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THE USE OF SMART PHONES TO ESTIMATE ROAD ROUGHNESS: A CASE STUDY IN TURKEY

ABSTRACT

Previous studies have shown that road surface conditions are an important factor for road quality. To provide quality on road surface, it should be observed steadily and repaired as necessarily. There are many process to determine road surface condition. Using a smart phone to collect data is an alternative and simple application because of it's low cost, wider population coverage property and easy utilization. This paper explores the utilization of Roadroid, a simple android application, as a low cost vehicle-based solution for road surface condition monitoring with using sensors from smartphones. In the scope of this study, site experiments have been conducted to collect data using acceleration and GPS properties of a smartphone in a specific (passenger car) vehicle type. This method was evaluated with 3259 km urban and rural road data collected from the site experiments in Turkey, and it was seen from the results that average 84.4% of Turkish roads have good, 7.9% have satisfactory, 3.8 have unsatisfactory and 3.8% have poor road roughness conditions. It shows that approximately 4% of Turkish roads need maintenance urgently. Also experimental study results confirm that Roadroid have a great potential to evaluate road surface roughness condition correctly, even under obstacle like, potholes, manholes and decelerating marks.
Keywords: Road Surface Condition, Road Roughness, Smartphone Sensors, Mobile Sensing, Roadroid

1. INTRODUCTION

Road surface conditions are have key importance for the safety movement of vehicles. Road pavements are generally designed based on an estimated traffic carrying capacity throughout a determined service life [1 and 2]. After the pavement surface begins to its service life, various road surface deformations (such as potholes, broken edges, rutting, cracking, swelling etc.) occur due to road infrastructure, superstructure deficiencies and excessive heavy vehicle loads [2]. Deformations or poor surface conditions may have adversely affect the service ability of a road in relation with their position and size. Additionally, the deformations cause persistent problems especially in undeveloped and developing country roads due to low-cost road policy [3]. Also developed countries have road surface problems caused by climatic conditions, road work zones and excessive vehicle loads etc. Especially, municipalities all over the world spend big moneys to

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maintain and repair their roadways [4]. Therefore, monitoring road surface conditions has received a significant amount of attention by road authorities, planners and researchers [5]. In order to determine these mentioned poor surface conditions problem, many researchers have been working to monitor these deformations by using special devices (such laser road surface scanner, light detection and ranging, and mobile phones) and techniques (such as GPS devices and accelerometers in vehicles or cameras on roadside and near traffic signals) [4 and 13].

The IRI (International Roughness Index) is commonly used to measure the road roughness as an indicator to determine the pavement surface quality. Since its first introduction (1986), the IRI standard has become very famous indicator to evaluate and manage road surface pavement quality [14]. To measure IRI, many methods are used and most of them require sophisticated profilers and tools. These profilers and tools are too expensive to acquire and operate. Additionally, in economically weak countries visual measurements have also popular utilization. This method is a cheap option but it is usually very labor intensive and time consuming [14].

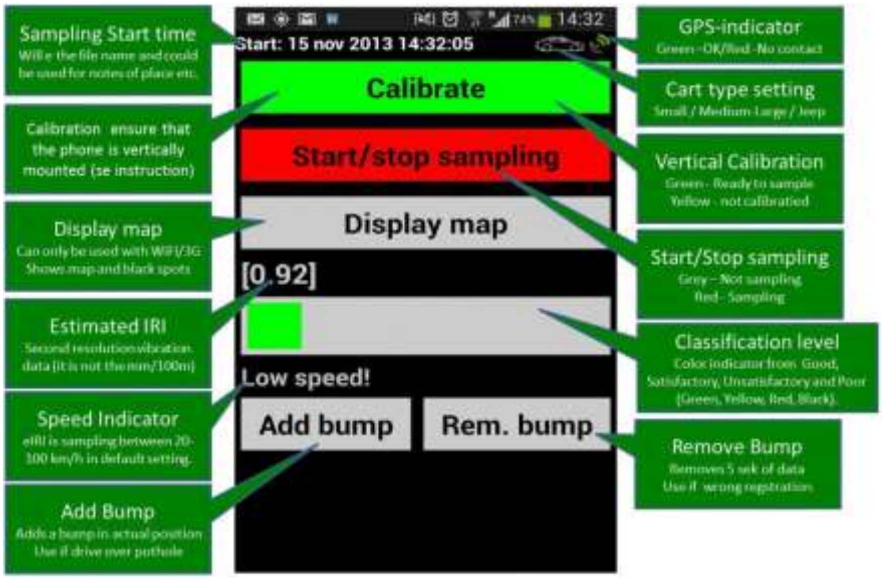
Nowadays, using smartphones for monitoring road surface quality data have a very popular utilization because of its low cost and easy implementation. Smart phones have many useful sensors inside of them. A 3D or 3-Axis accelerometer is one of the most important sensor in a smartphone [15]. An accelerometer can measure the acceleration in m/s2 along each axes (x, y and z). For this reason, smartphones are generally used to determine motion activities. In literature, there some studies about utilization of smartphones' accelerometer property to detect road bumps and anomalies [4, 5, 10 and 16]. But smartphones are generally used with developed road roughness measurement applications especially classifying roughness condition of road section by using simple techniques. In literature, there are some applications that can measure the road roughness such as Nericell [5], TrafficSense [17], Roadroid [18] etc.

