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DEVELOPING AN EVALUATION MODEL OF TIRE/PAVEMENT NOISE

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ABSTRACT

The aim of this study was to assess pavement performance that by measuring tire-pavement noise with onboard sound intensity method by use single probe, at different constant speed. Different site locations have been selected in Baghdad city. Onboard sound intensity had been used with the separate probe, RS-232 Sound level meter model: SL-4013 and measure the noise that produces as a result of interaction between tire and pavement. All tires new and in good condition that meet the requirement Tire Criteria By using the single probe and fixed it on the right rear tire according to specification AASHTOO TP76.The test sections (AL-Rubaaee Street, Muhammad – AL-Kassim parallel to the technology university, 14 July Street, AL-Fu rat Freeway Street) at a different distance so that we can evaluate the street and assess the condition of the pavement section. Testing AL-Mahmodia for free highway with heavy vehicle (Mercedes Benz tire type 315/80R22.5) and passenger car (SOUL tire 235/45R18) to show the effect the difference in loads on tire/pavement Noise. And reflect that on distress and road roughness. Regression analysis was applied to determine the effect of pavement distress on noise levels in Baghdad city. Multiple regression analysis on all sections shows that overall sound intensity Increases with pavement age and with the presence of raveling, rutting damage, cracking and patching

R^2 from the Model Summary is equal to 0.897 the high value of R^2 seen as proof of a good fit and variables have a statistically significant role to play in the model.

INTRODUCTION

Pavement texture is an important parameter in tire-pavement-interaction-noise Texture can be supposed of as the 'bumps and slopes' on the pavement surface. That might give the car a rough ride. As pavements carry traffic load over the years measurable degradation occurs in texture. The pavement surface is exposed to environmental and traffic elements, changes occur in ride quality. Variations in surface features affect acoustic durability. Therefore, the ability to predict these changes require the development of new survival algorithms. The On-Board- Sound-Intensity (OBSI) is a testing method, allow accurate characterization of pavement noise levels at the source. The use of OBSI gives a complete description of the road when used as a test method.

The onBoard Sound Intensity OBSI has been recognized as an effective method quickly, effectively for evaluating tire-pavement interface noise generated on in-service pavements [1]. This method only required the use of a fixture to hold the sound intensity (SI) microphones and can be readily used on most vehicles. This highly portable method can be used anywhere to get reliable results.

TEST PROCEDURE

A method is described in which a sound intensity probe is installed directly on a test vehicle using an appropriate fixture and tire-pavement noise from a standard test tire is measured. Data is acquired over a 440-ft section of pavement at a constant speed. Depending on local conditions and guidelines (www.illingworthrodkin.com)
The timeframes for every speed were selected to test 440 ft. (134 m) of the sections according to AASHTO Designation: TP 76 -08(1) Single probe of one microphone are in the OBSI system placed at the right back tire (passenger side). The microphones (see Figure 1) are located at distance (3) inches (76.2 mm) over the pavement surface and (4) inches (101. 6 mm) from the side of the tire. The sound intensity is stated in dB and the results are A-weighted. (4)

Global Journal of Engineering Science and Research Management

A   B

Figure1 A. sound level meter and standard sound cart.
B. The setups of the probes were verified to be within the limits set in TP 76, for height above the pavement, distance to the tire Photograph of the sound intensity measurement fixture installed on the right rear wheel of the test vehicle.

DESCRIPTION OF TEST PARAMETERS

- The OBSI system used to achieve real measurements contains:
- Devices: Sound measuring devices (one Sound level meter with the separate probe, RS-232 Model: SL-4013, 1 kHz. One condenser microphones for sound intensity, 10 m extension cables. And the physical parts include (central plate, intensity probe mounting meeting fixture, coupling nut, microphone holding block, strengthening plate, overhang-mounted steel bearing).
- Software: multi-displays, data acquisition software model: SW-U801-WIN, Iso-9001, CE, And IEC1010 (as shown in figure1), cable for RS232 interface to USB port model: USB-01. And processes these in a laptop computer using Lurton Data Acquisition software (Software for u-p instrument DMM) to obtain the sound intensity.
- Test Vehicles: figure (2) KIA soul Model 2016 gross vehicle weight 1820 Kg, NEXEN/KUMHO/ TIRE **235/45R18 94V**, Mercedes Benz truck 1993 gross vehicle weight 9 ton, Cristone TIRE **315/80R22.5** details in table1

Figure 2. OBSI fixtures on Kia Soul and Mercedes Benz truck test vehicle.

Table 1. Test tires and properties

Test tire	dimension	Durometer hardness number	Infatuation pressure(psi)
NEXEN/KUMHO/ TIRE	**235/45R18 94V**	64	35
Cristone TIRE	**315/80R22.5**	66	100

TEST DESCRIPTION

Test conducted in AL-Rubaaee Street in the two left a lane of the street, Muhammad AL-Kassim parallel to the University of Technology, 14 July Street the right lane, AL- Fur at freeway the left lane, AL-Mahmodia freeway the left lane. The purpose of this test focuses on the influence of all types of distress existing in this road on the overall onboard sound Intensity (dBA).

Pavement age effect

Figure 3. Presents the tire/road noise levels of the different pavement sections respect to pavement age depending on the speed. As observed, there was an increase of about 2.8 dB (A) from 2010 to 2012 and around 6.9 dBA from2010 to 2017 at speed 60km/h. while there was increase around 0.9 dBA from 2010 to 2012 and about 6.8 dBA from 2010 to 2017 at the speed of 80 km/h.

Pavement distress effect
The first Case study/AL-Rubaaee street in two sides

As seen in figure 5, 7. Illustrate the variability of the sound intensity over the distance in AL Rubaaee Street in the left lane in two sides maximal side and AL-Kukh side at speed (20, 40, 60) km/h. the noise intensity flocculating all over the distance because of presence cracking, raveling, and failure patching. Figure 5 describes the variability of the sound intensity over the distance. the Test section Started with patching that distance from the beginning to 100 meters there is two peak with value (86.60, 84.90) dBA at speed 20 km/h, distance from (50 to 100) meter, (100 to150) meter number of peak appear referred to raveling with value range about (87.20-87.70) dBA and this also contains cracking and patching. But the highest level of the noise intensity caused by raveling. These have been insured by visual inspection and these value increase with increasing speed and the variability taking similar in shape for each speed**.** Figure 7 stated the variability of the sound noise over the distance in AL-Rubaaee street side L-Kukh. The level of the sound intensity as shown in the figure is lower than from the other side as presented in figure 5 AL-Maximal side. The distance started to 100 meter with two peak due to raveling at value (86.40) dBA at speed 20 km/h and this value raised with increasing speed. Figure 8 focuses on the difference between these two sides at speed 60 km/h. we can recognize that AL-Rubaaee at side maximal is higher than at side AL-Kukh in sound intensity dB(A) and that describes the condition of the street from which lane give high sound intensity dB(A) refers to the bad condition of this lane. However, the similar in pavement type and mixes. While both streets include patching, raveling and cracking there is the difference in Sound Intensity due to having severed cracking, failure patching and potholes**.**

