ROUGHNESS EVALUATION OF THE EAST BLACK SEA COAST ROAD OF TÜRKİYE

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ABSTRACT

Pavement roughness is one of the most important performance measures for pavement conditions and most frequently the triggering factor which identifies a roadway as a candidate for maintenance, rehabilitation and reconstruction. The survey was designed to evaluate roughness performances and the priorities for highway maintenance work and activities. In this research the inertial profilometer was used to measure the roughness of The East Black Sea Coast Road in 10 th Division Highways of Türkiye. 687,180 km asphalt roads from Gülburnu to Sarp Border Gate were surveyed and analysed. As a result of this study, surface roughness performance was determined and the order of priority list for maintenance was prepared for the measured roads. It was found that 0,02% of the surveyed roads were classified as 'Very Good', while 16,82% were classified as 'Good', 50,45% were in'Fair' condition, 11,15% were in 'Mediocre' condition, 9,99% were in 'Poor' condition , and 11,57% in 'Very Poor' condition. Since about one third of the measured roads is in 'Mediocre', 'Poor' and 'Very Poor' conditions, it is recommended that serious actions and maintenance plans should be taken to improve road conditions in 10 th Division of Türkiye.

Keywords: Roughness, Pavement condition, Pavement performance

1. INTRODUCTION

Türkiye, being aware of its geographic importance, spends great effort to establish transportation connections between Europe, Asia and Africa. The system of highways network in our country is significant to provide national development, unity and general development in the region. General Directorate of Highways has 64 865 km road network, including 2 080 km Motorway, 31 395 km State Highway, 31 390 km Provincial Road.

There is a need of developing a scientific approach towards determining the maintenance and rehabilitation requirements of pavements. Road maintenance is an essential part of any country's transport programme and vital to the economy. Poor road maintanence has a negative impact on the economy. So it is necessary to measure and establish road conditon performance. Road roughness is one of the indices used to assess the road performance in a common and rapid way .

Roughness is an important indicator of pavement riding comfort and safety. Pavement roughness consists of random multifrequency waves of many wavelengths and amplitudes. Longitudinal roughness has been defined as 'the longitudinal deviations of a pavement surface from a true planar surface with characteristic dimensions that affect vehicle dynamics, ride quality and dynamic pavement load' [1-2].

The International Roughness Index (IRI) summarizes the roughness qualities that impact vehicle response, and is most appropriate when a roughness measure is desired that relates to: overall vehicle operating cost, overall ride quality, dynamic wheel loads (that is ,damage to the road from heavy trucks and braking and cornering safety limits available to passenger cars), and overall surface condition [3-4].

The evaluation of performance involves the functional analysis of pavements based on the history of the riding quality. The riding comfort and pavement performance can be conveniently defined in terms of roughness and pavement distresses. Thus different models have been developed relating roughness with distresses to predict pavement performance[5].

Pavement performance is a function of its relative ability to serve traffic over a period of time.Typically, a system of objective measurements is used to quantify a pavements condition and performance. These system are used to aid in making the following types of decision [6]:

- Establish maintenance priorities. Condition data such as roughness, surface distress, and deflection are used to establish the projects most in need of maintenance and rehabilitation. Once identified, the projects in the poorest condition are more closely evaluated to determine repair strategies.
- Determine maintenance and rehabilitation strategies. Data from surface distress surveys are used to develop an action plan on a year-to-year basis; i.e., which strategy (patching, overlays, recycling,etc.) is most apropriate for given pavement condition.
- Predict pavement performance. Data such as roughness, skid resistance, surface distress, or a combined rating, are projected into the future to assist in preparing long-range budgets or to estimate the condition of the pavements in a network given a fixed budget.

Pavement performance models are the best approximate preditors of expected conditions. Pavement performance modelling an important tool used by pavement managers in decision making in prioritisation and budgeting for maintenance work[7].

A model is also needed for calculating the permanent deformation of the pavement materials, which will result in rutting and roughness of pavement surface [8]. Condition performance models are used at both the network and project levels to analyze the condition and determine maintenance and rehabilitation (M&R) requirements [1]. And also pavement prediction models represent a key element of PMS. The measure of road condition is used IRI, as it is the primary indicator of a road's service level. Knowledge of road condition is an important part of data provision for the Pavement Management System (PMS). PMS is a tool and support system used to reach an optimal level of road maintenance, and is based on national economic assessments. PMS provides a systematic, consistent method for selecting maintenance and rehabilitation needs and determining priorities and the optimal time for repair by predicting future pavement condition [1]. The network data (roughness, rut depth, cracking, skid resistance, deflection, etc.) feed the Pavement Management System.

