Noise Pollution Assessment and Analysis at Benina International Airport

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Abstract. Many workers throughout the world experience noise at work. Unwanted sound, or noise, is a common occupational concern in industrial and service environments. High noise levels can lead to hearing loss, physical and mental stress, decreased productivity, communication difficulties, and an increased risk of accidents and injuries due to interference with warning signals. An airport is one of the most significant locations where employees are subjected to excessive noise. The study's measurement location is the Benina International Airport, which is located in Benghazi. Employees at Benina Airport, are subjected to noise and its consequences continuously. The manager of the safety department further stated that the dogs are completely deaf and that most of the staff suffer from hearing loss concerns. This is why investigating and comprehending the origins of noise, especially at airports, helps generate solutions for reducing or eliminating it. Data were gathered to gauge the noise level of aircraft engines during two distinct times: in the morning and the afternoon. These times were arranged with the head of the department responsible for air traffic controllers under the Libyan Civil Aviation Authority. Analysis was successful in creating a statistical prediction model and yielding valuable data.

Keywords: Noise, hearing loss, factors and response, and data analysis

1 Noise Pollution

1.1 Definition

Any unwanted or harmful sound that interferes with daily life is called "noise pollution". A few detrimental impacts on people's health and well-being include hearing loss, sleep disturbances, and increased stress. Numerous studies have linked prolonged exposure to noise pollution to heart disease, cognitive loss, and other health problems [1-2]. The World Health Organization estimates that noise pollution alone is responsible for losing at least one million healthy years of life in Western Europe annually [1]. This highlights the urgency of addressing this issue and developing ways to reduce noise pollution in our daily lives [3].

1.2 Noise at The Airports

The most obvious effect of airports is noise, which has a serious daily impact on both airport employees and locals living nearby.

I. U. Ahad (ed.), *Proceedings of the 4th International Conference on Key Enabling Technologies (KEYTECH 2024)*, Atlantis Highlights in Engineering 35,
https://doi.org/10.2991/978-94-6463-602-4_26

Specifically, several regulations set international limits on aircraft noise during takeoff and landing phases, prohibit aircraft that are too noisy, promote the use of the best technologies available, and advise member states and airports on how to implement efficient procedures for mitigating aircraft noise at the European level or set limits on perceived noise in addition to other measures to address this issue [1]. An enormous global problem that impacts millions of people is noise pollution in airports. The continuous roar of jet engines, ground support equipment, and air traffic control may have detrimental effects; on people's health and well-being [1]. Research indicates that exposure to high decibel levels might result in hearing impairment, disrupted sleep patterns, and increased stress [4-8].

Aircraft engines are one of the main sources of noise pollution in airports. The noise generated by these engines can exceed 140 decibels, equivalent to standing next to a jet taking off [9]. The engines of an aircraft produce the majority of its noise, although the airframe also contributes to some degree. The way sound travels through the atmosphere has an impact on its propagation. Sound waves propagate and change with the aircraft's wind direction, speed, and altitude relative to the ground. Temperature and humidity have a significant impact on how sound travels from the atmosphere to the ground because of absorption linked to air viscosity and instability [10].

As previously stated, luggage carts and fuel trucks are examples of ground equipment that contributes to noise pollution at airports. These cars make noise while they drive, and they frequently pass near runways and airport terminals. This is little, though, in comparison to the noise produced by airplane engines.

1.3 Noise Effects

Noise is a physical and social problem with several undesirable effects [11]:

- Noise can damage the sensitivity of the inner ear, and cause permanent or temporary “noise-induced hearing loss” (NIHL), annoying tinnitus, or ringing in the ears.
- Noise can produce annoyance (a psychological effect); which results in sleep disturbance stress, tension, and loss of performance .
- Noise interferes with activities, such as speech communication, which may annoy .
- Noise can cause structural failures and injury .
- Noise can influence consumers to buy competitors' quieter products .
- Noise-induced cardiovascular effects have been extensively studied in occupational medicine .

Occupational Safety and Health Administration (OSHA) standards for workplace noise exposure ensure that workers are protected from excessive noise levels as shown in Fig.1 [11].