The second Case study/ Mohamed AL-Kassim Road parallel to the University of Technology

Figure 7. Presenting variability of sound intensity in Mohamed AL-Kassim Road parallel to the University of Technology over the distance at speed (20, 40, 60) km/h

The test section asphalt pavement distance about 550 meters from visual inspection
The section contains raveling, potholes, Rutting, the High severity of longitudinal and transverse cracking. To illustrate the effect of these distress on tire/ pavement noise by using the sound level meter as seen in figure 7. The sound intensity level fluctuates all over the distance depending on speed, figure 7. At speed 60 km/h illustrated two peaks below 100 meter due to cracking appear in this area with value (108.5-109) dBA. Also, there is cracking at distance (400, 550) meter with value (110.10-110.30) dBA. respectively, while at distance (133,250,300)meter raveling covered this area with(111.40,111.40,112.60)dBA .the highest level caused by Rutting at distance(183,483,500)meter by(114.40,113,20,113,20)dBA. Respectively.

Global Journal of Engineering Science and Research Management

The Third Case study/ AL-Fur at Road Versus Mansur municipality
Figure 11. Giving variability of Sound intensity in AL-Fur at Road over the distance by use tire (2235/45R18, 285/60R18) at speed 60 km/h. the test section 440 ft. (134.2) meter the right lane from the road. The figure illustrates the difference between two tires passing the test section in this test the difference is very clear and sound intensity take the same shape for speed (60) km/ h. Figure 12 stated that the difference between Dunlop tire and Kumho tire by about (1) dBA at speed (60) km/h**.** while the difference for the Dunlop tire for the same test section at speed (40, 60) km/h is equal to (3) dBA and Kumho tire at speed(40,60)km/h. similarly, Figure14. Focuses on the changing of noise intensity over the left lane from AL-Fu rat at the road. By visual inspection the test section includes patching, cracking and raveling. For each speed (60,80)km/h sound intensity measurement Fluctuate all over the section due to cracking and patching existing in this area that is followed with sharp rise at distance(400)meter continued to distance(444) meter making a peak at distance (422)meter with value (120.40)dBA because of raveling came after the failure patching.

The Fourth Case study/ AL-Mahmodia Road
Figure 16. Showing variability of Sound intensity level with distance over the test section at speed (60) km/h by using passenger car and truck in AL-Mahmodia Road**.** The test section about2000meter. the sound intensity started with severe increase at distance 83 meter due to raveling covered this area established on manual observations with value 115 dBA for passenger car tire (235/45R18) and 123.20 dBA for Truck tire (315/80R22.5).the results are in line with previous research and Reflects a lot of tests," traffic noise prediction methods assign around 6-10 dB (A) higher noise levels to trucks than to typical cars". Often, "an experimental base says that a heavy truck is 10 dB (A) "noisier" than a car is used" [2]. The load of the truck compared to that of a car also makes it natural to think of those lines. In addition. Tire the width is a very influential factor [2] (Walker and Williams, 1979) experimentally measurements the influence of tire width on tire-pavement noise, indicating that there is a clear increase with tire width increasing [3] Figure 17. Elucidate different street at speed 60 km/h. tire type 235/60R18 The level of sound intensity and variability in new pavement street 2 Locality 902 resurfaced at the end of the year 2017 is very low compared to another street. For the same type of pavement. The highest dBA at Muhammad –AL-Kassim street parallel to the University of Technology takes the first degree installed in year2008. As the later contain distress such as raveling, Rutting and cracking .according this we can classified these test section from worst to best condition and identified the priority or which section need for maintenance.

The Five Case study/ 14 July Road
Figure 18. Explained sound intensity for 850 m at 14 July street tire type235/45R18 at speed 60 km/h test section start from the intersection of Damascus the Right lane. It can be noticed that at distance 50 meters there is a slight increase in Sound Intensity (dBA) about 94.8 and followed with sharply raise at a point over 100 meters As results of cracking covered this area.

