a

Table 1. Multivariate regression analysis

Regression statistics			
Multiple R	0.874141763		
R square	0.764123		
Adjusted R square	0.713430212		
Standard error	0.428802081		
Observations	28		
ANOVA			
	Df	**F**	
Regression	3	6.979487301	
Residual	24		
Total	27		
	Coefficients	**Standard error**	**P-value**
Intercept	4.18499659	0.336814624	0.0000006
T8.2	-3.55E-07	3.62648E-08	0.0114956
1/AHTTRN	825.30179	522.468139	0.0433075
ALTTRN	-2.71921E-05	5.80708E-05	0.0546803

performance criterion and assumed to correspond to service capability (Classification of Present Service Ratio - PSR) in AASHTO method. RN = 2.5 is thought to be the limit for intervention.

In this study, a model, showing the shift on state highways' pavement performance, is developed by using these measurements (between 1992 and 2004). With this model, the relationships dependant on aging are classified by considering the seasonal conditions (temperature) that the road takes place in besides the traffic effect that is defined by the $T_{8,2}$ Equivalent standard axle load. In this purpose, multivariate regression analysis is carried out to setup a deterioration model to estimate the RN values, actually the pavement performances that correspond to longitudinal evenness (Iyinam, 1997).

After the different environmental parameters is evaluated in the regression analysis for performance estimation, the best result shows that two environmental parameters could represent the model. These two environment parameters are considered as some of the most important parameters in pavement design and pavement service life that are very efficient on pavement performance. annual high temperature total repeat number (AHTTRN) and annual low temperature total repeat number (ALTTRN) values, calculated by monthly highest (over 25°C) and lowest (below 0°C) temperature data at city level collected from the regions that the considered state roads passes, are processed as environmental parameters obtained from the Turkish State Meteorology Authority Statistics (monthly statistics between 1992 and 2004).

The proposed RN equality, developed with multivariate regression technique, is equality (model) of performance estimation;

$$\mathbf{RN} = 4.185 - 3.5 \times 10^{-7} \times \mathbf{T_{8,2}} + 825.3 / \mathbf{AHTTRN} - 2.72 \times 10^{-5} \times \mathbf{ALTTRN} \quad (1)$$

The multivariate regression correlation coefficient of this equality is 0.87, as seen in Table 1. In this model, the RN limit value (level of intervention) that the structural maintenance is to be applied on state highways is assigned 2.5 (Iyinam, 1997).

The model, obtained as a result of multivariate regression, is the closest one to real life that reflects present condition of the state roads and it is clear that the curve obtained by the proposed model seemed alike the theoretical performance curve as shown in Figure 1.

As it is understood from the figure that shows the relationship between the model and $T_{8,2}$, the structural maintenance periods vary due to $T_{8,2}$ value. The model shows that the deteriorations naturally increase when $T_{8,2}$ value increases and structural maintenance is required when RN decreases down to a certain value (limit). At the end of the study, the maintenance costs of the 28 state roads that are considered in regression analysis can be calculated. In these calculations, the continuous maintenance cost is assumed to be constant for each Kilometre and assumed to increase dependant on the increase on traffic volume. When RN = 2.5, the structural maintenance, as the addition of modified asphalt concrete wearing surface, all maintenance cost can be calculated. The most important phase at the project level evaluation in a PMS is the single evaluation of the sections (Kirbas and Gursoy, 2010). For this reason, the total, routine and structural maintenance costs of one example state highway section is calculated via

