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Traffic Noise Prediction Model in Irbid District, Jordan

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ABSTRACT. The relationship between the speed of vehicles and their emitted noise levels were investigated in this paper. Vehicles were classified into three distinct classes: Automobiles (A), Medium Trucks (MT) and Heavy Trucks (HT).

Measurement sites were in rural or quiet suburban locations in Irbid District so that passing vehicles would be measured independently as signle events. The measurements were sorted by speed classes as well as by vehicle type. Each vehicle class was statistically analyzed. Linear regression analysis led to the development of a set of noise prediction models. These models may be used to establish noise level standards and will assist in land use planning.

A comparison of the developed noise models of Irbid District with those suggested by FHWA and Ontario Ministry of Transporation was made.

The noise levels that are generated by street traffic is the most unpleasant feature of the noise problem. This is true because street traffic is existing everywhere, while the other noise sources are located in certain places that are chosen with much care and protective measurements.

The pollution of the environment – whether it is due to particulate emissions or noise emissions – has led many nations of the world to set certain regulations to enhance the quality of the environment, as well as, its preservation for today's and tomorrow's life (Nelson 1987) (ISO 1981) (Alexandre 1975) (Oglesby 1975). As Jordan is concerned, a special Acoustic Code has been set. This code specifies the acceptable sound levels in different types of buildings as well as in different types of rooms (Ministry of Public Works 1988). The factors that affect the generation of traffic noise are:

1. Traffic volume.
2. Traffic speed.
3. Percentage of heavy vehicles (traffic mix).
4. Gradient.
5. Road surface texture.
6. Type, severity and extent of pavement distress.

Moreover, the path followed by sound waves affects the degree of attenuation to them. Factors affecting the propagation of traffic noise are as follows:

- Attenuation due to distance.
- Screening of traffic noise.
- Atmospheric conditions.
- Sound conditions.
- Reflection and scattering

Oglesby (1975) indicated the permissible noise level in different types of areas. For example: (1) in quiet residential neighborhood at night it is in the range (32-43) dB (A), and at day time it may be (41-53) dB (A), (2) in industrial areas the range is (48-66) dB (A), and (3) in downtown commercial locations with heavy traffic it is (62-73) dB (A).

The study of traffic noise in Jordan is of great importance because it is widespread. So, in response to the high exposure of citizens to this type of noise, this research was initiated to investigate the existing road noise levels and compare it with other countries. The relationship between noise levels and speeds of different types of vehicles are to be investigated aiming at to explain how speeds of different types of vehicles contribute to the problem of traffic noise.

Due to the multiple factors that affect the traffic noise, an area of level terrain was chosen in the district of Irbid, Jordan. All the factors that contribute to traffic noise other than speed (for example: pavement surface type and its condition) were excluded (or neutralized) from this research by choosing similar observation station sites in the district of irbid.

Little has been reported regarding the effect of highway traffic noise in developing countries. One of the few studies that were reported in transportation journals was that undertaken in Trinidad (Underwood and Boodlal 1983); however the study was concerned with a survey investigating the impact of traffic noise on residential areas. The emphasis of this study will be on the effect of traffic speed for different vehicle classes on traffic noise. The results of the present study may also be helpful in highlighting the serious problem of road traffic noise in the Arab world and appropriate measures for noise control.

Materials and Methods

The required data was collected from seven observation stations located in different parts of Irbid District, in the 1991 Summer season. These observation stations were similar in gradients and pavement condition. The passing vehicles were observed as single events. The measured parameters were:

1. Speed of passing vehicle: speed was measured indirectly by means of determining a certain distance (30 meters in this case) on roadway and the elapsed time of the observed vehicle is then registered.
2. Vehicle type or class: vehicles were divided into three distinct classes. These classes are: Automobiles which were assigned the letter A. Medium Trucks denoted by MT, and Heavy Trucks denoted by HT. This classification process is similar to the one given in previous work (Hendriks 1985).
3. Maximum level of sound pressure: this was done through the use of a special Sound Level Meter (SLM). This SLM is the Bruel and Kjaer 2430 (B & K – 2430) precision instrument type which gives the Sound Pressure Level (SPL) as the vehicle passes by.

Only single and isolated events were considered and registered. The vehicle was considered isolated if it was separated from both the following and preceding vehicles by more than 100 meters. The measuring instrument was located 7.5 meters from the center line of the outermost traffic lane, (Fig. 1). Also it was about 120 cm above roadway pavement level. The selected observation stations were in level rural or suburban areas.