Overall, violent fluctuate over the distance that is happening as a result of longitudinal, transverse cracking and raveling, besides, they were at their highest at 500 meters while the weakest at beginning of the section [6]
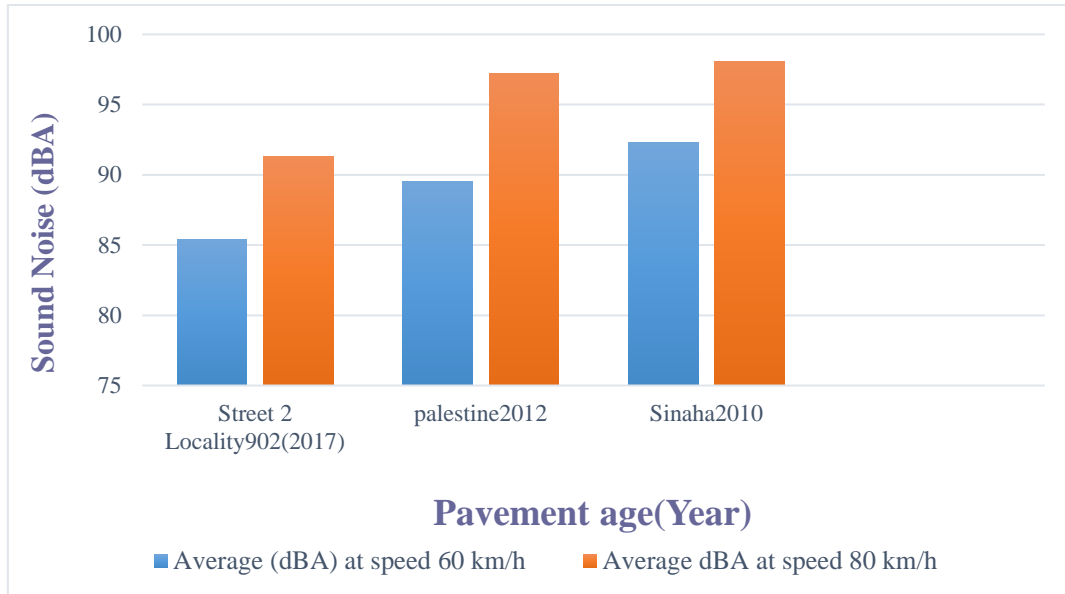
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Figure 3. Effect of pavement age on tire/road noise, Baghdad roadway sections.
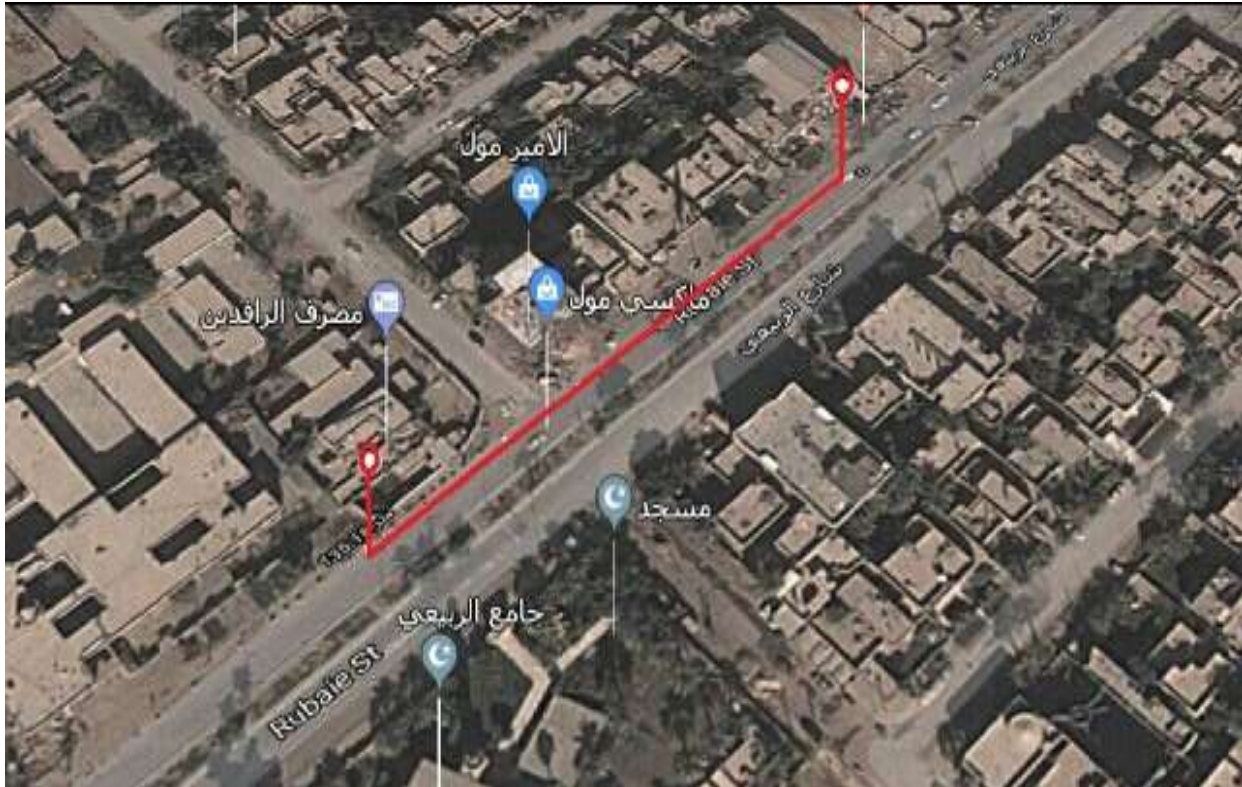
Figure4. AL-Rubaaee street side AL maximal.

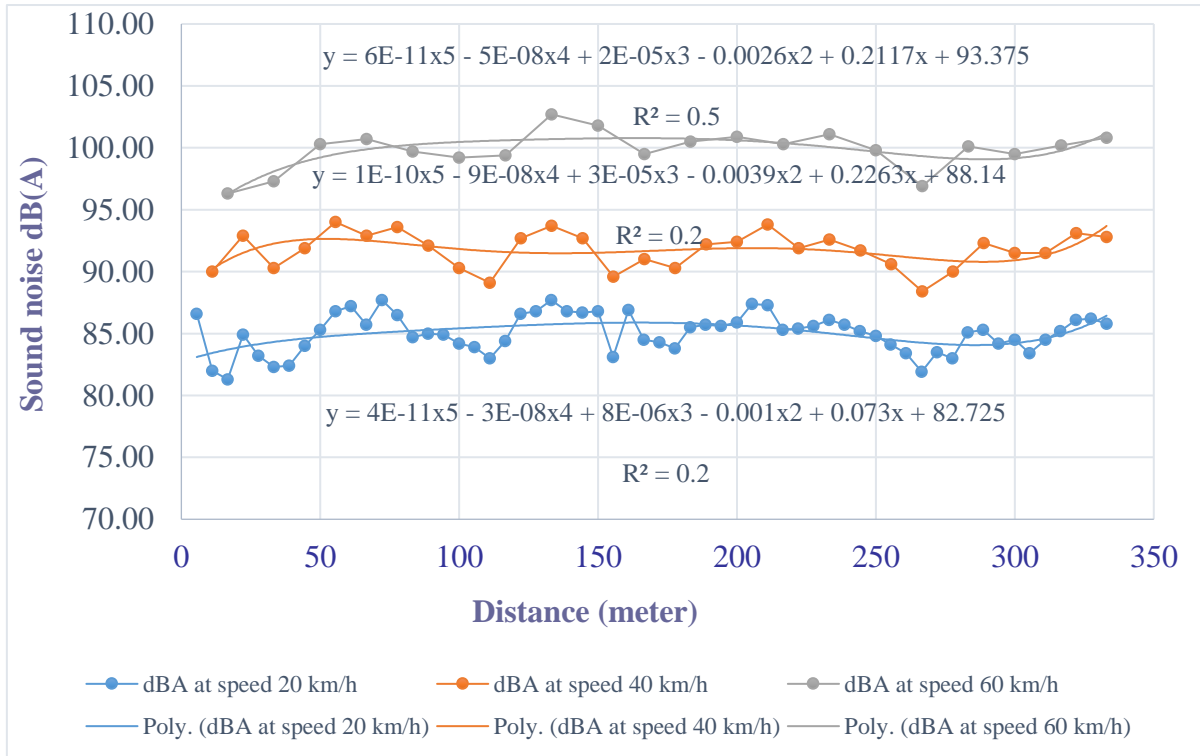Global Journal of Engineering Science and Research Management

The chart shows equations:

$$y = 6E\text{-}11x^5 - 5E\text{-}08x^4 + 2E\text{-}05x^3 - 0.0026x^2 + 0.2117x + 93.375$$
$$R^2 = 0.5$$

$$y = 1E\text{-}10x^5 - 9E\text{-}08x^4 + 3E\text{-}05x^3 - 0.0039x^2 + 0.2263x + 88.14$$
$$R^2 = 0.2$$

$$y = 4E\text{-}11x^5 - 3E\text{-}08x^4 + 8E\text{-}06x^3 - 0.001x^2 + 0.073x + 82.725$$
$$R^2 = 0.2$$

