Abdelsalam Yousef Shtayat. International Journal of Engineering Research and Applications
www.ijera.com
ISSN: 2248-9622, Vol. 11, Issue 5, (Series-III) May 2021, pp. 01-06

RESEARCH ARTICLE OPEN ACCESS

An Alternative Pavement Evaluation System in Jordan

*Abdelsalam Yousef Shtayat
Assistant mayor of Great Irbid Municipality, Ministry of Local Administration, Jordan

ABSTRACT
The pavement management system plays a significant role in maintaining the road networks in high performance and excellent conditions to provide high-quality service for users. Pavement monitoring is the main key of the pavement management system; it is also the first step to evaluate the health status of road surfaces. Besides, many investments have been made by transport agencies and governments to develop monitoring techniques to get accurate evaluation results of road surfaces. Furthermore, there are highly competitive among the universal companies to find the most accurate monitoring techniques to be used in the future of pavement management system. On the other hand, economic hardship is a significant factor affecting developing countries' ability to participate in pavement management revolution. Therefore, most developing courtiers like Jordan have some limitations in using and applying high slandered monitoring techniques to evaluate the road surfaces condition. In this study, a cost-effective monitoring technique using a smartphone application was used to monitor the pavement condition in Jordan. The results showed that this monitoring technique is able to be applied by governments instead of the existing inspection technique.

Date of Submission: 01-05-2021 Date of Acceptance: 15-05-2021

I. INTRODUCTION

Nowadays, governments and transport agencies focus on infrastructure engineering, especially on pavement management systems and equipment used to evaluate the performance of pavement health status. Many efforts have been implemented to study the sustainability of road networks and pavement surfaces. Besides, developed countries passed all challenges and obstacles in the field of research to understand the behaviour of pavement condition during a time and how to keep up the pavement in acceptable standard condition during the service life of paved and unpaved roads. Therefore, most of these countries' investments go to the research field to enhance the performance of pavement and the whole infrastructure sector. On the other hand, most developing countries still have a shortage in adjustment with new inventions in the pavement management field due to several factors, including the availability of equipment, economic status, financial hardship, and standard and principle of design. These factors directly affect these countries' ability to keep up with new techniques related to infrastructure engineering.

The pavement management system focuses on five main approaches: monitoring, evaluating, planning, estimating, and maintaining pavement health status, respectively. Between monitoring the pavement condition to maintain the pavement damages, several steps are to be performed to satisfy accurate pavement performance assessment. Also, maintenance levels depend mainly on the accuracy of pavement monitoring results. More clearly, transport agencies always want to determine accurate reasons and causes of pavement degradations in order to select appropriate maintenance and treatment actions. Besides, accurate monitoring of the pavement condition minimises the maintenance costs and time consumed by identifying the type, severity and quantity of surface anomalies. Many studies have been conducted on pavement monitoring using different devices and equipment such as laser, visual inspection, profilometer, pavement condition indices, and vibration data.

On the other hand, in most developing countries, limited numbers of studies have been performed on pavement management system due to various factors such as scarcity of capabilities and financial hardship. Therefore, most pavement monitoring works can be done manually by the walk and look method. This method is a traditional evaluation method used to capturing in-person pavement damages and anomalies along specific road segments. Besides, this monitoring method is still used in Jordan for medium, and low ranked unpaved and paved roads. While, for a high ranked road like a highway, a profilometer is used to evaluate the level of riding comfort by measuring the degree of surface roughness. The mentioned methods can indicate pavement surface condition;

however, the real health status and severity of distress still need to be evaluated accurately.

Therefore, the need for a simple, accurate, and cost-effective monitor technique becomes necessary to be used by governments in developing countries to save time and money. The main objectives of this study are to present a new monitoring technique using available and cheap equipment to monitor and evaluate road pavement condition in different local roads in Jordan. Besides, this study focuses on using a smartphone application to measure vibration during vehicle movement. These vibrations represent the level of comfort for roadway users and the quality and quantity of surface damages [1].