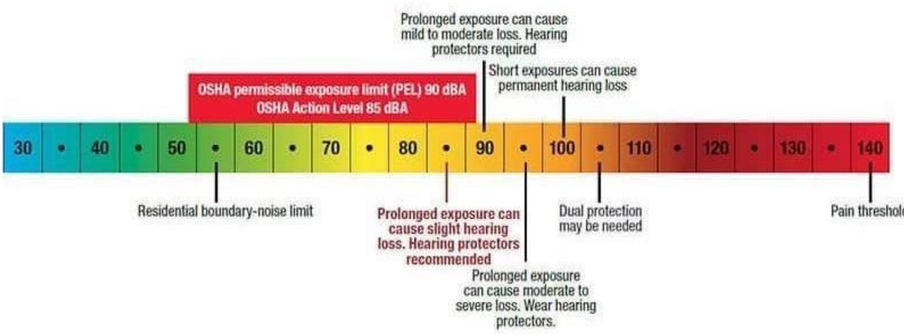

Fig. 1. OSHA standards for noise

1.4 Factors Affecting Hearing Loss

Sound level, distance, and time are the factors that cause hearing loss, as shown in Fig. 2, [11].

Fig. 2. Factors Affecting Hearing Loss

- Decibel Level: How loud the sound is. Sound is measured in units called decibels. Any sound at or above 85 decibels can damage hearing.
- Distance: How close are you to the source of the sound? A sound gets louder near the source and softer away from it .
- Time: The length of time being exposed to the sound. Limit exposure to sound at or above 100 decibels to no more than 15 minutes [11].

public spaces. Shrinkage and solid density are the characteristics that are currently being studied. High-density polyethylene (HDPE), grade F00952 from SABIC Inc., was used as the raw material. The private company's commercial machine was used in this study under typical operating conditions. It was therefore unable to alter the machine's settings. The scenario of the work is illustrated in full in Fig.2.

2 Aim of the Study

The current study intends to assess the current state of noise at Benina International Airport by recording data on noise levels at various times of the day over a month and comparing it with the International Organization's standard noise limitation levels (OSHA).

3 Process of Data Gathering

3.1 Case Study Location

Measurements for this study are conducted at Benina International Airport, located in Benghazi's Benina area.

3.2 The Study Duration

The Libyan civil aviation authority's chief of the air traffic controller department arranged two distinct times for data collection to measure the noise level produced by the aircraft engines (identical engines): the morning and the afternoon. According to the guidelines of the airport's safety management, the period permitted for the work to conduct all measurements within the airport's boundaries was 30 days (daily) during the summer season.

3.3 The Measurement Position Determination

Due to the security restrictions of the Benina International Airport, the position that will be allowed in this work is about 15 meters from the plane.

3.4 Measuring the Noise Levels

Due to the high-security restrictions of the Benina International Airport, the time allowed to record the noise measurements is about 15 minutes per period (am or pm). Therefore, 3 readings were recorded for each period (1 reading every 5 minutes).
The Hand-Held Analyzer 2250 Light, a type 2250-L-D02 sound meter equipment (manufactured by Bruel & Kjaer Company), was used to record the noise measurements for this investigation.

4 Model Development, and Key Results

4.1 Factors and Response

The factors chosen (input variables in this study) in this study are the periods and days for measuring the noise. The response selected (output variable) in this work is the percent of permissible dose, which is calculated based on the formula (1), [12]:

$$D = 100 * \sum Cn \qquad (1)$$

Where,
D = percent of permissible dose
C_n = actual exposure in hours (in this study C_n = 2 hours based on the Benina airport data) T_n = Permissible exposure in hours

n = Number of periods with different noise levels

The Permissible exposure in hours (T_n) can be calculated according to equation 2, [12]:

$$T = 8 * 2^{(90-L)/5} \quad (2)$$

Where,
T = Permissible time in hours
L = A-weighted sound pressure level in dBA
Table 1 shows the design matrix which includes all data for factors and response.