Figure5. On-Board Sound Intensity in AL-Rubaaee street side AL maximal at speed (20, 40, 60) km/h.
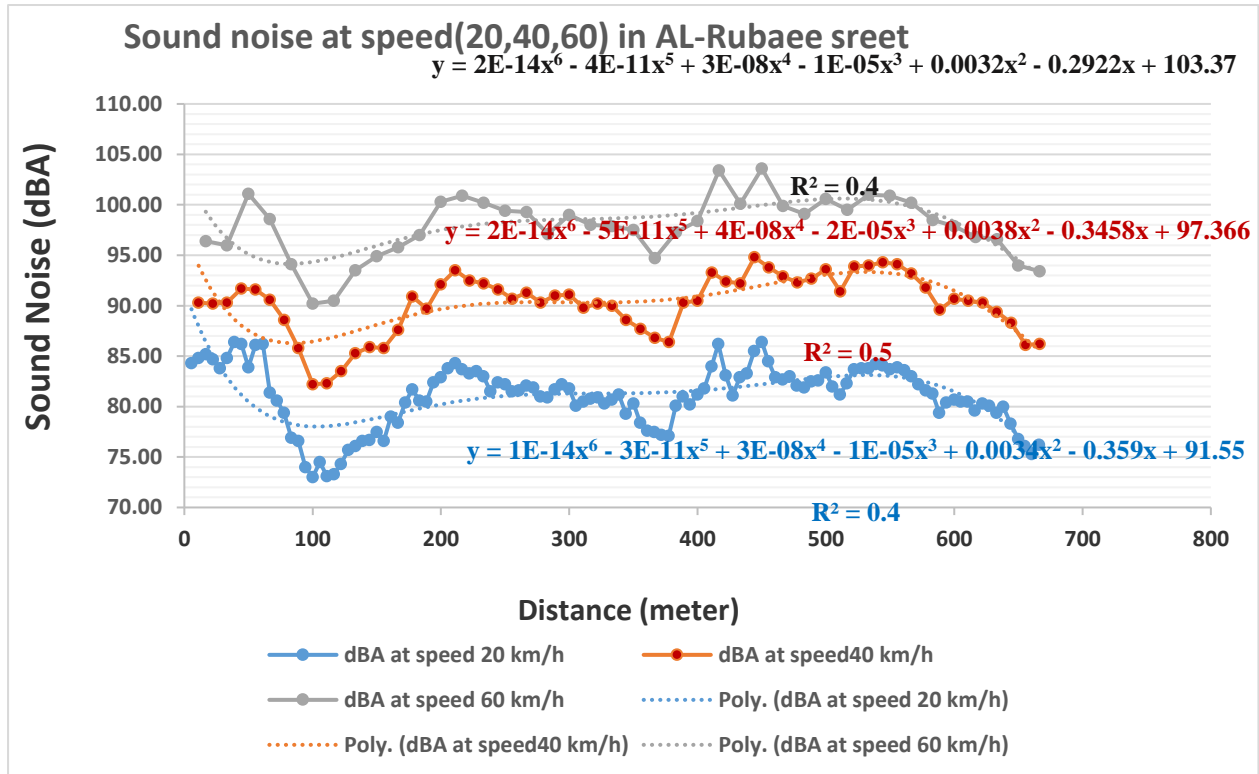

Figure 6. AL-Rubaaee street side AL-Kukh Mall.

Global Journal of Engineering Science and Research Management

Figure 7. Sound intensity in AL-Rubaaee street side AL-Kukh Mall presenting variability over the distance.
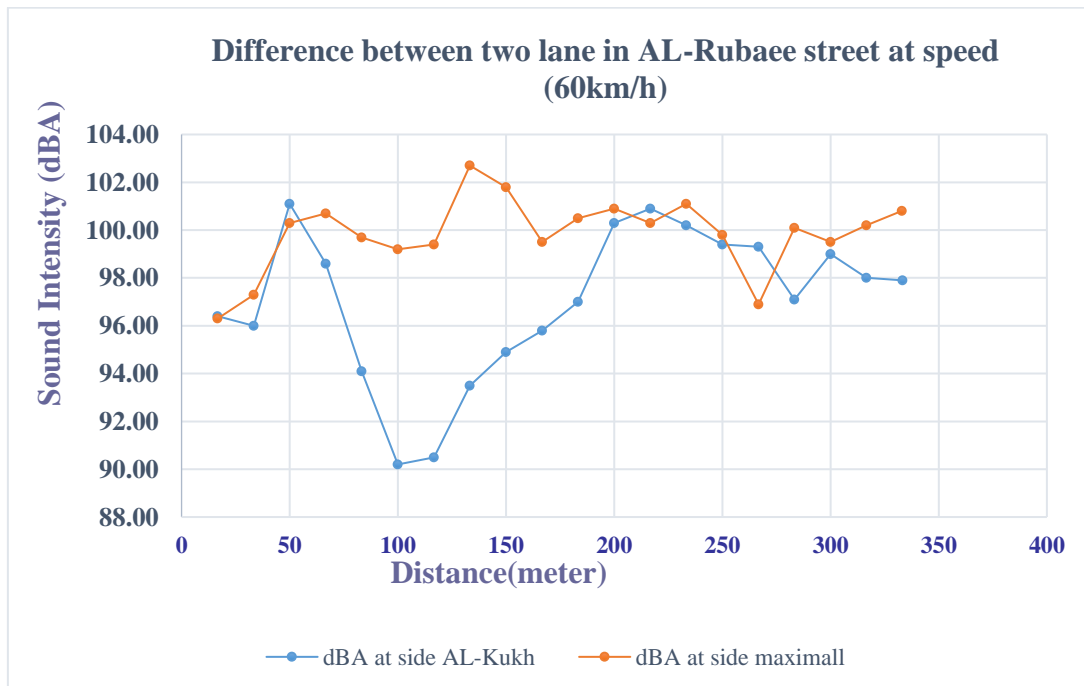

Figure 8. The difference of the sound intensity for two sides in AL-Rubaaee Street.