2. RESEARCH SIGNIFICANCE

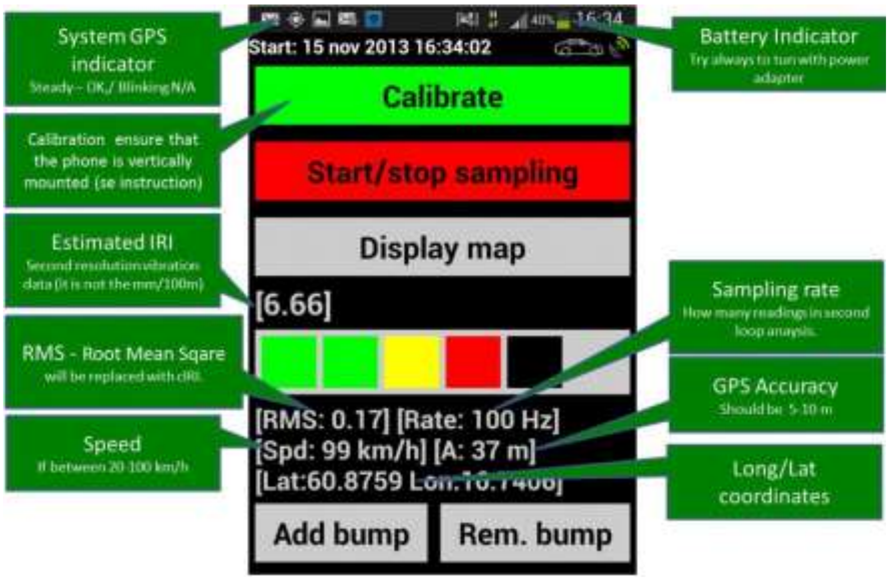
Unfortunately, road authorities in Turkey have a not a common method to observe road surface quality. They generally choose expensive methods to observe surface quality of Turkish urban and rural roads. Whereas, many urban and rural roads' surface qualities can be measured easily and very cheaply with the help of smartphone applications. For this purpose in this study first time, a road roughness smartphone application was used to determine road roughness property of Turkish roads. With this method, one of the famous road roughness measurement application, Roadroid, was used to evaluate the current situation of Turkish roads and performance of smartphone application on road roughness measurement.

3. EXPERIMENTAL METHOD-PROCESS

Roadroid is a Swedish innovation smartphone application and it was developed by Roadroid Company. It measures road roughness by using the accelerometer and Global Positioning System (GPS) property of the smartphones [19]. It supports different vehicle types, car speeds and phone models. In the field trials and calibration process of the application, over 10 million sample data were collected globally. Roadroid also uses Android programming and global mapping service inside. It is continuously developed and new versions were released by the developer company. Basically, Roadroid application analyze the vibration data and estimate an International Road Index (eIRI) value (m/km) by considering current speed, vehicle type and used smartphone model (Figure 1). The correlation of the application was originally developed towards Swedish IRI measurements by using laser beam [18 and 20].