In this research, Road Surface Profiler (RSP) was used to measure roughness of The East Black Sea Coast Road in 10 Th Division of Türkiye. 687,180 km asphalt pavement were measured and evaluated. This study helped to establish a priority list for maintenance and also provide reliable data to evaluate road performance. Roughness results were used to select the road sections that required further analysis and maintenance. In addition to this roughness data is used pavement performance models which will be performed for 10 th Division roads and also PMS.

2. METHOD AND METHODOLOGY

Pavement roughness is one of the most important performance measures for pavement conditions and most frequently the triggering factor which identifies a roadway as a candidate for maintenance, rehabilitation and reconstruction [9]. A comprehensive measure of pavement condition would require data on other pavement performance indexes such as distresses, skid resistance and deflection.

Roughness levels of asphalt pavement are given in the Table 1 for Türkiye.

Table 1: Asphalt pavement roughness levels

IRI (m/km)	**Roughness level**	Performance **or Order of priority for M&R**	**Definition of pavement Condition Class**
0-0,71	Very Good	6	New or almost new pavement. It will not require improvement for some time.
0,72– 1,11	Good	5	In decent condition. .Pavement will not require improvement near future.
1,12– 1,58	Fair	4	Pavement will likely need in the near future.It depends on traffic use.
1,59 - 1,80	Mediocre	3	Pavement needs near term improvement to to preserve usability*
1,81 - 2,13	Poor	2	Pavement needs immediate improvement to restore serviceability*
>2,13	Very Poor	1	Maybe, it could be reconstruction*

*It should be established extra performance criteries in addition to roughness.

This study explains the roughness measurement and evaluation of the asphalt pavement for 10 th Division highways. Roughness measurements are collected using the Road Surface Profilometer . It is capable of real time measurements of longitudinal profile, International Roughness Index (IRI), transverse profile, rut depth, macro texture and geometrics. Measurements are carried out at normal traffic speed, located with DGPS (Differential Geographical Positioning System) and complemented with digital photographs of the road inventory and surface. In addition, they allow easy integration to GIS (Geographic Information Systems).

1.1 Roughness Measuring Device

RSP is a World Bank Class 1 roughness measurement device. World-Bank TP-46 and ASTM E-950 specified test procedures were followed in this survey [10-11]. The RSP test system can collect a wide variety of information ranging from ride quality measurements (International Roughness Index and Ride Number) to high accuracy transverse and longitudinal inertial profile as well as geometric information such as grade, crossfall, and curve radius or degree of curve. RSP compute, display and store longitudinal and transverse profile as well as roughness indices, rutting measurements and crossfall in real time and at highway speeds. The RSP can measure pavement texture and faulting.17 laser sensors, 2 accelometers and Inertial Motion Sensor were mounted in rigid aluminium housing (rut bar) at the front of the vehicle. The RSP can collect data at speed of up to 110 km/hr (the RSP is driven recommended speed which is 70 km/hr).

2.2 Road Measurement

Roads were measured with RSP. The roughness measurements were performed for the extreme right lanes. For the divided dual carriage ways, both directions were surveyed. Measurements are carried out at normal traffic speed **(**70 km/hr), located with DGPS (satellite support) and complemented with digital photographs of the road environment and surface.

2.3 Data Analysing

Two different computer programs were used for data analysis. Both of the computer programs have GPS coordinates value and Google Earth Map. One of both programs is 'Dynatest Explorer'. It was used for the roughness data analysis. IRI is calculated from the left and right wheel path profile. Figure 1 shows Dynatest Explorer software windows for 20 m length. (This 20 m length is optional).