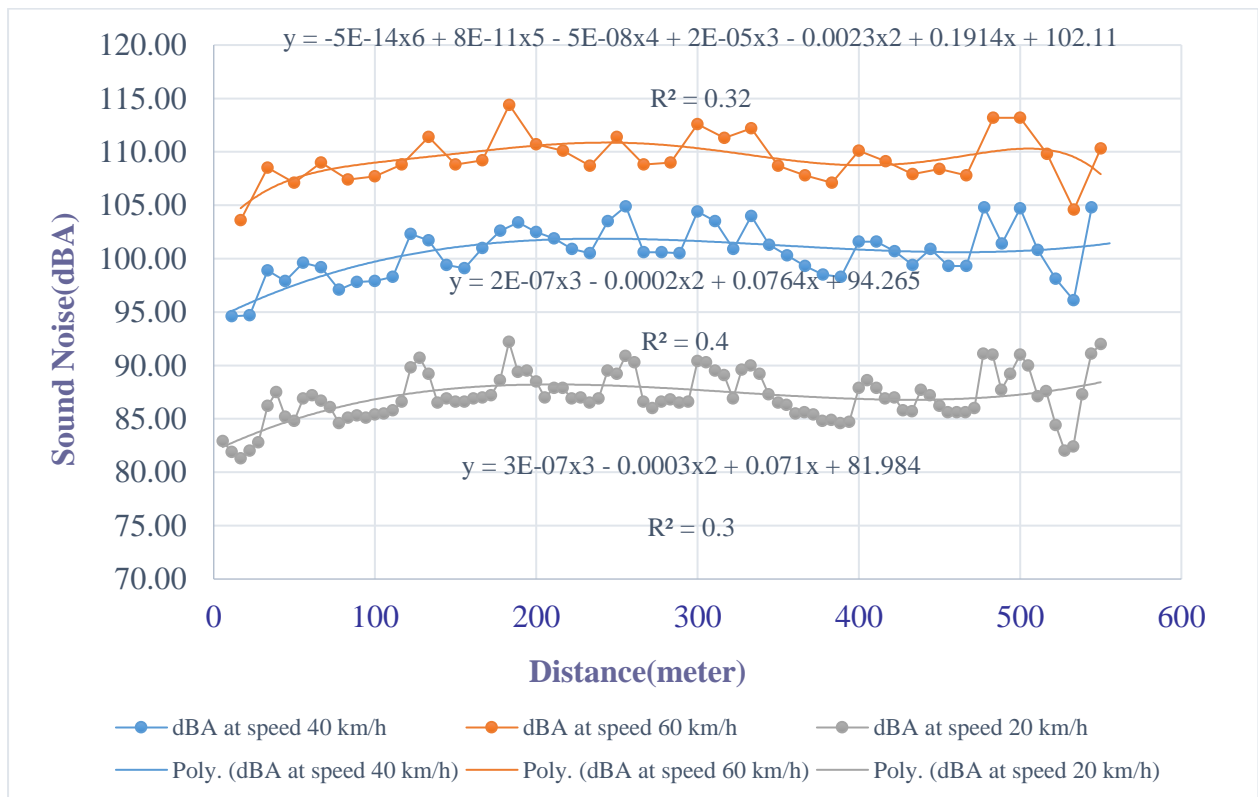*Figure 9. Mohamed AL-Kassim Road parallel to the University of Technology*

$$y = -5E\text{-}14x6 + 8E\text{-}11x5 - 5E\text{-}08x4 + 2E\text{-}05x3 - 0.0023x2 + 0.1914x + 102.11$$

$$R^2 = 0.32$$

$$y = 2E\text{-}07x3 - 0.0002x2 + 0.0764x + 94.265$$

$$R^2 = 0.4$$

$$y = 3E\text{-}07x3 - 0.0003x2 + 0.071x + 81.984$$

$$R^2 = 0.3$$

Figure 10. Sound intensity in Mohamed AL-Kassim Road parallels to the University of Technology
presenting variability over the distance.

Global Journal of Engineering Science and Research Management

$$y = 2E{\text -}10x^6 - 1E{\text -}07x^5 + 2E{\text -}05x^4 - 0.0021x^3 + 0.0987x^2 - 2.166x + 112.5$$

$$R^2 = 0.80$$

$$y = 2E{\text -}10x^6 - 8E{\text -}08x^5 + 2E{\text -}05x^4 - 0.0016x^3 + 0.0744x^2 - 1.6379x + 107.97$$
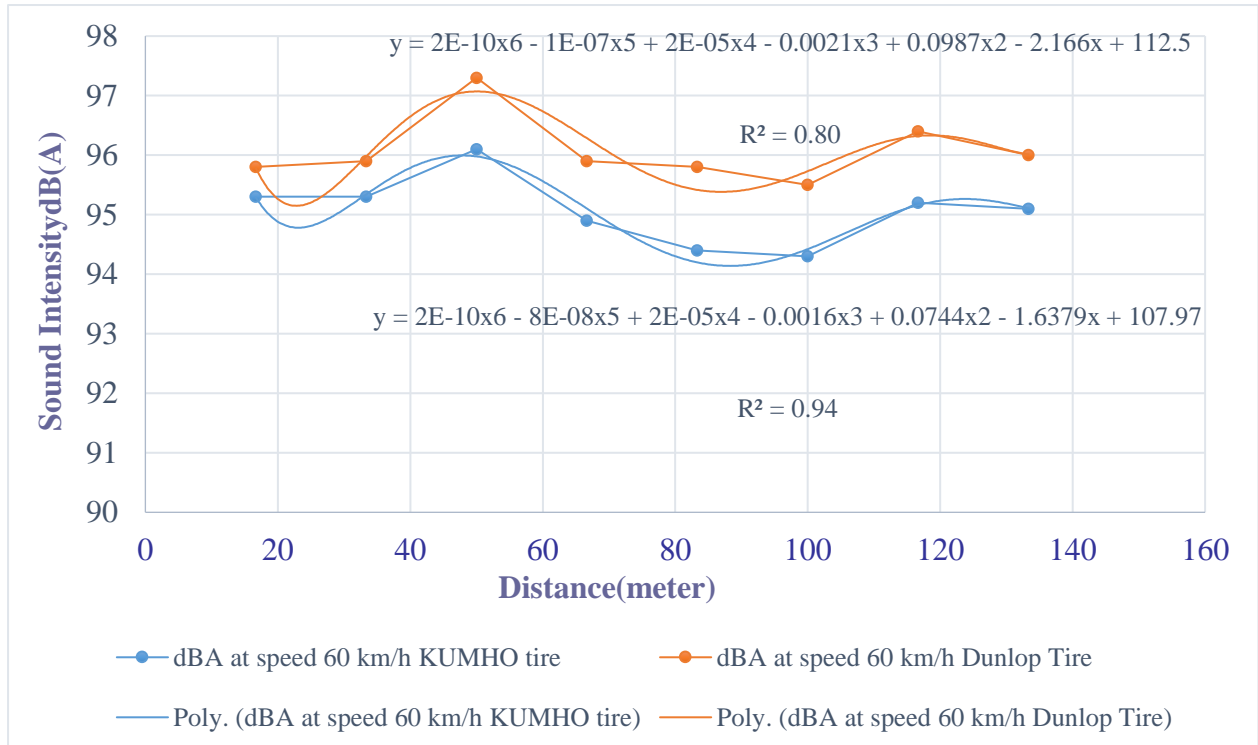
$$R^2 = 0.94$$