The collected data was then sorted in ascending order of speeds, then grouped into speed intervals of 5 km/hr width each. These data sets are listed in Tables 1, 2 and 3. The vehicle types that were observed and their corresponding percentages are as shown in Fig. 2. This process was recommended in previous research (Jung 1986).

Table 1. Automobile Sound Pressure Level – Speed Date

Speed km/hr	Sound Pressure Level Max dB (A)	Number of Observations
30 - 34	73.8	9
35 - 39	73.6	9
40 - 44	73.6	14
45 - 49	75.5	30
50 - 54	76	37
55 - 59	77.9	14
60 - 64	76.9	27
65 - 69	79.3	7
70 - 74	78.5	4
75 - 79	80.3	15
80 - 84	78.6	5
90 - 94	80.5	7
95 - 99	80.7	2
105 - 110	80.6	2
Total Number of Observations =		**182**

Table 2. Medium Trucks Sound Pressure Level – Speed Date

Speed km/hr	Sound Pressure Level Max dB (A)	Number of Observations
30 - 34	80	14
35 - 39	78.3	5
40 - 44	80.3	14
45 - 49	80.7	23
50 - 54	81.4	13
55 - 59	82.8	8
60 - 64	82.3	6
65 - 69	84.2	2
90 - 94	89.8	1
Total Number of Observations =		**86**

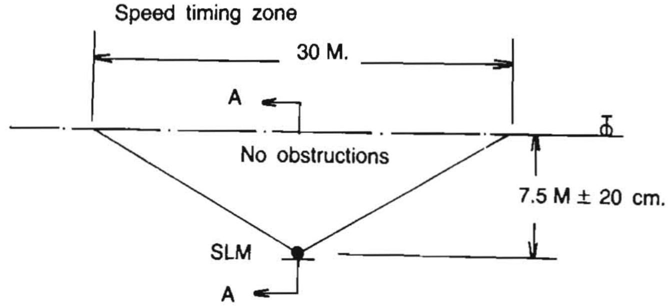
Table 3. Heavy Trucks Sound Pressure Level – Speed Date

Speed km/hr	Sound Pressure Level Max dB (A)	Number of Observations
30 - 34	83.9	2
35 - 39	82.9	2
40 - 44	81.1	6
45 - 49	86.7	5
50 - 54	85.4	14
55 - 59	86.1	3
60 - 64	89.7	6
75 - 79	87.9	1
105 - 110	89.4	1
Total Number of Observations =		**40**

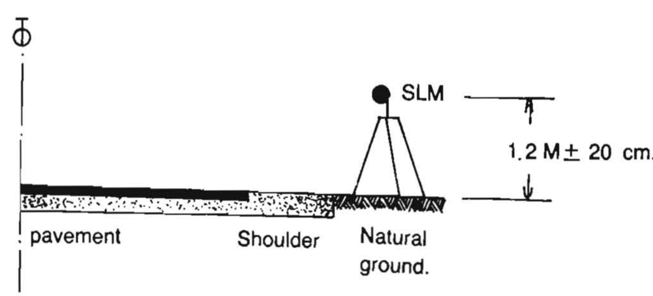
It should be noted that the seven observation stations were on major highways surrounded by suburban or rural residential areas in the outskirts of the city of Irbid. Furthermore, the research did not investigate the effect of highway type and surrounding land use. The emphasis was on the comparison of noise levels in Jordan and other developed countries using the same model structure.

In addition to collecting noise levels for single and isolated events a limited study was conducted for the study of equivalent emission sound pressure levels (Leq). This noise level differs completely from the single event exposure (SEE). The measured Leq can be used to judge on the existing noise levels emitted by traffic as well as by other sources of noise in a specified area. A case study to investigate the existing noise in a residential area was carried out in Shaikh Khaleel area in Irbid City. This area was chosen because it contains a major public transportation terminal that serves cities and villages to the south of Irbid City.

The same instrument used in the SEE investigation mentioned before was used here also. It was set-up inside a room with windows in the area for a full day and night.



a- Typical observation station.



b- Section A-A.
(Drawing is not to scale)

Fig. 1: Typical observation station layout.
(Note: SLM = Sound Level Meter.)