Table 1. Design matrix

Std	Factor 1	Factor 2	Response	Std	Factor 1	Factor 2	Response
	A: Time (hr)	B: Day (weekdays)	Permissible dose (%)		A: Time (hr)	B: Day (weekdays)	Permissible dose (%)
1	AM	Tues	54.6	29	AM	Tues	51.0
2	PM	Tues	60.7	30	PM	Tues	68.9
3	AM	Wed	51.6	31	AM	Wed	56.1
4	PM	Wed	54.1	32	PM	Wed	55.6
5	AM	Thu	59.1	33	AM	Thu	50.7
6	PM	Thu	69.1	34	PM	Thu	88.4
7	AM	Fri	51.3	35	AM	Fri	54.1
8	PM	Fri	83.0	36	PM	Fri	90.8
9	AM	Sat	41.5	37	AM	Sat	35.5
10	PM	Sat	59.6	38	PM	Sat	75.4
11	AM	Sun	59.3	39	AM	Sun	68.0
12	PM	Sun	97.3	40	PM	Sun	81.2
13	AM	Mon	87.3	41	AM	Mon	86.3
14	PM	Mon	73.0	42	PM	Mon	61.0
15	AM	Tues	42.7	43	AM	Tues	55.6
16	PM	Tues	77.6	44	PM	Tues	68.5
17	AM	Wed	69.4	45	AM	Wed	47.3
18	PM	Wed	46.7	46	PM	Wed	52.1
19	AM	Thu	72.7	47	AM	Thu	53.8
20	PM	Thu	71.7	48	PM	Thu	92.4
21	AM	Fri	55.6	49	AM	Fri	44.1
22	PM	Fri	77.6	50	PM	Fri	80.8
23	AM	Sat	50.7	51	AM	Sat	38.2
24	PM	Sat	58.5	52	PM	Sat	40.4
25	AM	Sun	71.7	53	AM	Sun	73.0
26	PM	Sun	75.1	54	PM	Sun	79.7
27	AM	Mon	88.3	55	AM	Mon	87.3
28	PM	Mon	77.6	56	PM	Mon	70.5

4.2 Data Analysis

The data, as shown in Table 1, is analyzed using the method of design of the experiments, specifically two factors factorial categoric design. Design expert software (Ver.9) is utilized, and analysis of variance (ANOVA) is shown in Table 2. The model F-value of 12.87 implies the model is significant.

Table 2. Analysis of variance

Source	Sum. of Squares	df	Mean Square	F-value	p-value Prob > F	
Model	10841.15	13	833.93	12.87	< 0.0001	significant
A-Time	1949.80	1	1949.80	30.09	< 0.0001	
B-Day	5629.10	6	938.18	14.48	< 0.0001	
AB	3262.26	6	543.71	8.39	< 0.0001	
Pure Error	2721.31	42	64.79			
Cor Total	13562.47	55				
Std. Dev.		8.05	R-Squared			0.79934966325123
Mean		65.07	Adj R-Squared			0.73724360663852
C.V. %		12.37	Pred R-Squared			0.64328829022441
PRESS		4837.89	Adeq Precision			11.373417127054

"The "Pred R-Squared" of 0.6433 is in reasonable agreement with the "Adj R-Squared" of 0.7372; i.e. the difference is less than 0.2. "Adeq. Precision" measures the signal-to-noise ratio. A ratio greater than 4 is desirable. Here, the ratio of 11.373 indicates an adequate signal. Therefore, this model can be used to navigate the design space. To diagnose this model graphically, Fig. 3. shows how this model is adequate; in terms of (a): the degree of normality of the residuals, (b): the accepted range for the residuals vs. predicted, (c): the behaviour of the residuals vs. run, and (d): predicted vs. actual. The final equation in terms of actual factors is shown in Table 3.

Table 3. The final equation in terms of actual factors

Time	AM	Time	PM	Time	AM	Time	PM
Day	Tus	Day	Tus	Day	Sat	Day	Sat
Permissible dose =	50.97	Permissible dose =	68.90	Permissible dose =	41.49	Permissible dose =	58.48
Time	AM	Time	PM	Time	AM	Time	PM
Day	Wed	Day	Wed	Day	Sun	Day	Sun
Permissible dose =	56.12	Permissible dose =	52.11	Permissible dose =	68.02	Permissible dose =	83.33
Time	AM	Time	PM	Time	AM	Time	PM