Figure 11. Sound intensity in AL-Fur at Road giving variability over the distance by use tire (235/45R18, 285/60R18) at speed 60 km/h.
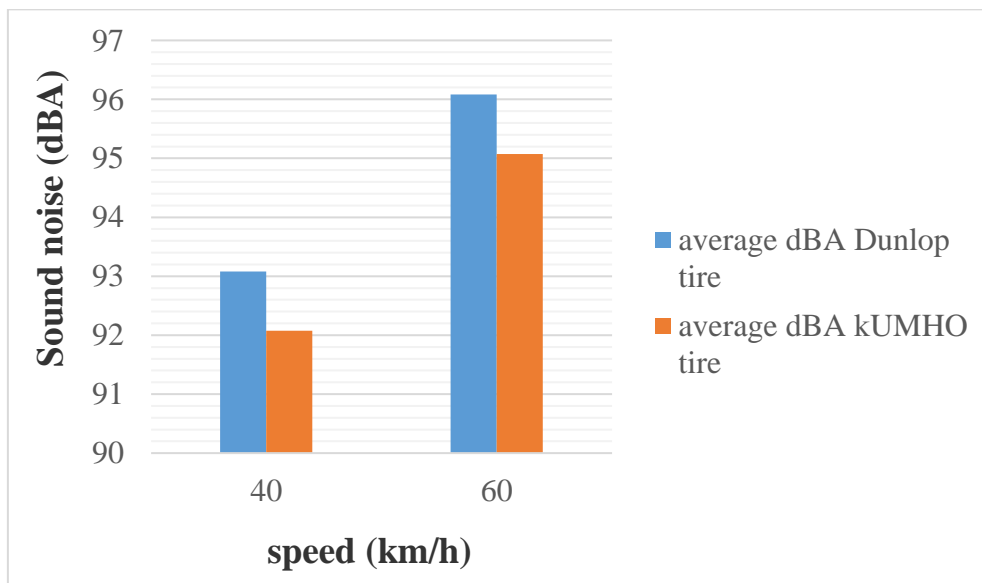
Figure 12. The difference of Sound intensity versus speed by use tire (235/45R18and 285/60R18) at speed 40, 60 km/h in AL-Fur at Road.
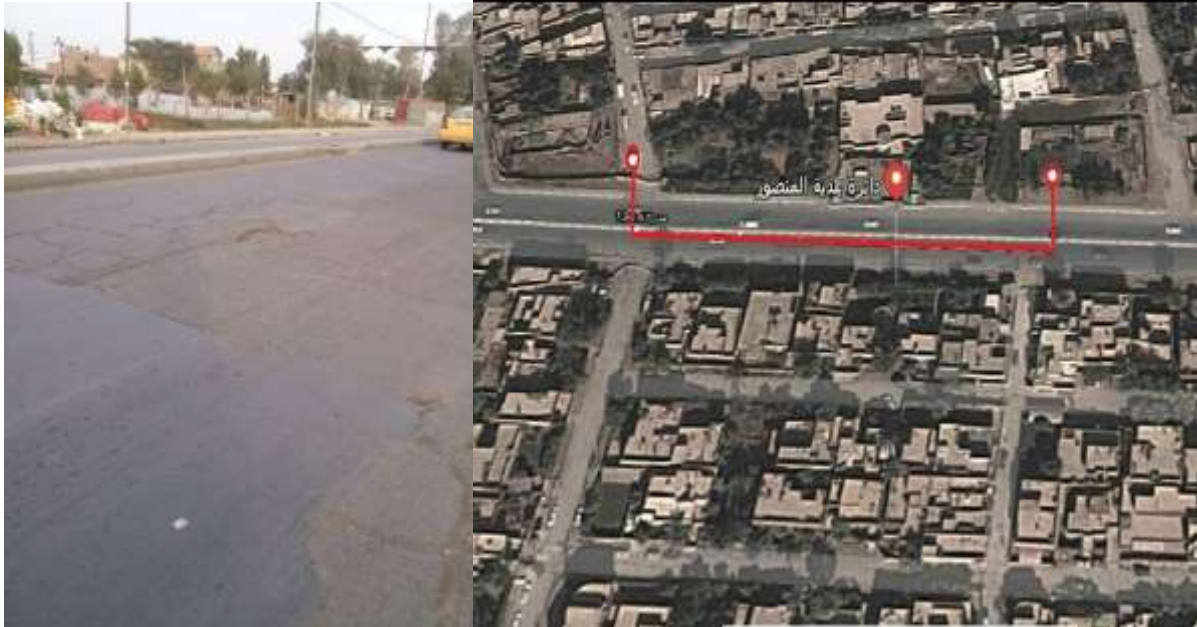
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Figure 13. Sound intensity in AL-Fur at Road

$$y = -6E-13x^6 + 8E-10x^5 - 4E-07x^4 + 1E-04x^3 - 0.011x^2 + 0.5435x + 89.952$$

$$y = -3E-13x^6 + 3E-10x^5 - 2E-07x^4 + 3E-05x^3 - 0.0034x^2 + 0.1622x + 91.816$$
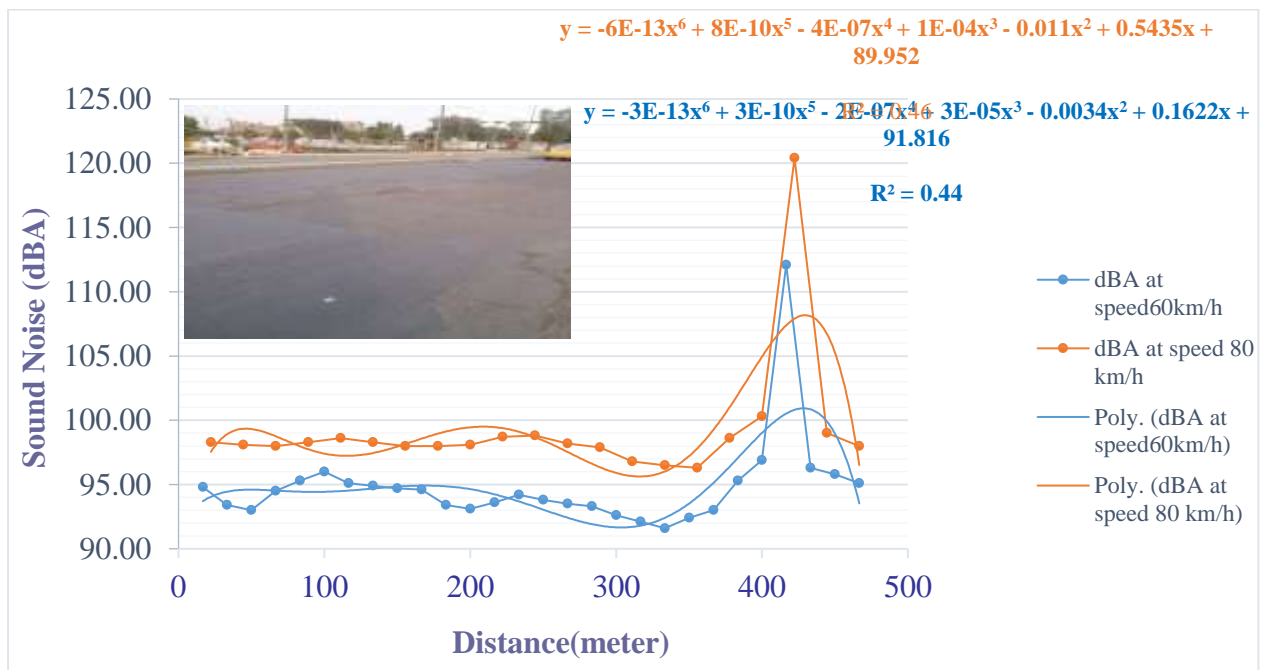
$$R^2 = 0.44$$

Figure 14. Sound intensity in AL-Fur at Road giving variability over the distance by use tire (235/45R18) at speed (60, 80) km/h on the left lane.