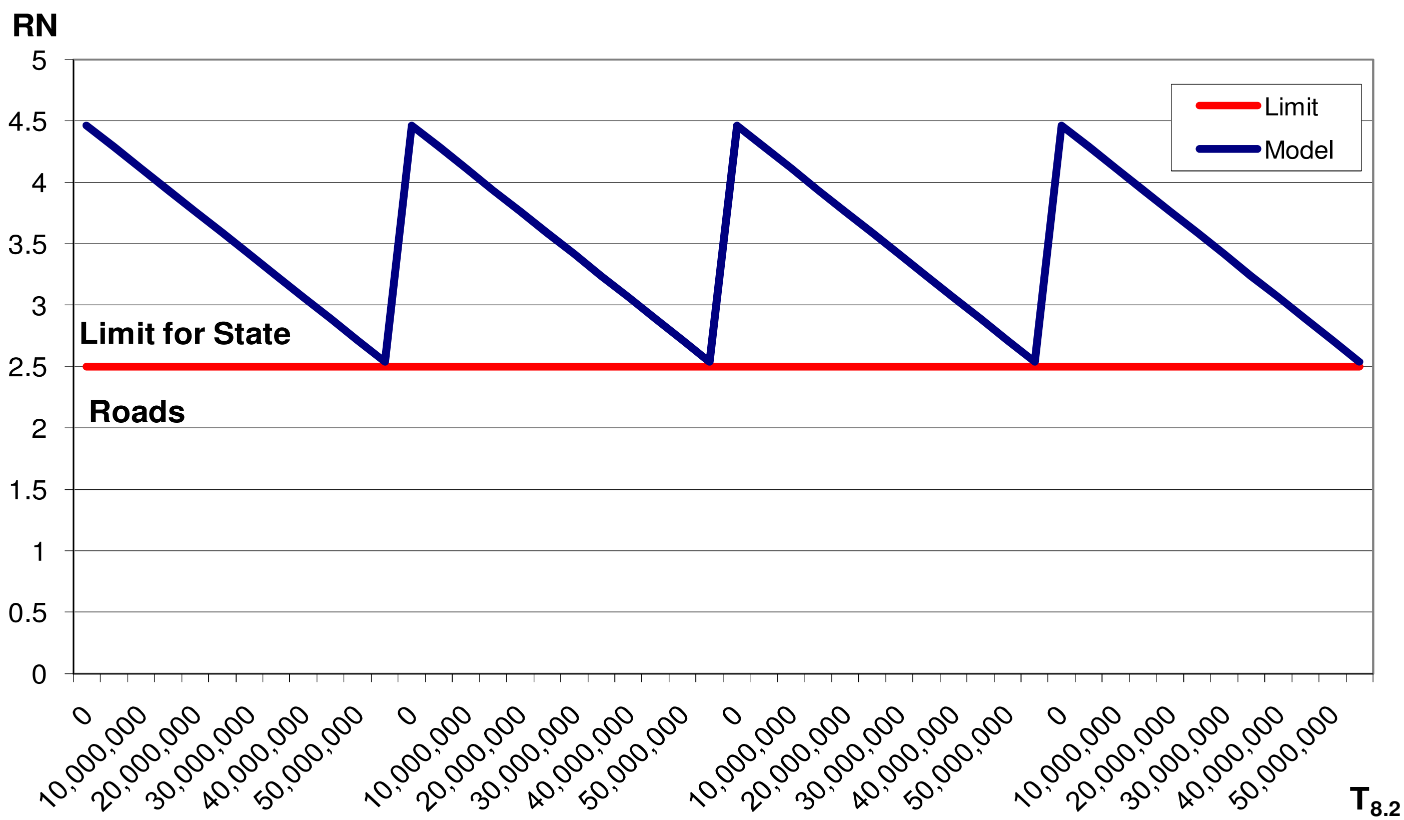

Figure 1. Structural maintenance model (for AHTTRN = 3000 and ALTTRN = 250).

model and shown in Table 2 (Iyinam, 1997).

CONCLUSION

As it is proved by the sample given in this study, a great number of the state highways in Turkey completed their 20-year service life. By looking at this aspect, to give priority to increase the capacity of state highways rather than constructing new ones is inevitable and necessary.

The model obtained in this study shows the variations of highway pavement performance in time due to traffic load and environmental effects. Together with equivalent standard axle load ($T_{8,2}$), the environmental parameters such as annual high temperature total repeat number (AHTTRN) and annual low temperature total repeat numbers (ALTTRN) are important parameters of model. Besides, it is possible to determine the structural maintenance, due to variations on highway pavement performance in time, period and cost by utilizing the proposed model.

REFERENCES

AASHTO (2001). Pavement Management Guide, American Association of State Highway and Transportation Officials, Urban Transportation Center at the University of Illinois-Chicago, U.S.A.

Ergun M, Iyinam S, Iyinam AF (2005). Prediction of Road Surface Friction Coefficient Using only Macro- and Microtexture Measurement, ASCE, J. Transport. Eng., 131-4: 311-319.

Table 2. Maintenance cost for Balikesir-Akhisar State road (one direction)