Day	Thu	Day	Thu	Day	Mon	Day	Mon
Permissible dose =	59.08	Permissible dose =	80.42	Permissible dose =	87.26	Permissible dose =	70.52
Time	AM	Time	PM				
Day	Fri	Day	Fri				
Permissible dose =	51.27	Permissible dose =	83.05				

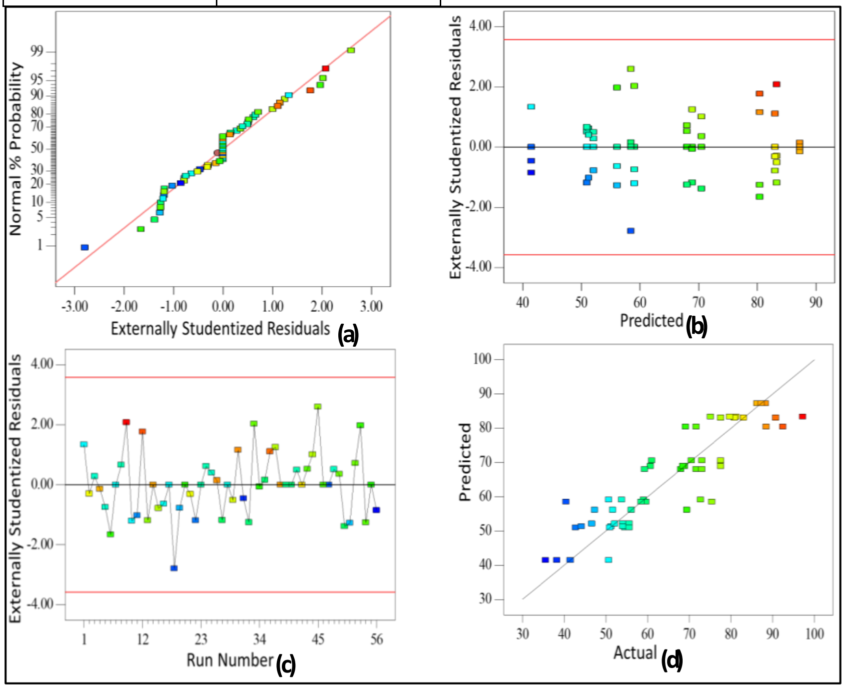

Fig. 3. Model diagnostics. (a): Normal plot of residuals, (b): residuals vs. predicted, (c): the residuals vs. the run, and (d): predicted vs. actual

4.3 Key Results

According to ANOVA analysis, permissible dose (%) as response has a significant model. This is due to all the adequacy measures being in logical agreement and indicating the significant relationships. Moreover, the model shows clear interaction between the factors, as shown in Fig. 4. (a, b, c). Based on Fig. 4. (a), the afternoon period “pm” has a higher permissible dose (%) than the morning period “am” on all days except Mondays; this is possible because the number of morning flights is more than the afternoon on Mondays. On the other side; there are differences between days regarding the permissible dose values as shown in Fig. 4. (b); this could be justified based on the weekly flight schedule. In addition, Mondays have the highest value of the permissible dose (%), this is possibly explained based on the weekly flight schedule as well as seen in Fig. 4. (c).

Even if noise levels vary during the week between the morning and evening hours, these levels are still regarded as extremely excessive when compared to the OSHA-recommended limit. The morning and afternoon Timeweighted average (TWA) values over weekly days, as displayed in Fig. 5, have dropped within the range of 8389 dB. OSHA (CFR 29 1910.95(, [12], states that this range is very harmful since prolonged exposure to noise levels of 85 dB can result in hearing damage [12]. Consequently, employees at the Benina Airport are subjected to high noise levels, particularly if they work long shifts.