(a)



(b)

Figure 1. A General overview to roadroid application [21]

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Roadroid has easy usable, user friendly and cost efficient probability to measure road roughness in different road, vehicle, width, speed, weather and smartphone conditions. It can be used almost anywhere - where heavy and expensive equipment cannot be used. Data collection cost of the method only depends on fuel consumption and vehicle maintenance cost of the used test vehicle per kilometer. For this reason, it supplies easy and cheap road surface data collection for the examined roads. Application has not a limit values for road width. It only evaluates the current lane of the used vehicle. Thus researchers can collect road surface property data both urban and rural roads easily and quickly. Roadroid saves IRI values with longitudinal and lateral positions, altitude and vehicle speed each second, and obtained data is presented on an internet GIS tool. User can extract data with 100 meter section. Also in the process of data extraction roughness data, vertical road profile and vehicle speed can be mapped. Obtained results of the system have shown that the correlation of the estimated IRI (eIRI) towards laser beam measured IRI is about 70-80% depending on road surface types [21]. The accuracy of the system can be increased with some tuning and the IRI sampling is currently developed with a calculated IRI (cIRI) to enhance the correlation factor. Roadroid application also use the camera property of the smartphones. It can take GPS tagged photos from the site in the data collection process and it can be transferred to the map tool of the system (Figure 2).

(a) (b)

Figure 2. Site observation photos from Turkish roads taken by the roadroid application.

This application is mainly supports early warning system to road user and road maintenance authorities. For example, in winter season daily road surface data can be shared by the grader operations and grader operators can make a plan to clean roads. Also in winter and spring seasons, roads are deformed easily caused by the frost heave effect. Road users or road maintenance authorities can monitor the roughness of the roads day by day. Then they can clearly see when and where the problem occurs on road surfaces.

4. SITE OBSERVATION AND DATA COLLECTION

In this study, Researchers from Akdeniz and Manisa Celal Bayar Universities have worked as Turkey Partner of Roadroid Company. In the site observations a Samsung Galaxy S2 smartphone (supplied by Roadroid Co.) with Roadroid Classic Application has been used to observe and measure road roughness (Figure 3). For this purpose, only passenger car vehicle type is used in data collection process and vehicles speeds were chosen between 0-100km/hr. But Roadroid application can only calculate eIRI (m/km) when driving speed of experiment vehicle is 20km/h or faster [21]. For this reason, some data were not obtained because of the low speed (because of the interrupted traffic flow effects such intersection effect, high traffic volume effect, signal effect etc.).

(a) (b)

Figure 3. Used Galaxy S2 smartphone with roadroid road roughness measurement application

To make a site observation, firstly system should be installed according to given flowchart as given below (Figure 4).

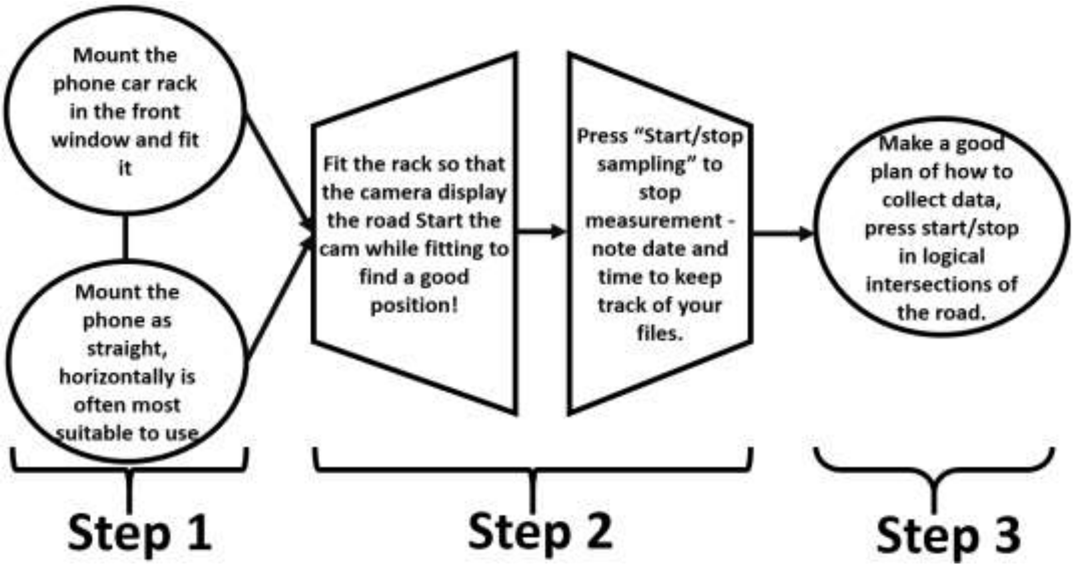

Figure 4. Installation of roadroid system into the car

Measurements were conducted in different urban and rural roads of 18 various cities in Turkey (Table 1). It means approximately 22% (18 cities) city roads of (81 cities) total cities were used as example for the analysis. All research data were collected between 2014-2017 years and shared with Roadroid Co. as Turkey Partner. Total 3259 km urban and rural roads were observed during this period. From the previous studies, it was found that different road surface conditions cause vehicles to vibrate differently [15]. For this reason in this study, placing smartphones that come with acceleration sensors, the variation of the vibration is believed to be captured as become Douangphachanh and Oneyama [15]'s study. Then drivers drove the vehicles with normal driving conditions along many roads that have different surface and traffic conditions.