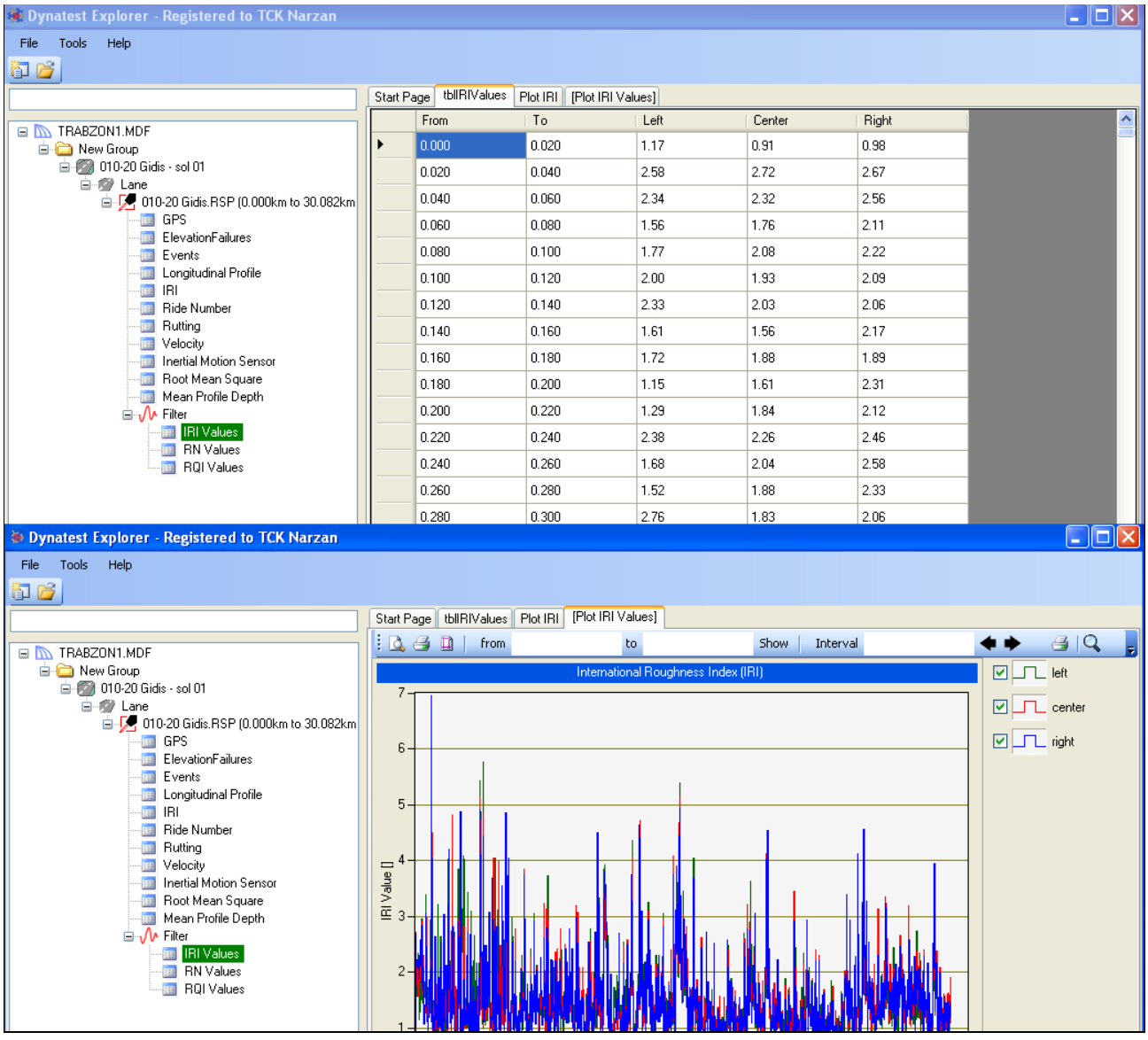
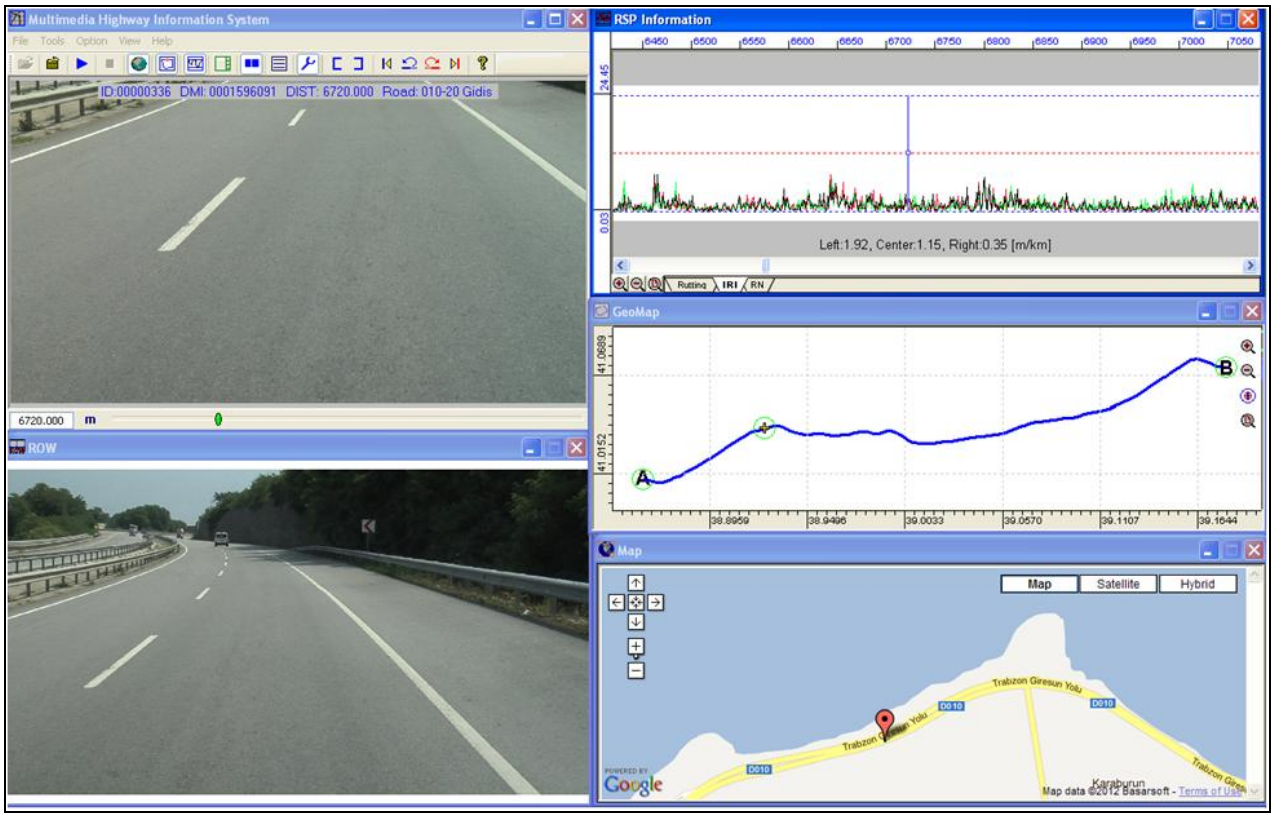