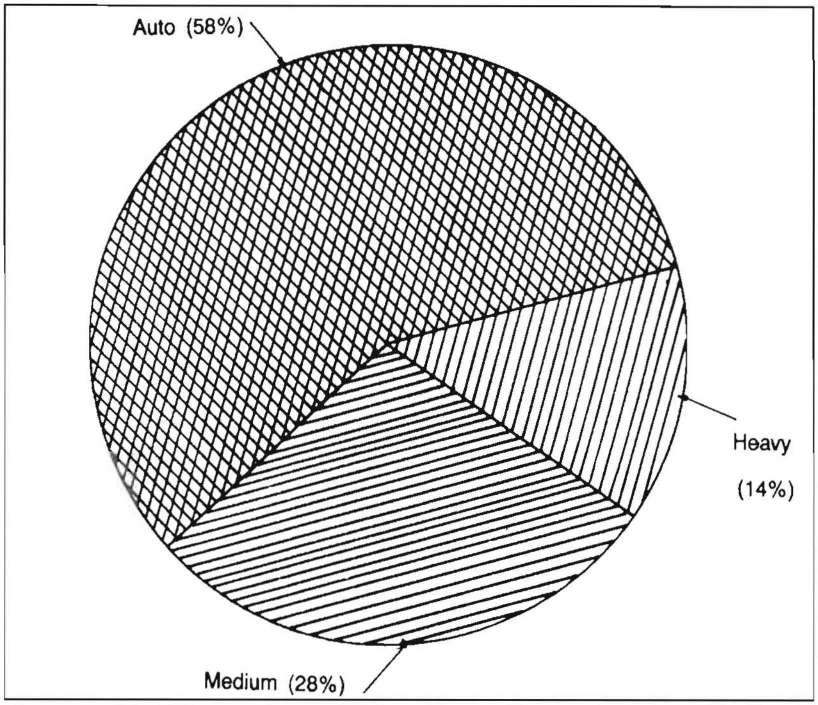


Fig. 2: Types of vehicles considered in the survey and their percentages.

Statistical Analysis

Noise levels for each vehicle class were statistically analyzed by the use of linear regression methods. Moreover, each vehicle class data set was treated by two different statistical approaches. These approaches are:

1. Analysis of means: where the data were pooled in speed intervals such that, at each interval midpoint speed, a single mean value of sound pressure level is obtained. This was the method used by the Federal Highway Administration (FHWA) and Ontario Ministry of Transportation in setting their own noise prediction models.
2. Analysis based on all individual observations: where the data set for the whole sample were treated as they were obtained from the field.

To achieve the goal of statistical analysis, the available Statistical Analysis System computer package (SAS) was used as well as other available statistical software.

Noise Levels Emitted by Automobiles

1. Analysis of Means for Automobiles

The data obtained for automobiles were shown in Table 1. The bar chart shown in Fig. 3 illustrates the nature of the distribution of speeds.

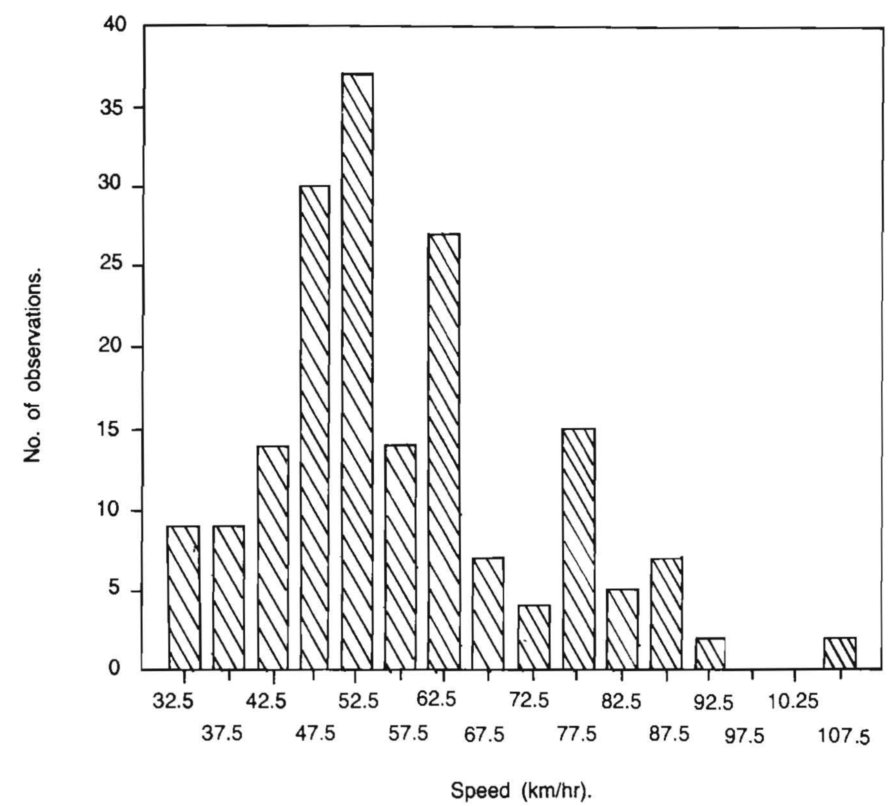


Fig. 3: Speed distribution of Automobiles.