Table 1. Observed Cities of Turkish Roads

No	City Name/ (Plate Number)	Examined Road Length (Km)	Pavement Type
1	Ankara (06)	134.6	Hot Mix Asphalt
2	Afyonkarahisar (03)	120.6	Hot Mix Asphalt
3	Amasya (05)	92.1	Hot Mix Asphalt
4	Antalya (07)	702.6	Hot Mix Asphalt
		75.5	Bituminous Surface Treatment
5	Artvin (08)	28.9	Hot Mix Asphalt
		113.5	Bituminous Surface Treatment
6	Burdur (15)	27.1	Hot Mix Asphalt
		132,7	Bituminous Surface Treatment
7	Bursa (16)	84.2	Hot Mix Asphalt
8	Çorum (19)	78.1	Hot Mix Asphalt
9	Erzurum (25)	67.1	Hot Mix Asphalt
		12.9	Bituminous Surface Treatment
10	Eskişehir (26)	41.3	Hot Mix Asphalt
11	Gümüşhane (29)	121.2	Hot Mix Asphalt
		32.3	Bituminous Surface Treatment
12	Isparta (32)	180.1	Hot Mix Asphalt
		42.5	Bituminous Surface Treatment
13	Kütahya (43)	163.7	Hot Mix Asphalt
		21.1	Bituminous Surface Treatment
14	Rize (53)	86.6	Hot Mix Asphalt
15	Samsun (55)	97.9	Hot Mix Asphalt
		18.2	Bituminous Surface Treatment
16	Trabzon (61)	58.6	Hot Mix Asphalt
17	Bayburt (69)	43.7	Hot Mix Asphalt
18	Kırıkkale (71)	63.6	Hot Mix Asphalt
		12.1	Bituminous Surface Treatment
	Σ	2652.8Km	

After the site observations, data were uploaded to Roadroid website and all collected data were obtained from the Roadroid website data import system as shown in Figure 5.