Figure 1. Example of Dynatest Explorer Software windows

The other program is 'Multimedia Highway Information System (MHIS)'. It was used to see inventory and surface images, and rougness value for 20 m length. Figure 2 shows MHIS Software's windows which contain IRI profile, global coordinate, and map. And also measurements were seen every 20 meters and stored in digital format General Directorate of Highways processed the data combined them into longer homogeneous segments and implemented them in the road data base module for the pavement management system.

Figure 2. Multimedia Highway Information System Software Windows



3.2 Obtained Roughness Results

The RSP was used to measure the roughness of asphalt pavement, which consist of 687,180 km a part of Türkiye highways network. It is called The East Black Sea Coast Road from Gülburnu to Sarp Border Gate.This road marked in Figure 3. These roads were measured with profilometer first time in 2008. Measurement are made priodically. Table 2 shows the roads information and traffic volume. Annaul average daily traffic (AADT) is given for 2010.

Figure 3. The East Black Sea Coast Road from Gülburnu to Sarp Border Gate

Tablo 2: 10 Th Division Roads information

Road No	Go (Up) km	Down km	Total	GPS - Direction Go Start/End			GPS - Direction Down Start/End			AADT Vehicle/ day 2010
				X Latitude	Y Longitude	Z Altit.	X Latitude	Y Longitude	Z Altit.	
010-19	72,640	72,584	145,224	40,957645/ 41,011482	38,114223/ 38,859509	1,12/ 5,03	41,011593/ 40,957859	38,860374/ 38,115685	5,63/ 1,44	14,37
010-20	30,120	30,131	60,251	41,011482/ 41,073051	38,85976/ 39,180744	4,65/ 7,93	41,073177/ 41,01157	39,18132/ 38,860615	7,47/ 5,54	7,935
010-21	57,413	57,442	114,855	41,073051/ 41,001961	39,18066/ 39,757416	12,15/ 1,33	41,002178/ 41,073185	39,757904/ 39,181129	2,02/ 11,39	11,13
010-22	55,894	55,990	111,884	41,001984/ 40,988712	39,75753/ 40,330498	3,13/ -1,14	40,98941/ 41,00211	40,330799/ 39,757336	(-5,75/ -0,8)	14,62
010-23	62,829	62,792	125,621	40,988941/ 41,188198	40,330696/ 40,960537	(-1,55 /1)	41,18848/ 40,989517	40,960823/ 40,33094	2,83/ (-2,43)	12,44
010-24	30,697	30,644	61,341	41,188274/ 41,331760	40,960598/ 41,258598	(-0,36/ 0,65)	41,333843/ 41,188599	41,256531/ 40,961117	1,95/ 3,43	5,902
010-25	34,140	34,242	68,382	41,333977/ 41,517002	41,256565/ 41,546272	0,61/ 33,96	41,517342/ 41,333977	41,545689/ 41,256607	9,26/ 0,99	6,987