The upcoming section focuses on the literature review around the road pavement vibrations and general monitoring techniques. Then, the data, methodology, and location of this study will be explained. It is followed by explaining the results of data analysis. Finally, the section describes the discussion and conclusion of the results.

II. LITERATURE REVIEW

Monitoring the pavement condition is a key to comfort riding, less maintenance cost, and high-quality road networks. Also, it is the first step of the pavement management system. The pavement management system considers monitoring the pavement condition is a significant process to use appropriate maintenance and treatment process on pavement surfaces. Therefore, due to the importance of the monitoring process, many researchers focused on using different monitoring methods to get the most accurate pavement condition results. Besides, many studies have been conducted to evaluate the performance of paved roads and identify the type and severity of road surface defects.

In developed countries, different monitoring devices are used to assess pavement condition. Selecting an appropriate monitoring device depends mainly on the type of monitoring, including dynamic and static monitoring techniques [2]. Accelerometer sensor [3][4], smartphone [5], laser [6][7], profilometer [8], and image acquisition system [9][10] are used in dynamic monitoring system due to the need for movement with equipped vehicles on road segments. While, in the static monitoring system, penetrated device such as ground-penetrating radar GPR [11][12], penetrated geophone sensors and strain gage [13] are used to measure the deflection and condition of pavement at a specific point on a road surface.

Chang et al. [14] used a 3D laser scanning technology to determine various types of pavement distresses such as potholes, patches, and cracks. Their laser technology scanned a road segment, then an auto feature extraction process was applied by using a grid approach system to identify specific distress features. Besides, laser technology provided high accurate monitoring of the pavement condition. This technique can be used in all pavement types, including flexible pavement, rigid pavement, and combined pavement. Barbarella et al. [15] used a terrestrial laser scanner to monitor the health status of rigid airport pavement. This technique used rectangular strips to be evaluated separately using the laser technique. Also, for each strip, this methodology used to detect faulting and computation on the rigid joint pavement. Another monitoring technique depends mainly on image acquisition and processing system to detect the type, severity and quantity of pavement anomalies. A video camera system is also used as a monitoring device it can be mounted on an equipped vehicle to record the pavement condition during vehicle movement [2]. Mahler et al. [16] applied an image processing technique to evaluate pavement degradation due to cracking. They used an acquisition system named Automatic Crack Monitor (ACM) to determine the direction and dimension of individual cracks.

Pavement vibration is the new technique used to evaluate the pavement condition depending on the vibration of vehicle chassis during movement. Moreover, high vibrations during movements on pavement surface lead to less comfortable riding. Therefore, high severities and quantities of pavement distress cause high vibrations and inconvenience riding. Hence, researchers focused on using pavement vibrations as an indicator of pavement health status [5]. Pavement vibration data can be conducted using accelerometer seniors or mobile phone application. The accuracy of vibration data depends mainly on some factors such as speed, traffic condition, environmental condition, and vehicle type. Chen et al. [3] used an accelerometer sensor, private vehicle, and GPS sensors to monitor and evaluate the pavement condition. A comparison was also made between the data conducted and international roughness index IRI data.

Another study by Chih-Wei et al. [17] focused on evaluating the pavement condition using a smartphone probe car. This system was used to monitor only two high severity pavement distresses, including potholes and bumps. Amir et al. [1] used a smartphone application named Sensor Log to measure pavement vibration data for local roads in Melbourne. They found that the smartphone application provided high-quality monitoring results and clear information of the real pavement performance. They also recommended that transport

agencies can use vibration data to decide on appropriate maintenance actions. Also, how to keep the pavement in excellent condition during service life [18]. This study focused on using a smartphone application and passenger car to evaluate the pavement condition in a rural road in Jordan. It also focused on presenting the efficiency of this monitoring technique in road pavement projects instead of the transitional walk and look technique used in Jordan that depends on an approximate evaluation of the pavement condition.