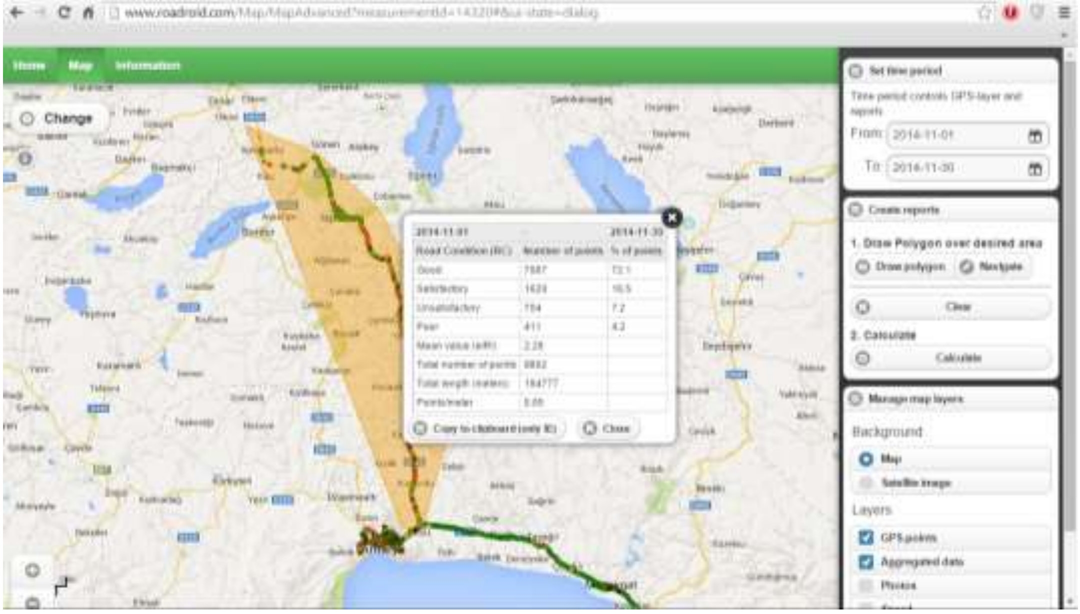

Figure 5. Data obtaining from the roadroid website

After obtaining data from the Roadroid website, all data were extracted to the excel spreadsheets. Then all spreadsheets are carefully controlled to determine estimated International Road Index (eIRI) data. All data were obtained from the system by selecting the aggregation lengths (meters) as 100 meters. It was seen from the data extraction process that sections with incomplete data set are the sections that have no data from Roadroid. Because, Roadroid cannot calculate an eIRI value (m/km) when vehicle speed<20km/hr as mentioned previously.

5. FINDINGS AND DISCUSSIONS

In this study, during the observation period total 3259 km different urban and rural roads of Turkish cities were measured by using Roadroid road roughness measurement application (Figure 6).

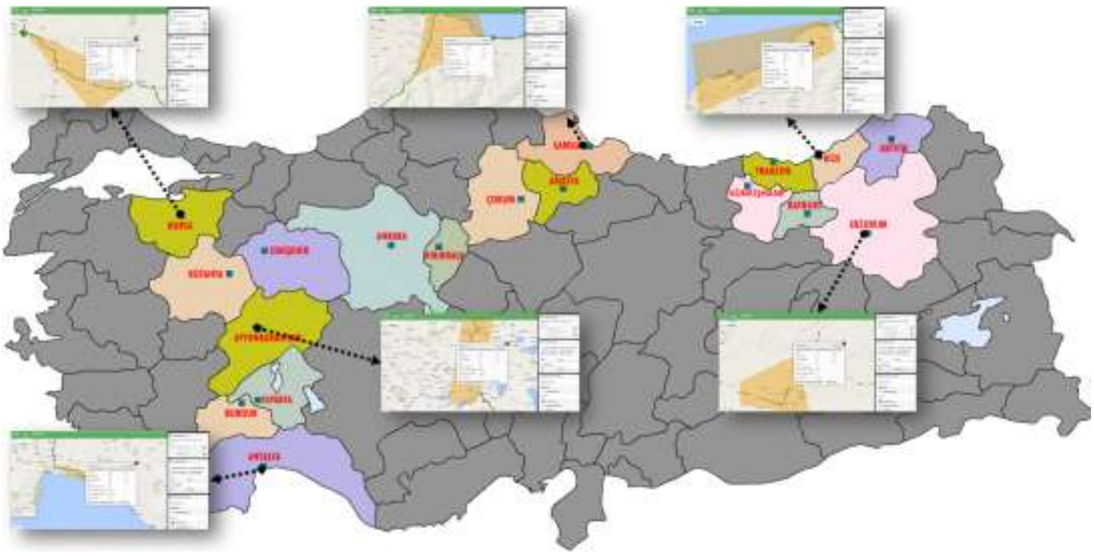
Figure 6. Example data analysis from different cities of Turkey

All obtained results for these 18 city roads are given in Table 2. As can be seen from the Table 2, Eskişehir has the highest and Burdur has the lowest road roughness properties. According to analysis results, five cities' (Eskişehir, Isparta, Bursa, Çorum and Samsun cities, respectively) good road roughness properties are above 90%. On the other hand, two cities' (Burdur and Artvin) good road roughness properties are below 70%. It can be concluded that Burdur and Artvin roads need maintenance earlier than the other 16 cities. Also according to general results, average 84.4% of Turkish roads have good, 7.9% satisfactory, 3.8 unsatisfactory and 3.8% poor road roughness conditions. It shows that approximately 4% of Turkish roads need maintenance urgently. eIRI values obtained from the analysis provides a reasonable assessment of the pavement condition, which can provide useful inputs for pavement maintenance decision making. According to site observation and analysis results, it can be concluded that eIRI is estimated for the gravel roads which have very poor surface conditions. From the literature, it can be seen that the minimum acceptable IRI values vary in different countries [22]. It effected by the maintenance type and plan, road type and budgetary of road maintenance authorities. For example, an acceptable IRI threshold value would be 2 due to higher operating speeds expected. FHWA criteria acceptable for arterial roads is about 3.5 [23]. However this value can be changed for low volume roads with lower operating speeds. Typically, for low volume roads, pavement with IRI in the range of 6-10 is considered to be in moderate/poor condition [23]. Once these threshold values are established by the road authorities, they first select the roads that violate the threshold and then prioritize the roads for maintenance works for those roads based on the condition and the maintenance treatment plan.