The data set was then fed to the SAS package. The final best model for automobiles was:

$$SPL = 48.74 + 6.96 \text{ Ln } (v) \quad (1)$$

$(n = 13, \ F = 123.6, \ t = 11.1)$

Where:

SPL = mean sound pressure level, dB (A).

Ln (V) = the natural logarithm of speed. V in Km/hr.

The coefficient of simple determination (r^2) for model 1 is (0.91) which indicates a very good regression relationship. The F-test was performed to test the overall significiance of the regression model at 5% level. The t-test led to the conclusion that the independent variable was significant.

Using this model, the estimated SPL is plotted in Fig. 4 along with the pooled actual data observations to illustrate the suitability of the model to actual situations.

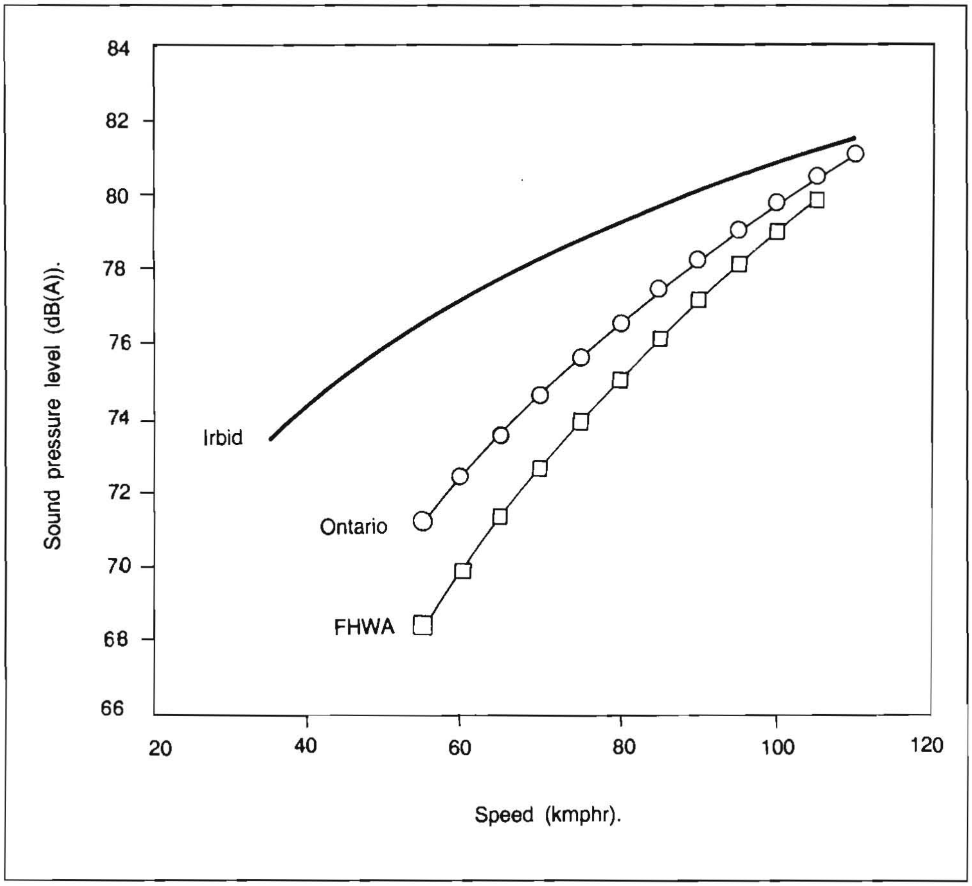


Fig. 4: Comprison of emission levels for automobiles class (A).

2. Analysis Based on all Individual Observation

The raw data, as it was obtained in the field without any pooling or grouping, was analyzed by SAS which led to the following model:

$$SPL = 47.67 + 7.3 \, Ln\,(V) \quad (2)$$

($n = 181$, $F = 76.9$, $t = 14.35$, $r^2 = 0.3$)

Where SPL and V are as explained peviously.