The traditional inspection technique "walk and look" is also used for a long time, and it is still a good method to collect pavement condition information, it is common in most developing countries. Furthermore, visual inspection data provides an approximate idea of pavement health status. Pavement condition indices are used to evaluate the performance of pavement surfaces. These indices, including pavement condition index PCI, international roughness index IRI, and present serviceability index PSI, depend mainly on visual inspection and inspectors' experience. The advantages of using the pavement condition indices are cost-effective, simple, and can be done in different road classifications [4].

There are significant factors that need to be considered during the pavement monitoring process. These factors affect the accuracy of monitoring results, including traffic volume, traffic loads, weather condition, quality of pavement materials, travel speed, age of pavement, and the accuracy of monitoring equipment [1][2]. In dynamic pavement monitoring, the type of test vehicle is an important factor to get accurate monitoring results. According to Nizar et al. [18], travel speed, road classification, and traffic load are the most effective factors in a pavement evaluation system. Most of the past studies have focused on using expensive and complex equipment to monitor high ranked roads such as arterial, highway, freeway roads. On the other hand, limited numbers of studies have focused on local or unpaved roads to be monitored. This research focused on monitoring the pavement condition of local roads in Jordan. Also, available, cheap, and simple monitoring equipment, including a smartphone application and a passenger vehicle, was used to monitor the pavement health states. Besides, the most benefit of using this method is to measure the possibility if adopting the smartphone application and vibration results in monitoring the pavement. The accuracy of vibration data can be taken into consideration by Ministry of Local Administration and Ministry of Public Works and Housing to be applied in pavement maintenance projects in Jordan.

The pavement management system in most developing counties is still not activated as it should be. There are no routine inspection or frequents monitoring the pavement condition or even gravel road condition. The governments depend mainly on citizens' complaints to start any monitoring and maintenance project. Therefore, there are no clear procedures to be followed to keep the pavement in excellent health status. Besides, visual inspection is still the main way to estimate the severity of damage and appropriate treatments. Hence, the need for a simple and accurate monitoring system becomes necessary to help governments start doing frequent monitoring of the pavement condition using my cost-effective method to save time and effort [19].

III. METHODOLOGY

Monitoring the pavement condition is a significant process that guarantees pavement sustainability and its ability to provide a service for roadway users. In this study, all information about the case study area and methodology of data collection are covered in this section. Jordan is one of the countries that care about infrastructure and how it can be sustainable. Therefore, many Jordanian researchers offer their expertise to develop the infrastructure system in Jordan and improve road pavement networks' performance. Many studies based on smart technologies have been put forward to assess the state of road pavement [20].

However, the scarcity of capabilities and financial hardship have prevented them from being implemented on the ground. Thus, the use of traditional evaluation methods is still the solution to monitor the pavement.

In Jordan, the main responsible for maintaining roads and pavements are local municipalities and public works and housing. Therefore, pavement monitoring and maintenance projects can be performed according to specific bidding systems that construction companies use to perform bids. While, in some minor road maintenance projects like patching, municipalities usually perform these types of works using cold mix asphalt.

Figure 1 shows the site location of the study at Aqraba-Hartha Street, Irbid, Jordan. This street is located in Bani-Kinana suburb which is located in far North of Irbid city. This local street is two-way with two lane. The speed limit for the vehicles is 60 Km/hr. The traffic volume is the selected site location is considered to be light. Besides, the condition of pavement in the selected street indicates that there are some types of pavement distresses such as patching, rutting, cracking, and potholes see Figure 2.

Fig. 1 The site location.