Table 2. Analysis of road roughness of various cities in Turkey

No	City Name (Plate Number)	Good		Satisfactory		Unsatisfactory		Poor		Mean Value (eIRI) (m/km)	Total Number of Points
		Point Number	Percentage (%)	Point Number	Percentage (%)	Point Number	Percentage (%)	Point Number	Percentage (%)		
1	Ankara (06)	6342	88.8	460	6.4	187	2.6	153	2.1	1.84	7142
2	Afyonkarahisar (03)	5657	89.2	367	5.8	120	1.9	198	3.1	1.92	6342
3	Amasya (05)	4169	85.6	430	8.8	153	3.1	121	2.5	1.94	4873
4	Antalya (07)	33417	81.2	3815	9.3	1837	4.5	2109	5.1	2.30	41178
5	Artvin (08)	5250	69.9	759	10.1	392	5.2	1109	14.8	3.04	7510
6	Burdur (15)	5285	62.5	1742	20.6	788	9.3	637	7.5	2.92	8452
7	Bursa (16)	4208	94.9	94	2.1	59	1.3	72	1.6	1.17	4433
8	Çorum (19)	3824	92.7	223	5.4	37	0.9	41	1.0	1.42	4125
9	Erzurum (25)	3241	83.2	308	7.9	199	5.1	148	3.8	2.19	3895
10	Eskişehir (26)	2149	98.1	25	1.1	11	0.5	5	0.2	1.38	2190
11	Gümüşhane 29)	11353	76.0	1864	12.5	767	5.1	947	6.3	2.57	14931
12	Isparta(32)	11435	95.1	356	3.0	154	1.3	84	0.7	1.48	12029
13	Kütahya (43)	7067	72.1	1620	16.5	704	7.2	411	4.2	2.28	9802
14	Rize (53)	3964	86.3	294	6.4	179	3.9	156	3.4	1.95	4593
15	Samsun (55)	5023	90.6	172	3.1	143	2.6	207	3.7	1.70	5545
16	Trabzon (61)	2493	80.2	290	9.3	203	6.5	123	4.0	1.95	3109
17	Bayburt (69)	2050	88.3	156	6.7	71	3.1	45	1.9	1.80	2322
18	Kırıkkale (71)	3088	84.8	288	7.9	157	4.3	109	3.0	2.01	3642
Average (μ)		6667	84.4	737	7.9	342	3.8	371	3.8	1.99	8117

6. CONCLUSION AND RECOMMENDATIONS

Previous studies have shown that road surface conditions are an important factor for road quality, and smooth roads will provide more comfortable and more safety driving experience. To provide quality on road surface, it should be observed steadily and repaired as necessary. There are many process to determine road surface condition which usually requires high costs and skillful operators such as visual inspection and instrumented vehicles that can take physical measurements of the road surface deformations. To estimate road roughness, Android OS based smart phones that has a mobile sensing system can be used for road surface condition detection. Using a smart phone to collect data is an alternative and simple application because of its low cost, wider population coverage property and easy utilization. This paper explores the use of Roadroid, one of the famous road roughness measurement smartphone applications, as a low cost vehicle-based solution for road surface condition monitoring with using sensors from smartphones. In the scope of this study site experiments have been conducted to collect data using acceleration and GPS properties of a smartphone in a specific (passenger car) vehicle type. The application is used on 18 different cities and total 3259 km urban and rural roads data in Turkey, and it was seen from the results that average 84.4% of Turkish roads have good, 7.9% satisfactory, 3.8 unsatisfactory and 3.8% poor road roughness conditions. It shows that approximately 4% of Turkish roads need maintenance urgently. Also experimental study results confirm that Roadroid have a great potential to evaluate road surface roughness condition correctly, even under obstacle like, potholes, manholes and decelerating marks. Mainly, this study was a pilot study to see Roadroid application's performance on Turkish roads. For this reason, it is applied only 18 city and total 3259 km roads in Turkey. In this study, urban and rural roads are evaluated with together because of the limited urban road data. Therefore, in future studies, total 81 city roads should be examined and data should be evaluated for urban and rural separately.

NOTICE

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