Global Journal of Engineering Science and Research Management

Figure 15. AL-Mahmodia Road test section.

$y = -1E\text{-}08x^3 + 3E\text{-}05x^2 - 0.0292x + 112.4$

$R^2 = 0.71$

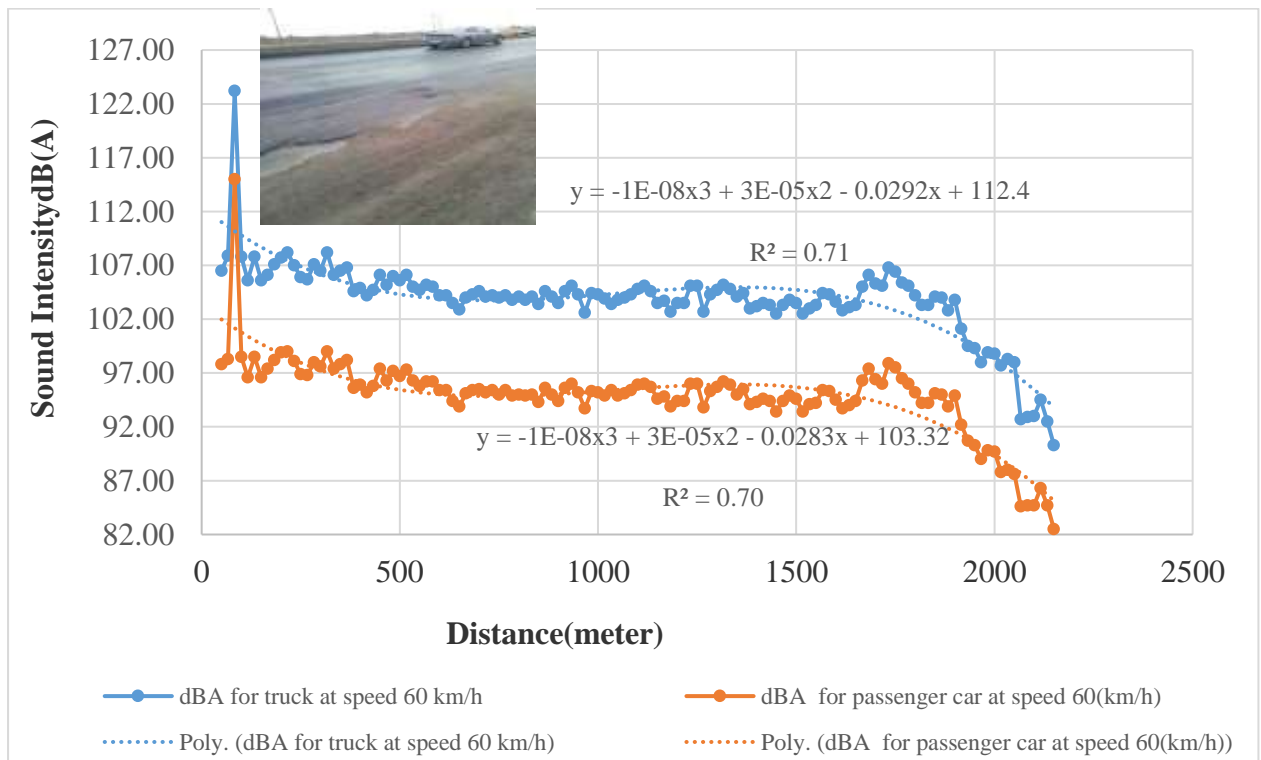$y = -1E\text{-}08x^3 + 3E\text{-}05x^2 - 0.0283x + 103.32$

$R^2 = 0.70$

Figure 16. Onboard Sound intensity level with distance showing variability over the test section at speed (60) km/h by using passenger car and truck in AL-Mahmodia Road.
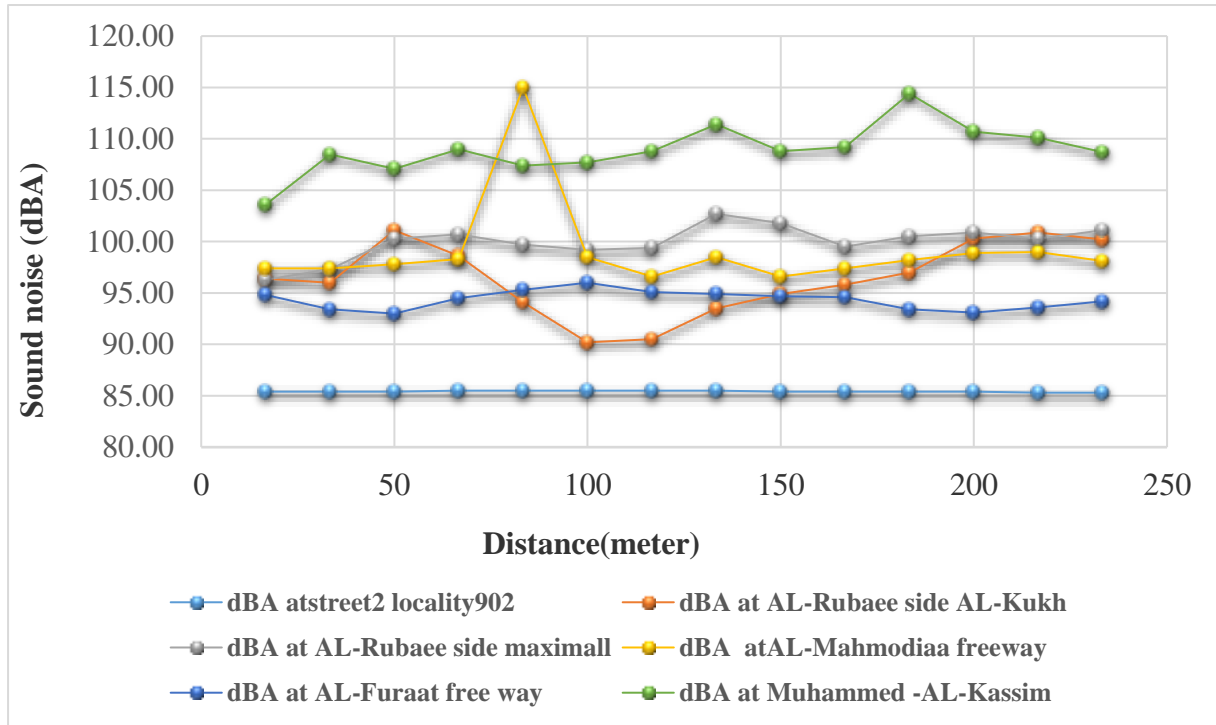
GLOBAL JOURNAL OF ENGINEERING SCIENCE AND RESEARCH MANAGEMENT