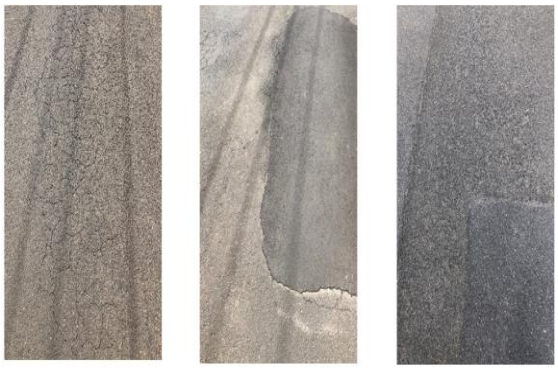

Fig. 2 Sample of pavement distresses on the selected road surface

Figure 3 below also shows the set-up of the monitoring devices, including the smartphone, on a passenger car. The smartphone is used to monitor the pavement condition according to acceleration data representing the vertical vibration during vehicle movement. The mobile phone type iPhone 8 was mounted on the floorboard to measure the vibration of vehicle chasses. A passenger car type Toyota highlander 2010 was also used as a test vehicle to move on pavement surface with a minimum speed of 10 km/hr. This vehicle is hybrid, so at this 10 km/hr speed, there is no engine noise or any other body noises due to the electricity mode of moving. Thus, the speed provides a pure pavement vibration to be recorded by the smartphone application. Moreover, Figure 2 shows samples of pavement distresses along the road segment.

Fig. 3 The sit-up of the smartphone

IV. RESULTS

Acceleration data is an indication of the comfort riding and safety of users during their movements. The high vibration values mean discomfort riding and more risk riding. Figure 3 below shows the acceleration data along the road length measured by a smartphone application. The smartphone was used to record the vibration during vehicle movement and then locate the spots with high vibrations. The following figure shows the vehicle body vibration along the selected road segment.

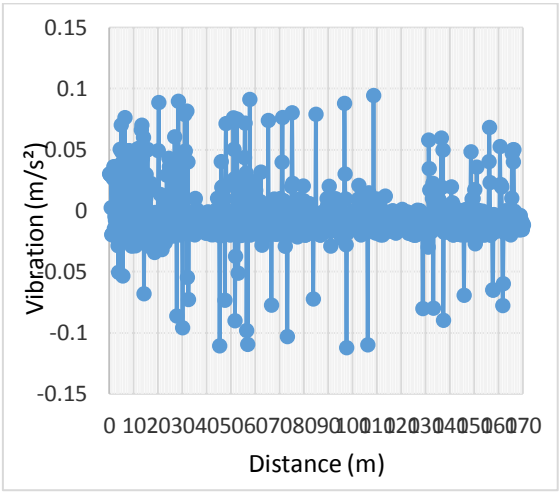

Fig. 4 Pavement vibration data along the Hartha-Aqraba road segment.

In this study, 170 meters of the selected road was monitored and evaluated using a mobile phone application mounted on the floorboard of a passenger car; the test speed was 10 km/hr to detect the vibration carefully without any rush or noise from other ongoing traffic. These low speed can easily let the driver drive over the distresses to identify the start and end point of each distress and identify the length of distresses.

According to Figure 4, there are significant fluctuations in vertical acceleration data at specific locations along the road segment. These fluctuations in acceleration data represent the type and severity of the surface distresses. More clearly, high spikes values indicate high severity of pavement anomalies and also less comfort riding. According to the visual inspection, the location, type and severity of these pavement distresses matched with locations and values of vertical acceleration spikes. Besides, the high spike values indicated that there was alligator cracking, rutting and potholes with an absolute vibration range of more than (0.055 m/s²). In comparison, medium (0.03 m/s²) and low severity range less than (0.02 m/s²) of vibration values indicated that there were low to medium severities of distresses such as edge cracking, longitudinal cracking and ravelling. According to Figure 4, the maximum acceleration value was (0.09415 m/s²), and the minimum acceleration value was (-0.1122 m/s²).