The computed statistical parameters led to the conclusion of the significancy of this regression model at the 5% level.

Noise Level Emitted by Medium Trucks

1. Analysis of Means for Medium Trucks

The data for medium trucks class was shown in Table 2. The best model found was:

$$SPL = 79.19 + 0.00001388012 \ V^3 \quad (3)$$

(n = 8, F = 131, t = 11.4)

Where:

SPL = mean sound pressure level, dB (A).

V = speed, Km/hr.

The coefficient of simple determination (r^2) for this model is 0.94, which indicates a very good regression relationship. The F-test was performed to test the overall significance of the estimated relation at 5% level of significance indicating a significant model. The t-test was also done which indicated that the independent variable was found significant. A graphical representation of medium trucks model is illustrated in Fig. 5.

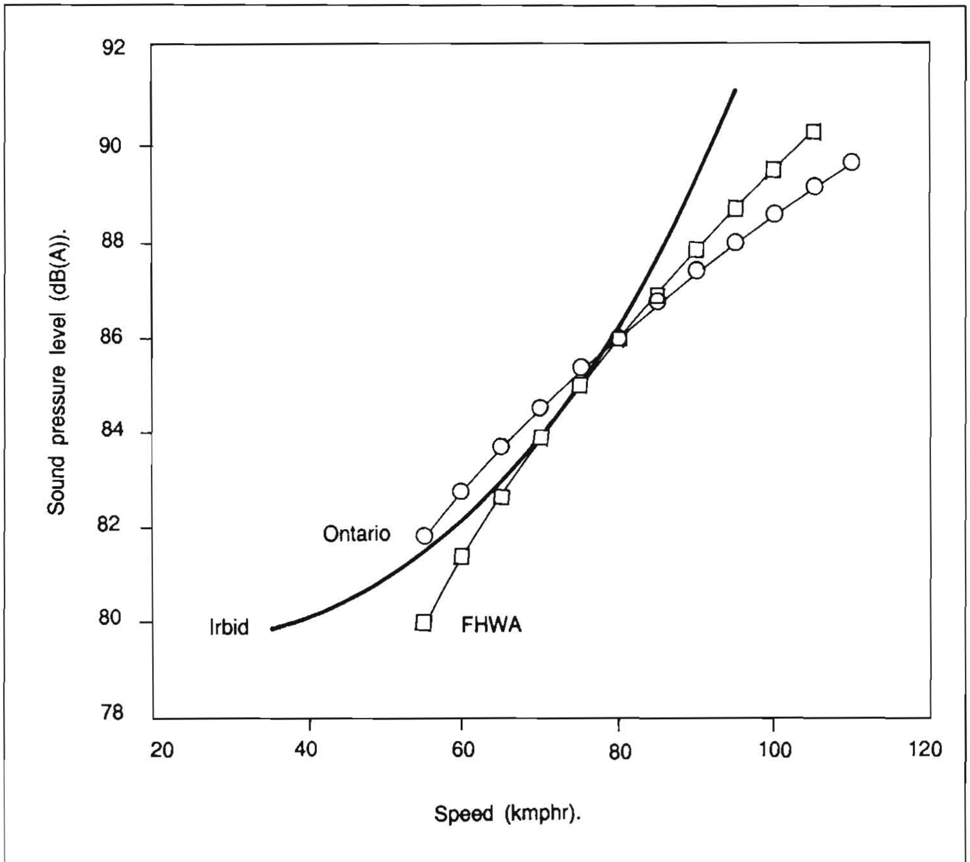


Fig. 5: Comprison of emission levels for medium trucks class (MT).

2. Analysis Based on all Individual Observations

The raw data for medium trucks obtained in the data collection stage was analyzed using SAS to get the following model:

$SPL = 79.31 + 0.00001457\ V^3$ (4)

($n = 85$, $F = 19$, $t = 4.36$ $r^2 = 0.18$)

The computed statistical parameters led to the conclusion of the significancy of this regression model at the 5% level.

Noise Levels Emitted by Heavy Trucks

1. Analysis of Means for Heavy Trucks

The data for heavy trucks were shown inTable3.After **processing** this data set, the following model is obtained:

$SPL = 60.88 + 6.27\ Ln\ (V)$ (5)

($n = 8$, $F = 12.28$, $t = 3.5$)

Where:

SPL = mean sound pressure level, dB (A)

V = speed Km/hr.