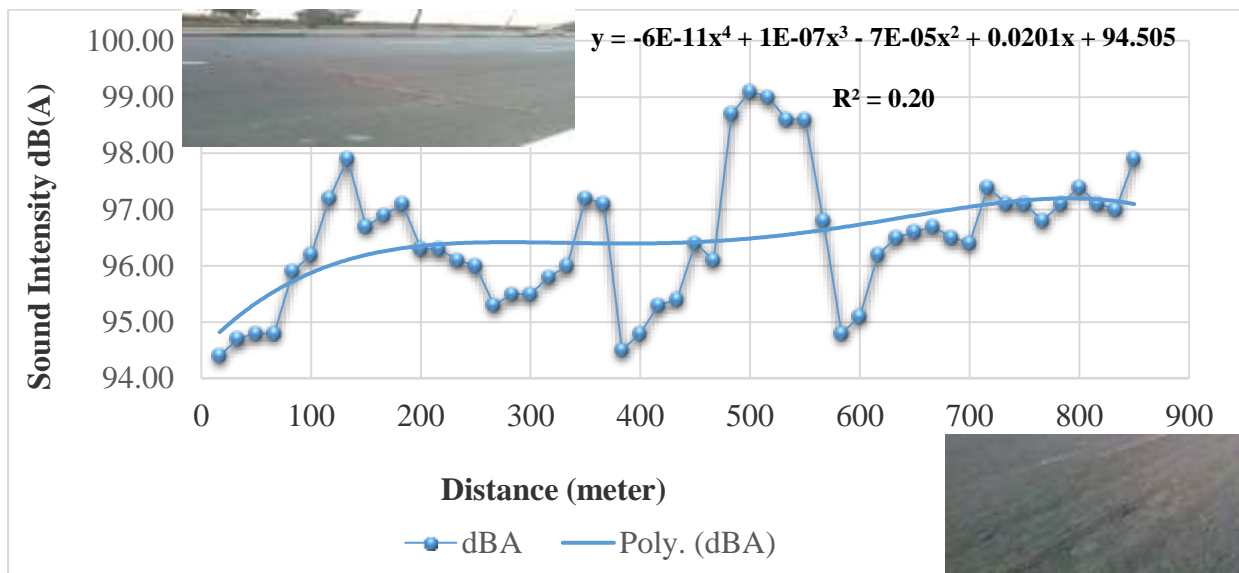*Figure 17. Illustrate compared between different street at speed 60 km/h. tire type 235/60R18*

Figure 18. Onboard Sound intensity level with distance presenting variability over the test section at speed (60) km/h use tire (235/45R18) in the Right lane of 14 July Road.

REGRESSION ANALYSIS APPROACH

The model contains vehicle speed, pavement age, pavement condition, Raveling, rutting, cracking, patching.
From Table 3. Coefficients[a] The regression model appears below as Eq
OBSI=$_{\beta}0$ +$_{\beta}1T$+ $_{\beta}2v$+$_{\beta}3$ IRV+$_{\beta}4$ IRT+$_{\beta}5IC$+$_{\beta}6$ Ip
OBSI = 66.917 +.288v+.921 T+3.449 IRV+6.446 IRT +2.200 IC+2.061 IP

Global Journal of Engineering Science and Research Management

OBSI= on-board sound intensity, dB (A);
T= pavement age, year;
v=speed (km/h)
IRV=indicator variable, 1 if raveling distress is present on the pavement, 0 otherwise;
IRT=indicator variable, 1 if rutting distress is present on the pavement, 0 otherwise;
IC = indicator variable, 1 if cracking distress is present on the pavement, 0 otherwise;
Ip = indicator variable, 1 if patching distress is present on the pavement, 0 otherwise;
βi=coefficients, i=, 1… 5.

From table 2. ANOVA[a] the value of F is 21.742 is high as shown by the p-value in the column Sig. This means that the variables have played a significant role in the model.R^2 from the Model SummaryTable4 is equal to 0.897 the high value of R^2 seen as proof of a good fit and variables have a statistically significant role to play in the model.

2. ANOVA[a]

	Model	Sum of Squares	df	Mean Square	F	Sig.
1	Regression	980.266	6	163.378	21.742	.000[b]
	Residual	112.714	15	7.514		
	Total	1092.981	21			

a. Dependent Variable: Decibel (dBA)
b. Predictors: (Constant), patching, (KM/H), AGE (YEAR), rutting, cracking, raveling.

3. Coefficients[a]

Model	Unstandardized Coefficients B	Std. Error	Standardized Coefficients Beta	t	Sig.	95.0% Confidence Interval for B Lower Bound	Upper Bound
(Constant)	66.917	2.917		22.9	.000	60.701	73.134
(KM/H)	.288	.042	.603	6.83	.000	.198	.377
AGE(YEAR)	.921	.266	.388	3.46	.003	.354	1.487
raveling	3.449	2.468	.245	1.39	.183	-1.811	8.709
rutting	6.446	2.690	.314	2.39	.030	.713	12.178
cracking	2.200	1.908	.153	1.15	.267	-1.866	6.266
patching	2.061	2.510	.130	.821	.425	-3.290	7.411

a. Dependent Variable: Decible (dBA)

Global Journal of Engineering Science and Research Management

4. Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin Watson
					R Square Change	F Change	df 1	df 2	Sig. F Change	
1	.947[a]	.897	.856	2.7412	.897	21.7	6	15	.000	1.67

a.Predictors: (Constant), patching, (KM/H), AGE (YEAR), rutting, cracking, raveling
b. Dependent Variable: Decible(dBA)

CONCLUSIONS

1) The use of digital sound level meter for noise pavement recording, crack detection and subsequent classification have subject to continuous improvements over the past decade. Furthermore, it is Easy, simple, need less time in seconds and far from risk compare to visual inspection.

2) The sound intensity increase as the speed increase for a different type of pavement In case of presence or absence the distress, the level varies greatly depending on the specific range of tires and on the pavement surface.

3) Tire/pavement noise generally increases with pavement age. For newly paved overlays. The sound intensity measured on, Street 2Locality 902 is lower than the values measured on Muhammad AL-Kassim street, Sinaha Street, Palestine Street.

4) Distress and roughness largely increase the noise level. Multiple regression analysis on all sections appears that overall sound intensity Increases with the presence of raveling, rutting damage, cracking and patching. The four coefficients ($_\beta 3$, $_\beta 4$, $_\beta 5$, $_\beta 6$) indicate that the presence of raveling, rutting, cracking, patching increases tire/pavement noise by about (3.449, 6.446, 2.2, 2.061) dB (A).respectively. The highest level of noise intensity caused by Rutting with a positive coefficient equal to 6.446 and it represents about the double of raveling with value 3.449 in addition to about three times of cracking and patching, It is clear that cracking and patching are given a similar effect to sound and have the nearly equal value 2 dBA.

ACKNOWLEDGMENT

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