As mentioned previously, a visual inspection was performed to inspect and monitor the pavement condition. This inspection aimed to identify each pavement distress's type and severity to find appropriate maintenance. The pavement condition rating form evaluates the pavement in terms of type and severity of pavement damages. Although this monitoring technique provided an accurate evaluation of the pavement condition, monitoring long streets or road networks may take too much time to be done. In addition, visual inspection needs experts to implement the monitoring and deciding appropriate treatments. Moreover, it is pretty hard for municipalities in Jordan to providing staffing and experts to evaluate roads periodically (monthly, quarterly, and annually).

Therefore, in this study, monitoring the pavement condition using a smartphone application provided a clear indication of pavement health status with very short time and accurate data. Also, according to the pavement vibration data, engineers and technician people can identify the exact severity of pavement distresses to apply appropriate maintenance. The total time needed to complete monitoring the pavement condition of the selected road segment was about 60 seconds, taking into account the selected text speed at 10km/hr. While for the same 170 meters of the road segments, walking speed about 1.4 m/s and without counting the time taken to stop at each distress, the time needed to complete inspection was about 121 seconds.

That mean using smart techniques can help governments to save time and money and get highly accurate results. However, some factors affect the accuracy of using both techniques. Traffic condition, weather condition, vehicle type, and speed are the main factors that affect data accuracy. While in visual inspection, weather condition, traffic condition, and experience of the inspector are also factors that affect pavement evaluation outcomes.

V. CONCLUSION AND RECOMMENDATIONS

Pavement vibration data has become one of the most accurate monitoring techniques. Many studies have been conducted using the vertical acceleration data as an indication of pavement condition. Different types of sensors used to measure vibration data during vehicle movement. However, in developing countries, pavement monitoring techniques still away from any advanced or intelligent technologies. Ministry of local administration and Ministry of public works and housing are responsible for managing and maintaining road pavements. Monitoring and evaluation techniques are still basic and depend primarily on the experience of the responsible engineer in evaluating the condition of the pavement and proposing appropriate solutions to treat diseases. In addition, there are no periodic tracking, and real monitoring systems for the pavement condition as citizens' complaints about some distress spots primarily rely on ministries' works to be treated.

Hence, this study tried to provide a significant solution for ministries to focus on pavement management system and maintain the pavement condition in very good condition during service life. The pavement vibration monitoring technique can help governments save time and money by using very simple, accurate, available, and cheap monitoring techniques to evaluate the pavement condition performance. According to the results, the vibration data provided enough information on the type severity and quantity of pavement distresses. Hence, this information can help engineers decide the capable and appropriate maintenance action quickly. As well, this technique can be performed frequently to keep the pavement free of damages. This study recommended using another smartphone with a camera to record a video during vehicle movement. From video recordings, engineers can match the vibration data and video to determine each pavement degradation's exact location and type. This video can also enhance the monitoring results and get more accurate evaluation data. Furthermore, other vehicle modes like motorcycle or bicycle can be used to evaluate the condition of roadway shoulders or sidewalk and provide significant data of the condition of the road elements.

REFERENCES

[1]. Shtayat, A., Moridpour, S., Best, B., Shroff, A. and Raol, D., Dynamic Monitoring of Asphalt Pavement Using Mobile Application. In *26th World Road CongressWorld Road Association (PIARC), 2019*.

[2]. Shtayat, A., Moridpour, S., Best, B., Shroff, A. and Raol, D., A review of monitoring systems of pavement condition in paved and unpaved roads. *Journal of Traffic and Transportation Engineering (English Edition), 2020*.

[3]. Chen, K., Lu, M., Fan, X., Wei, M. and Wu, J., 2011, August. Road condition monitoring using on-board three-axis accelerometer and GPS sensor. In *2011 6th International ICST conference on communications and networking in China (CHINACOM)*, pp. 1032-1037. IEEE.

[4]. Lee, T., Chun, C. and Ryu, S.K., Detection of road-surface anomalies using a smartphone camera and accelerometer. *Sensors*, *21*(2), 2021, p.561.