The coefficient of simple determination (r^2) was found to be 0.637 which indicates a good regression relation at the 1% level. The computed statistical parameters led to the conclusion of the significancy of this model at the 5% level. The estimated sound pressure levels using this model are shown in Fig. 6.

2. Analysis Based on All individual Observation

The raw data for heavy trucks obtained in the data collection stage was analyzed using SAS and yielded the following model:

$SPL = 51.0 + 8.8\ Ln\ (V)$ (6)

($n = 39$, $F = 18$, $t = 4.25$, $r^2 = 0.32$)

The computed statistical parameters led to the conclusion of the significancy of this regression model at the 5% level.

Comparing the two models obtained for each of automobiles, medium trucks and heavy trucks it was found that:

1. All models are significant.
2. The estimates of regression parameters are very close to each other in the two models.
3. The transformations used were found to be the same in the two models.
4. Model (1), model (3) and model (5) with higher r^2 values can be used to perform the required comparison with other models developed by FHWA (Bowlby 1981) and Ontario (Jung 1986), since these models were based on the analysis of means.

It should be noted that fewer observations were available in the low speed ranges due to the nature of the sites (rural or suburban). Very fews vehicles travel in the low speed ranges (below 40 km/hr). Definitely more observations at all speed ranges would produce statistical models that are more accurate; however, the levels of significence of the models outlined above are acceptable.

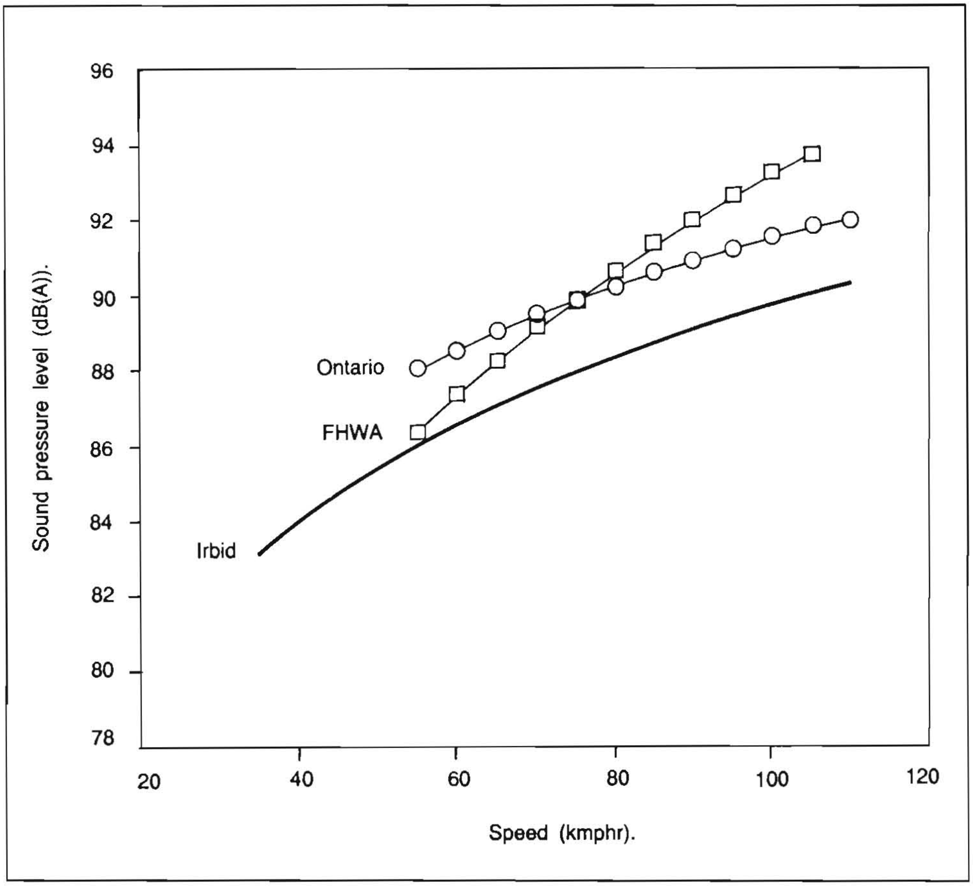


Fig. 6: Comprison of emission levels for heavy trucks (HT).