IRI data were evaluated and grouped in six roughness level groups according to IRI levels which is shown in Table 1. The measured data analyzed with computer programs and roads were divided into homogeous groups. Table 3 shows the example of the 10 th Division Roads IRI evaluation and performance list.

Tablo 3: 10 th Division Roads IRI evaluation list.

No/ Total km	West - East Direction (Eynesil - Trabzon)		Performance / Order of Priority for M&R	East - West Direction (Trabzon- Eynesil)		Performance / Order of Priority for M&R
	IRI (m/km)	Distance and Note		IRI (m/km)	Distance (km) and Note	
010 - 20/ 30,12	1,94	0,000 – 0,460 = 0,460 km= 0+037 bridge	2	1,76	0,000- 0,360 = 0,360	3
	1,39	0,460 – 0,540 = 0,080	4	0,98	0,360- 0,840 = 0,480	5
	2,23	0,540- 0,660 = 0,120	1	1,7	0,840–1,000 = 0,160	3
	1,22	0,660 - 0,760 = 0,100	4	1,8	1,000-1,140 = 0,140	3
	1,76	0,760 - 0,860 = 0,100	3	1,25	1,140-1,740 = 0,600 km=1,257 tunnel	4
	3,56	0,860- 0,940 = 0,080 km= 0,890bridge	1	2,39	1,740-1,820 = 0,080	1
	1,19	0+940- 1+000=0,060 city passing	4	1,13	1,820-1,940 = 0,120	4

It is determined the performance and order of priority. Table 4 shows the example of performance and order of priority for maintenance & rehabilitation list for whole roads which were measured.

Table 4 : The example of performance and priority list

Road Number/ City	Road Name	Distance (km)	West - East Direction (Piraziz - Hopa Direction)		Performance / Order of Priority for M&R
			IRI	Section and Not	
010-22 Trabzon	(010 - 21) DYA (Değirmendere Köp) - (Trabzon - Rize) İl sn.	3,3	2,29	km = 13,000 – 16,300 Trabzon city passing	1
010-25 Artvin	(Rize-Artvin) il sn. - (Türkiye - Gürcistan) Devlet Sınırı	1,6	2,15	km = 18,760- 20,360	1
010-25 Artvin	(Rize-Artvin) il sn. - (Türkiye - Gürcistan) Devlet Sınırı	4,516	2,1	km = 20,360- 24,876	2
010-19 Giresun	(Ordu - Giresun) İl sn. - (877-01) DYA (Harşit Köprüsü)	1,7	2,08	km = 0,000- 1,700	2
010-19 Giresun	(Ordu - Giresun) İl sn. - (877-01) DYA (Harşit Köprüsü)	0,95	2,06	km = 55,245 – 56,195 Gülburnu city passing	2
010-21 Trabzon	(Giresun - Trabzon) il sn. - (010-22) DYA (Değirmendere Köp)	3,25	2,03	km = 40,100 -43,350 Akçaabat city passing	2
010-19 Giresun	(Ordu - Giresun) İl sn. - (877-01) DYA (Harşit Köprüsü)	2,9	1,99	km =62,398 – 65,298	2
010-19 Giresun	(Ordu - Giresun) İl sn. - (877-01) DYA (Harşit Köprüsü)	4,6	1,93	km= 32,493 – 37,093	2
010-22 Trabzon	(010 - 21) DYA (Değirmendere Köprüsü) - (Trabzon - Rize) İl sn.	4,1	1,82	km= 16,300- 17,700 Trabzon city passing	2

The East Black Sea Coast Road was measured in 2008, 2010 and 2011. The results of the measurement made in 2011 are shown in figure 4. It shows the percentage of each IRI levels for 10 th Division roads. It was found that 10 th Division asphalt pavements are in 0,02% 'Very Good', 16,82% 'Good', 50,45% 'Fair', 11,15% 'Mediocre', 9,99% 'Poor', and 11,57% 'Very Poor' roughness levels in 2011. 21,56% 'Poor' and 'Very Poor' levels pavement is in critical level and needs immediate improvement to restore serviceability.