[5]. Seraj, F., van der Zwaag, B.J., Dilo, A., Luarasi, T. and Havinga, P., RoADS: A road pavement monitoring system for anomaly detection using smart phones. In *Big data analytics in the social and ubiquitous context, 2015*, pp. 128-146. Springer, Cham.

[6]. Bosché, F., Ahmed, M., Turkan, Y., Haas, C.T. and Haas, R., The value of integrating Scan-to-BIM and Scan-vs-BIM techniques for construction monitoring using laser scanning and BIM: The case of cylindrical MEP components. *Automation in Construction*, *49*, 2015, pp.201-213.

[7]. Akgul, M., Yurtseven, H., Akburak, S., Demir, M., Cigizoglu, H.K., Ozturk, T., Eksi, M. and Akay, A.O., Short term monitoring of forest road pavement degradation using terrestrial laser scanning. *Measurement*, *103*, 2017, pp.283-293.

[8]. Mactutis, J.A., Alavi, S.H. and Ott, W.C., Investigation of relationship between roughness and pavement surface distress based on WesTrack project. *Transportation research record*, *1699*(1), 2000, pp.107-113.

[9]. Rusu, L., Taut, D.A.S. and Jecan, S., An integrated solution for pavement management and monitoring systems. *Procedia Economics and Finance*, *27*, 2015, pp.14-21.

[10]. Wang, W., Wang, M., Li, H., Zhao, H., Wang, K., He, C., Wang, J., Zheng, S. and Chen, J., Pavement crack image acquisition methods and crack extraction algorithms: A review. *Journal of Traffic and Transportation Engineering (English Edition)*, *6*(6), 2019, pp.535-556.

[11]. Saarenketo, T. and Scullion, T., Road evaluation with ground penetrating radar. *Journal of applied geophysics*, *43*(2-4), 2000, pp.119-138.

[12]. Shangguan, P., Al-Qadi, I., Coenen, A. and Zhao, S., Algorithm development for the application of ground-penetrating radar on asphalt pavement compaction monitoring. *International Journal of Pavement Engineering*, *17*(3), 2016, pp.189-200.

[13]. Duong, N.S., Blanc, J., Hornych, P., Menant, F., Lefeuvre, Y. and Bouveret, B., Monitoring of pavement deflections using geophones. *International Journal of Pavement Engineering*, *21*(9), 2020, pp.1103-1113.

[14]. Chang, K.T., Chang, J.R. and Liu, J.K., Detection of pavement distresses using 3D laser scanning technology. In *Computing in civil engineering, 2005*, pp. 1-11.

[15]. Barbarella, M., D'Amico, F., De Blasiis, M.R., Di Benedetto, A. and Fiani, M., Use of terrestrial laser scanner for rigid airport pavement management. *Sensors*, *18*(1), 2018, p.44.

[16]. Mahler, D.S., Kharoufa, Z.B., Wong, E.K. and Shaw, L.G., Pavement distress analysis using image processing techniques. *Computer‐Aided Civil and Infrastructure Engineering*, *6*(1), 1991, pp.1-14.

[17]. Yi, C.W., Chuang, Y.T. and Nian, C.S., Toward crowdsourcing-based road pavement monitoring by mobile sensing technologies. *IEEE Transactions on Intelligent Transportation Systems*, *16*(4), 2015, pp.1905-1917.

[18]. Lajnef, N., Chatti, K., Chakrabartty, S., Rhimi, M. and Sarkar, P., *Smart pavement monitoring system* (No. FHWA-HRT-12-072), 2013, United States. Federal Highway Administration.

[19]. Obaidat, T.I.A.S., Shdeifat, M.S. and Ramadan, K.Z., Evaluation of Road Pavement Maintenance by Contract in Jordan. *Jordan Journal of Civil Engineering*, *1*(3), 2007.

[20]. Msallam, M., Al Rawi, O.S., Abudayyeh, D. and Assi, I., Development of a pavement management system to be used in highway pavement evaluation in Jordan. *Development*, *6*(9), 2014.