Results and Discussion

Comparison of Reference Mean Emission Levels of Automobiles

The available models for automobiles are plotted in Fig. 4 to illustrate the differences as much as possible. As shown in that figure, automobiles in Irbid emit higher noise level, especially at lower speeds, than those of Ontario (Jung 1986) and FHWA (Bowlby 1981). All models indicate that at the highest speed they tend to reach the same noise level. Furthermore, the increase in rate of noise in Irbid is less than the rest of the others. It was found that an increase in speed of 10 km/hr in Irbid would result in an increase of 1.28 dB (A) in noise level while in Ontario or FHWA the increase would be about 2.8 dB (A).

The higher noise levels of the automobiles of Irbid may be due to insufficient regular maintenance that would result in noisy vehicles at lower speeds. At the higher speed range, it seems that the noise levels in the three models coincide, simply because noise has a finite limit at those higher speeds.

It is worth mentioning here that some drivers in Irbid District did not respect the legal speed limit of 80-90 km/hr as can be noticed from the speed distribution given in Fig. 3. As a general observation poor maintenance of vehicles leads to higher noise levels especially at lower speeds. Furthermore the original mufflers are usually replaced with locally made mufflers which do not follow the original manufacturer's specifications.

Comparison of Reference Mean Emission Levels of Medium Trucks

The noise levels model of medium trucks of Irbid District is plotted with the other two models of FHWA and Ontario in Fig. 5. The highest speed of a medium truck observed in the data collection stage was in the range of 90-95 km/hr. Therefore, the estimated model for Irbid will not be used to predict noise levels emitted by vehicles travelling at speeds higher than the highest observed value. It is clear, as shown if Fig. 5, that the medium trucks of Irbid emit lower noise levels than the other two models. Also the trend of the noise levels of Irbid follows a polynomial increase, while the other models are tracing a logarithmic function. This result confirms Oglesby's (1975) remarks, that vehicle noise may increase as the third power of velocity.

It is important to note that drivers of medium trucks did not exceed the legal speed limit at the observation stations during the study time. This is because the sample of medium trucks was mainly composed of heavily loaded minibuses. It seems to be that when the driver feels the magnitude of responsibility laid on him by carrying passengers in his vehicle, he will drive more cautiously.

Comparison of Reference Mean Emission Levels of Heavy Trucks

The obtained model of heavy trucks in Irbid District is shown in Fig. 6 along with the FHWA and Ontario models. As shown in that figure it is clear that this vehicle class in Irbid District is quieter than in USA or Ontario. Also, the rate of increase of noise levels is lower than that of FHWA while it is somewhat higher than that of Ontario. The main reason for the phenomenon of lower noise levels of Irbid District is believed to be due to the number of axles. It is evident that the more the number of axles (i.e.: the more number of tires), then the more the tire-road interaction. So if the speed is high then the effect of the number of tires has a significant role in affecting the noise levels. Another factor is that most heavy trucks of Irbid District have the engine installed under the driver's cabin, which play its role in absorbing a portion of the emitted noise. Moreover, the exhaust outlets are long enough to damp the emitted sounds. It can also be noticed that some drivers of heavy trucks in Irbid District did not respect the legal speed limit.

From the previous sections it was found that on the one hand the medium and heavy vehicles of Irbid District are quieter than the FHWA and Ontario vehicles. On the other hand the automobiles of Irbid District are noisier.

The measured Leq values for day and night times were found to be 59.8 and 45 dB (A), respectively at the residential area near the public transportation terminal of Irbid. These measured values were then compared to the acceptable Leq levels given by Oglesby (1975). Both measured values indicate high noise levels in contrast to the permissible noise levels. The measurement process was carried out in such a way that the elapsed time by each Leq level was known. So the 60 dB (A) level was exceeded by 61% of the time. This percentage is quite high and would cause the study area to be considered as a noisy area that requires certain remedial measures. It should be noted that an exposure to a noise level of Leq = 90 dB (A) for 8 hours would cause hearing impairment, while an exposure of 60 dB (A) will prevent concentration and thinking by human beings (Rau 1980).

Conclusion

The major findings of this research are summarized below:

1. A set of noise prediction models was developed. Many benefits will be obtained when implementing them in other similar locations.
2. Speed, which was the unique independent variable in this research, proved to be a fairly good quantitative indicator for reference mean noise emission levels emitted by road traffic.
3. The class of automobiles of Irbid District was found noisier than those of FHWA and Ontario, while the class of heavy trucks was found quiter. Medium trucks were found noisy, especially at higher speeds.