Figure 5 shows IRI level distribution from 2008 to 2011. Some roads were maintained. The study showed that the roughness performance is not good from 2008 to 2011. The results of 2010 and 2011 IRI performans are almost same. While there is no critical section in the first measurement result, there are 21,88 % and 21,56% critical sections in the second and third results, respectively. 'Good' level is 9.0 % in 2008, it has increased from 9,0% to 15,24% and 16,82% in 2010 and 2011. On the other hand, mediocre and worse sections are 18% in 2008. It has increased from 18% to 32,61% and %32,71 in 2010 and 2011, respectively.

Maintenance activities carried out in 10 th Division Network were not enough to keep satisfactory performance conditions.

It is concluded that the study of roughness performance (Very Good,Good,Fair,mediocre,Poor,Very Poor) does provide an understanding of the performance of the road and can assist the management of the pavement. This result will help to take a decision about priority program and allocate funds for maintenance at both the present time and the future.

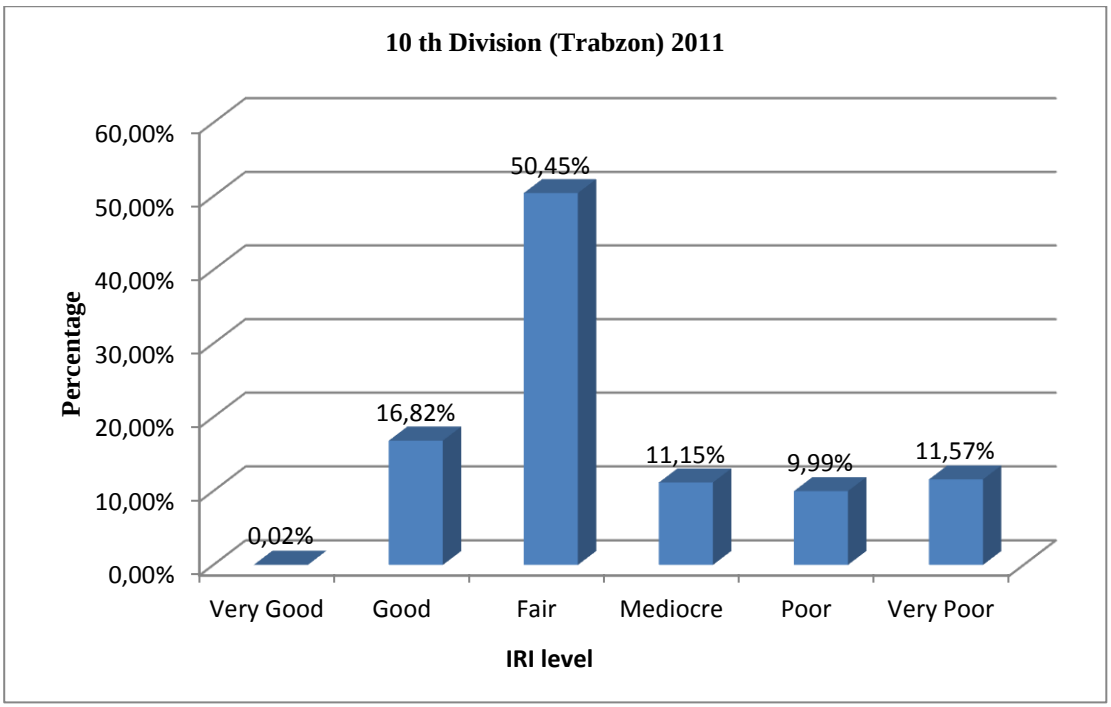
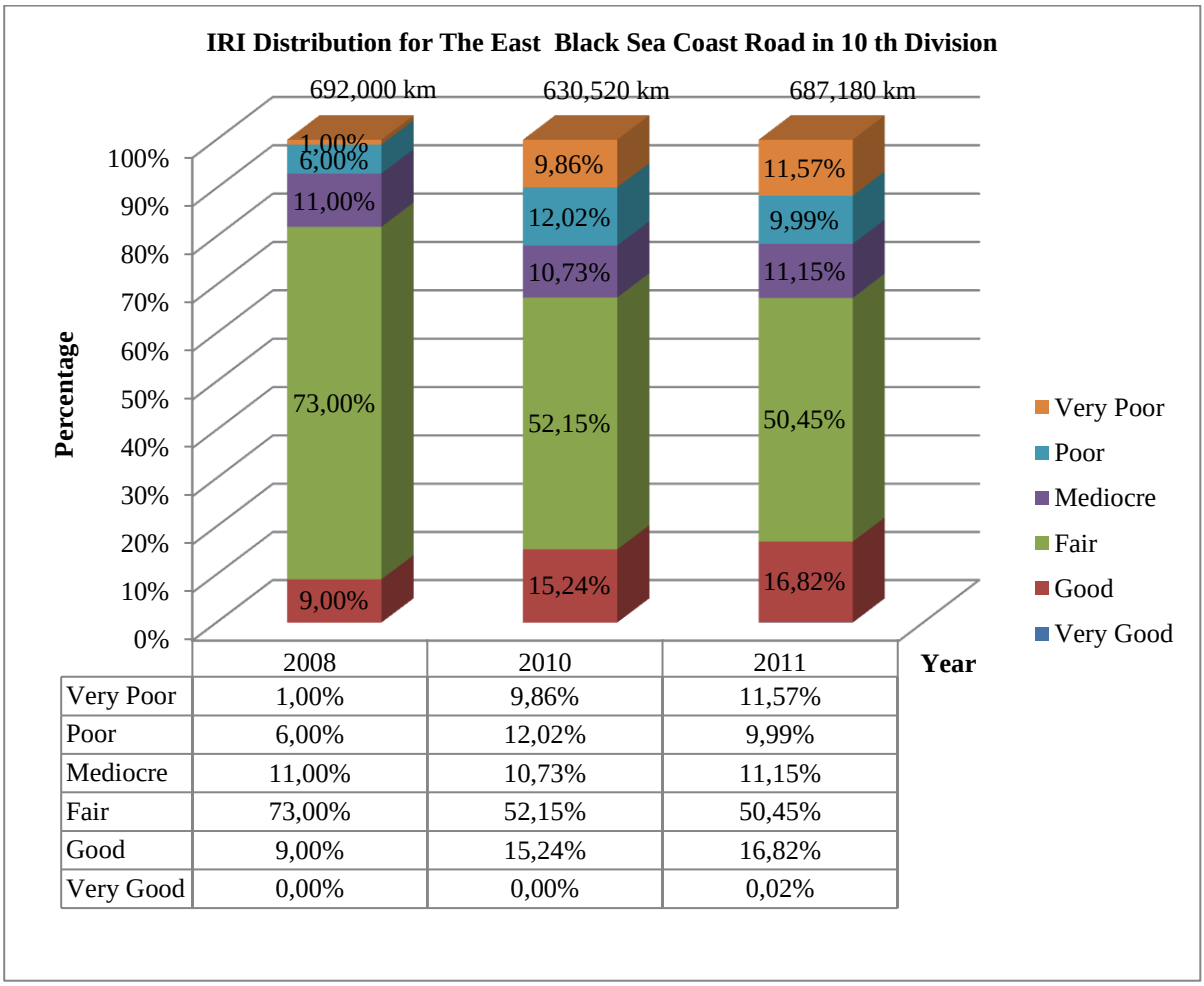