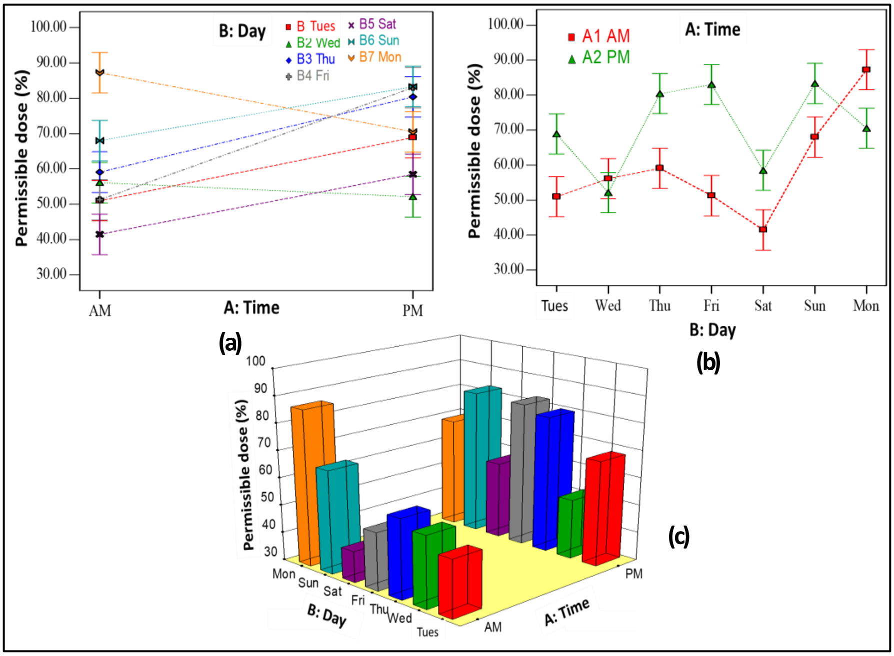

Fig. 4. Interactions. (a): Interaction x_1= time and x_2 =day, (b) Interaction x_1= day and x_2 = time, (c) 3D plot

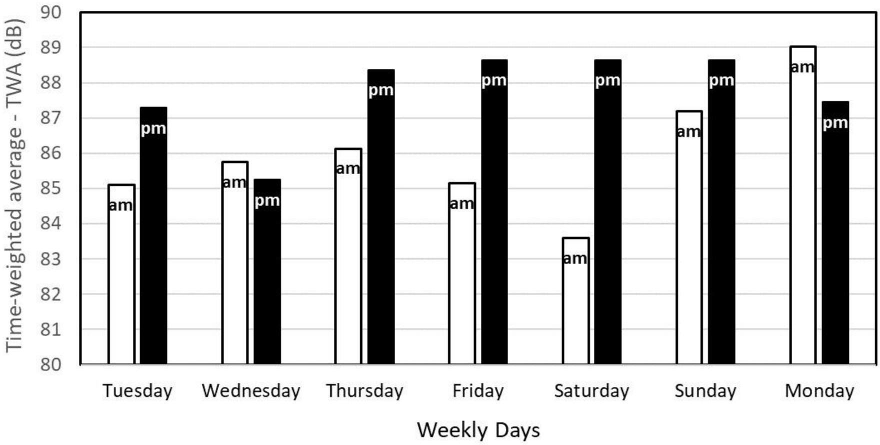

Fig. 5. Time-weighted average over weekly days

5 Summary and Remarks

This study focuses on a significant problem that airport personnel deal with exposure to loud airplane engine noises that significantly reduces hearing strength. This conclusion was reached based on the investigation's results, which were obtained at Benina International Airport in Benghazi. This is because the investigation's findings indicate that the noise level significantly exceeds the OSHA-permitted limit. Furthermore, the results clearly show that there are variations in noise levels throughout the weekly days. To highly reduce the risk of noise-related illnesses for Benina Airport employees, the following steps ought to be implemented:

- Altering flight schedules and allocating them properly.
- Increasing the number of work shifts and allocating them among various user groups.
- Using high-quality ear protection by specifications.
- Adhering continually to safety instructions.
- Using new technical devices to monitor and track noise levels regularly.

6 Future Works

Based on the constraints imposed by the Benina Airport management, including the fixed measuring period and location, it is recommended that further study be carried out while keeping the following factors in mind:

- This study can be repeated using different locations of noise measurements.
- This work can be performed in the winter to investigate the impact of noise on the different measurement times.
- It is advisable to examine the effects of noise levels produced by various aircraft engines because of the similarity of the aircraft engines that were available at the time of the study. An investigation in this regard should be conducted at Tripoli airport, where there are planes with various engines.

- Additional techniques, such as response surface methodology, fuzzy logic, artificial neural networks, etc., can be applied to data analysis to create appropriate prediction models.

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