Recommendation

Based on the previously mentioned results and conclusions, the following policy recommendations are suggested:

1. Acceptable road traffic noise emission standards for Jordan should be established and provided by the Jordanian Code of Acoustics.
2. Once the above mentioned point is implemented, a fair penalty system is recommended to urge both the driver and the manufacturer to respect the imposed standards.
3. Variables other than speed should be investigated and their effects on noise levels should be observed, especially the composition of the asphalt mix, pavement surface condition, and roadway slope.
4. Much care should be devoted to noise levels that will result from any new transportation project and it should be a major factor in urban planning policies.
5. In the yearly technical check-up for license renewal of vehicles the mufflers should be checked.
6. Studying the influence of traffic noise levels on the surrounding land uses is recommended.

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نماذج تقدير الضجيج الناشيء عن الحركة المرورية في منطقة اربد - الاردن

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يأتي هذا البحث على أثر أزدياد الأهتمام المحلي والدولي بالمحافظة على البيئة وذلك على مختلف الأصعدة والتخصصات. ومن هذا المنطلق تم البدء بهذا البحث وذلك للتعرف على مشكلة الضجيج الناشئة عن حركة المرور في محافظة أربد وبالتالي وضع الحلول المناسبة لها.

أما العوامل التي تؤثر في مستويات الضجيج المنبعثة من حركة المرور فهي كثيرة، لكن أهمها هو عامل السرعة تبعاً لنوعية المركبة لذلك تم التركيز على هذا العامل في هذا البحث. واستناداً إلى ذلك حلل البحث ودرس مستويات الضجيج الناشئة عن حركة المركبات على اختلاف أنواعها بسبب انتشارها الواسع في الأردن خصوصاً وان تأثيراتها تصل إلى أكثر التجمعات السكانية، وتؤثر على البيئة المحيطة أكثر من تأثير المصانع التي يتم اختيار مواقعها على أسس بيئية معتمدة. ولقد تم تصنيف أنواع المركبات إلى ثلاث فئات هي:

١ - **فئة السيارات الصغيرة**: وهي تلك السيارات التي يمكن قيادتها برخصة السير الخصوصيّة، وهي تتميّز بأنها تسير على أربعة عجلات فقط.

٢ - **فئة الشاحنات المتوسّطة**: وهي تلك الشاحنات ذات الحمولة الخفيفة أو المتوسطة والتي تسير على عدد من العجلات يتراوح بين الأربع والست عجلات.

٣ - **فئة الشاحنات الثقيلة**: وهي تلك الشاحنات التي تُستخدَم لنقل الحمولات الكبيرة عادة وتتميّز بأنها تسير على عدد من العجلات مساوٍ لست عجلات أو أكثر.

لقد تمّ اختيار أماكن القياسات في مواقع هادئة من مدينة اربد بحيث يمكن قياس سرعة السيارات العابرة الداخلة إلى المدينة أو الخارجة منها بشكل مستقلّ وكأن كل قياس هو ظاهرة فرديّة، وقد صُنِّفَت القياسات تبعاً لدرجات السرعة ولأصناف السيارات، بحيث تمّ تحليل كل صنف من العربات بشكل كافٍ. وتمّ التوصّل إلى وضع عدد من النماذج الرياضيّة المبنيّة على أسس احصائيّة تمكن من تقدير الضجيج حسب فئات السيارات المختلفة. وخلص البحث إلى أن عامل السرعة هو ذو تأثير كبير في مستويات الضجيج المنبعثة، فكلّما زادت السرعة زاد مقدار المستوى المنبعث للضجيج والعكس صحيح. ويمكن استعمال النماذج المطوّرة هذه لقياس الضجيج في وضع معايير للتحكّم بمستويات الضجيج الناشئة عن حركة المرور وبالتالي يمكن اعتمادها للمساعدة في تخطيط استعمالات الأراضي في الأردن.

ولبيان أوجه الشبه أو التمايز والاختلاف تّمت مقارنة نتائج البحث مع مثيلاتها في بعض دول العالم مثل البحث الذي أجرته إدارة الطرق الاتحاديّة الأميركيّة وبحث وزارة مواصلات أونتاريو الكنديّة، وقد تبيّن أن مستويات الضجيج المنبعثة من السيارات الصغيرة في محافظة اربد هي **أعلى** من مثيلاتها هنالك. ووجد أن مستويات الضجيج المنبعثة من الشاحنات الثقيلة في محافظة اربد هي أقل من مثيلاتها هناك. ويمكن بذلك تعميم نتائج البحث ومنهجيّته المستخلصة من مدينة اربد على مناطق حضريّة أخرى مشابهة سواء داخل الأردن أو خارجها وخاصة على مناطق عربيّة مشابهة.