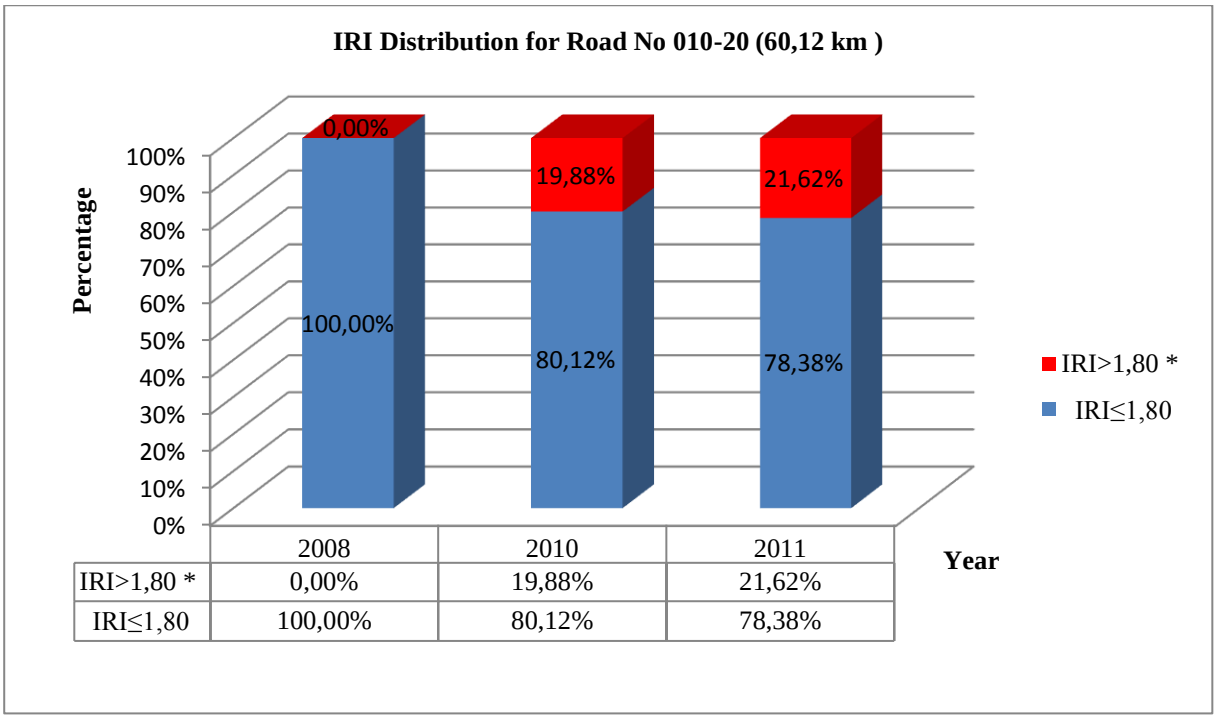
Figure 4 : Distribution of IRI level for 10 th Division (Trabzon) Highways.



	2008	2010	2011
Very Poor	1,00%	9,86%	11,57%
Poor	6,00%	12,02%	9,99%
Mediocre	11,00%	10,73%	11,15%
Fair	73,00%	52,15%	50,45%
Good	9,00%	15,24%	16,82%
Very Good	0,00%	0,00%	0,02%

Figure 5 : Distribution of IRI level from 2008 to 2011 for 10 th Division (Trabzon) Highways.

Roughness has changed over time. Seven different roads from 010-19 to 010-25 were analyzed and evaluated. All of them classified for 6 different IRI levels and critical section for each road was determined. Road No 010-20 is given as an example and shows two different roughness levels for different years from 2008 to 2011. The results show that there was no critical section in 2008. It has occurred after that year. This section immediately needs M&R to improve and preserve its condition .



	2008	2010	2011
IRI>1,80 *	0,00%	19,88%	21,62%
IRI≤1,80	100,00%	80,12%	78,38%

*IRI>1,80 *: 'Poor' and 'Very Poor' sections which is called critical section.

Figure 6: Roughness variations for Road No: 010-20

This road construction date is 2008. Road No: 010-20 has been measured periodically. These data will be used for performance models. One of the aim of this study is to collect roughness data. It is necessary to develop pavement performance models for 10th Division Roads and also PMS.

4. CONCLUSIONS

This investigation was undertaken to find the International Roughness Index of The East Black Sea Coast Road in 10 th Division Highways of Türkiye. Based on the findings of the performed roughness surveys, the following conclusions can be drawn:

Roughness level rates changed from 2008 to 2011. The results of 2010 and 2011 roughness performans are almost same. Mediocre and worse sections are approximately one third of roads measured in 2010 and 2011 .

In 2011, for the surveyed asphalt pavements, are in 16,84% 'Very Good' to 'Good' roughness levels, 61,60% are in 'Fair' to 'Mediocre' levels, 21,56% are in 'Poor' to 'Very Poor' levels. 21,56% critical section needs immediate improvement to restore serviceability. In other words, approximately one fifth of roads measured are in 'Poor' condition and 'Very Poor' which suggest that actions need to be taken to improve road conditions in 10 th Division. The current conditions of that highway network, if not improved, could have bad impact on Türkiye economy, endanger road safety and have environmental concerns.

Maintenance activities carried out were not enough to keep the present condition during the 4 years . The order of priority list for maintenance was prepared for measured 10 th Division asphalt pavement roads. These results were used to select the road sections that required further functional and structural performance indices .Information collected from road roughness measurements provides a basis for managing the maintenance of roads.

Pavement performance prediction models will be performed with roughness value collected for 10 th division. These are important input of PMS.

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