Year	Traffic volumes (AADT)			T. I. R.	$T_{8,2}$	Total $T_{8,2}$	Environmental parameters		RN	Routine maintenance cost $/KM/year				Total	Structural maintenance Cost $/KM/year	Total maintenance Cost $/KM/year
	Car	Bus	Truck				1/AHTTRN	ALTTRN		Pavement	Drainage	Traffic	Winter			
2003	4.510	1.015	1.520	950	1.367.565	1.367.565	0,0003	250	4,40	703	750	1.500	1.500	4.453		4.453
2004	4.772	1.092	1.621	1.013	1.460.375	2.827.939	0,0003	250	4,35	1.454	750	1.500	1.500	5.204		5.204
2005	5.048	1.174	1.730	1.081	1.559.495	4.387.435	0,0003	250	4,30	2.255	750	1.500	1.500	6.005		6.005
2006	5.341	1.263	1.845	1.153	1.665.356	6.052.791	0,0003	250	4,24	3.111	750	1.500	1.500	6.861		6.861
2007	5.651	1.358	1.968	1.230	1.778.418	7.831.209	0,0003	250	4,18	4.025	750	1.500	1.500	7.775		7.775
2008	5.979	1.461	2.099	1.312	1.899.170	9.730.380	0,0003	250	4,11	5.001	750	1.500	1.500	8.751		8.751
2009	6.325	1.571	2.239	1.400	2.028.138	11.758.518	0,0003	250	4,04	6.044	750	1.500	1.500	9.794		9.794
2010	6.692	1.689	2.389	1.493	2.165.881	13.924.399	0,0003	250	3,96	7.157	750	1.500	1.500	10.907		10.907
2011	7.080	1.817	2.548	1.592	2.312.998	16.237.397	0,0003	250	3,88	8.346	750	1.500	1.500	12.096		12.096
2012	7.491	1.954	2.718	1.699	2.470.128	18.707.525	0,0003	250	3,80	9.616	750	1.500	1.500	13.366		13.366
2013	7.926	2.102	2.899	1.812	2.637.954	21.345.479	0,0003	250	3,70	10.972	750	1.500	1.500	14.722		14.722
2014	8.385	2.260	3.092	1.933	2.817.206	24.162.685	0,0003	250	3,60	12.420	750	1.500	1.500	16.170		16.170
2015	8.872	2.431	3.299	2.062	3.008.663	27.171.348	0,0003	250	3,50	13.966	750	1.500	1.500	17.716		17.716
2016	9.386	2.615	3.519	2.199	3.213.159	30.384.507	0,0003	250	3,39	15.618	750	1.500	1.500	19.368		19.368
2017	9.931	2.812	3.753	2.346	3.431.582	33.816.089	0,0003	250	3,27	17.381	750	1.500	1.500	21.131		21.131
2018	10.507	3.024	4.004	2.502	3.664.885	37.480.974	0,0003	250	3,14	19.265	750	1.500	1.500	23.015		23.015
2019	11.116	3.253	4.271	2.669	3.914.083	41.395.057	0,0003	250	3,00	21.277	750	1.500	1.500	25.027		25.027
2020	11.761	3.498	4.556	2.847	4.180.261	45.575.318	0,0003	250	2,86	23.426	750	1.500	1.500	27.176		27.176
2021	12.443	3.762	4.860	3.037	4.464.579	4.464.579	0,0003	250	4,29	2.295	750	1.500	1.500	6.045	20.200	26.245
2022	13.164	4.046	5.184	3.240	4.768.276	9.232.854	0,0003	250	4,13	4.746	750	1.500	1.500	8.496		8.496
2023	13.928	4.352	5.530	3.456	5.092.676	14.325.530	0,0003	250	3,95	7.363	750	1.500	1.500	11.113		11.113
2024	14.736	4.680	5.898	3.686	5.439.193	19.764.723	0,0003	250	3,76	10.159	750	1.500	1.500	13.909		13.909

Haas R, Hudson WR, Zaniewski J (1994). Modern Pavement Management, Kriger Publishing Company, Florida, U.S.A.

ITU (2005). Strategic Project: National Transportation Master Plan of Turkish Republic, 2003–2005, Part 1, 5-7, Istanbul Technical University, Research and Implementation Centre for Transport and Transportation Vehicles, Istanbul, Turkey.

Iyinam S (1997) The Planning Methodology of the Pavement Maintenance Works on Highways, Doctorate Thesis, ITU Institute of Science and Technology, November 1997 (in Turkish).

Kirbas U, Gursoy M (2010). Scientific Research and Essays. 5(8): 806-812.

NHI (1994). AASHTO Design Procedures for New Pavements, Participant's Manual, National Highway Institute, U.S. Department of Transportation, Federal Highway Administration, Publication No. FHWA-HI-94-023.

OECD (1987). Pavement Management Systems, Road Transport Research, Report prepared by an OECD Scientific Expert Group, Organization for Economic Co-operation and Development, OECD, Paris, France.

OECD (1995). Road Maintenance Management Systems in Developing Countries, Road Transport Research, Report prepared by an OECD Scientific Expert Group, Organization for Economic Co-operation and Development, OECD, Paris, France.

TCK (1994). Pavement Management System Planning and Pilot Project Work, General Directorate of Turkish Highways, Technical Research Department, Ankara, Turkey.