

## **A MACHINE LEARNING FOR ENVIRONMENTAL NOISE MONITORING AND CLASSIFICATION USING MATLAB**

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### **Abstract:**

This project aims to make a case study using Machine Learning (ML) classification of sounds originating from the environment which are considered noise pollution in cities and compared them with the recommended levels by international standards such as the World Health Organization (WHO). The sound collection will be carried out using necessary sound capture tools before ML classification models are utilized for sound recognition. In addition to ML, noise pollution monitoring using MATLAB will be conducted to provide accurate results of sixteen different types of noise that have been collected in Malaysia in sixteen cities. The findings are expected to provide a guideline of the conducive environment for carrying out tasks in the presence of noise and recommend measures for noise mitigation under specific conditions.

**Keywords**—ML, MATLAB, WHO standers, Noise monitoring, Noise pollution

## INTRODUCTION

People's duties have had a significant impact on engineering and scientific careers in the last several decades. These obligations have been transferred to the preservation of public health and safety and medical treatment. To keep an eye on pollution levels, engineers and scientists have devised a variety of control measures. Activities and procedures that are necessary to keep an eye on environmental quality are outlined in environmental monitoring. To determine the state of a given environment or a certain environmental parameter, every strategy and approach has a rationale and a justification for being used. In this study, we provide a concept for employing IoT technology to monitor noise pollution. Affected areas are identified and mitigation and preventative measures are put in place. Controlling environmental noise pollution prevents cities from suffering from health difficulties, such as hearing loss. When a certain occurrence happens, the alarm or LED automatically warns you. Environmental changes and their consequences on animals, plants, and people may all be tracked and managed with the help of an advanced environmental monitoring system. An example of a smart environment application is the use of embedded intelligence to make the environment more interactive with other goals.

An unpleasant sound is referred to as a "noise." Extremely loud or obnoxious noise that disrupts. Machines and large vehicles generate the vast majority of ambient noise. Noise may have a negative influence on both human and animal health if it is constantly being broadcast. Among the most common causes of nuisance noise in residential neighborhoods are loud clubs and parties, as well as heavy equipment, construction, and other loud noises like those. Some of the adverse side effects of noise pollution are cardiovascular illness; mental stress; task interruption; tinnitus; hearing impairment; and sleep disruptions. The Committee on Noise Pollution Control has established acceptable limits of noise in residential areas of 55 decibels (dB) during the day and 45 decibels (dB) at night. At work, noise levels of 70-75 dB are considered tolerable. The World Health Organization has set a maximum noise level of 50 decibels (dB) for residential areas (WHO). According to research, sound pollution is more common in low-income and industrial minority areas. When excessive noise levels are combined with nutritional deficiencies, the results will be much more severe.

Swedes, who comprise 85 percent of the population, are adversely affected by noise pollution. What we call "noise" is a general word for any sound that is considered to be unwanted. There should be no more than 30dB in the bedroom and 35dB in the classroom for a good night's sleep, according to the World Health Organization (WHO). Noise pollution may increase the risk of heart attack, obesity, sleep deprivation, and mental health issues. Every five years, the EU member states are required by END 2017/49/EC to undertake an environmental noise assessment and provide noise maps. Noise monitoring is necessary when noise sources (such as traffic or construction sites) are constantly changing. It's impossible to keep track of how much hazardous noise there is in the environment every five years. Depending on the volume, the same dB level of sound might be either an annoyance or a soothing musical accompaniment. The present state-of-the-art systems just measure the dB

level of noise, but it is essential to go beyond this to determine the kind of noise. The police and environmental protection authorities in a city need to know precisely what's creating a gunshot sound if it's detected in the middle of the night. E-Health (electronic health records) and noise pollution in smart cities might benefit from the Internet of Things (IoT).

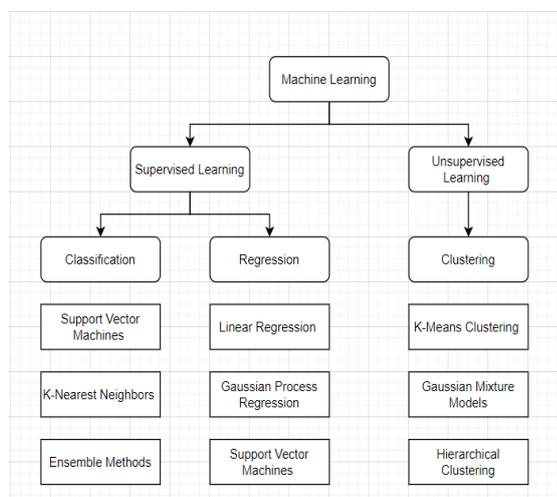
### **MACHINE LEARNING METHODS FOR SOUND CLASSIFICATION**

There, an SVM-KNN hybrid classifier was utilized, which utilized the MPEG-7 audio low-level descriptor as a sound feature. It was tested on 12 different types of noises. According to Khunarasal et al [1], there are 20 distinct types of extremely short-term noises. MFCC, MP, LPC, and Spectrogram were some of the audio characteristics examined in the research, along with KNN and neural networks.

### **MACHINE LEARNING KINDS**

If a computer program's performance on tasks in a certain task category increases as a result of experience, it is said to be learning from that experience. This definition of machine learning is provided in Mitchell [2]. For the most part, there are two kinds of machine learning techniques: supervised and unsupervised.

- Supervised learning: “learning techniques that build and train a model based on a known set of data (input and output) to predict the outputs of new data in the future. Supervised learning problems are divided into classification and regression problems.
- Classification: supervised learning technique that is used to predict qualitative responses, such as a color or disease.
- Regression: supervised learning technique that is used to predict quantitative responses like weight.
- Unsupervised learning: in contrast to supervised learning, unsupervised learning techniques are based only on input data, without corresponding output.
- Clustering: similar to classification, clustering techniques are used to group a set of input data based on the relationship between this data, such as grouping clients by their purchasing behavior.”

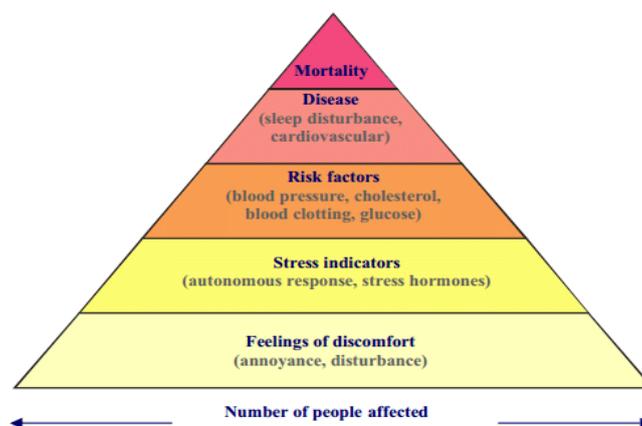


**Figure. 1. Machine Learning and its subtypes**

## OVERVIEW

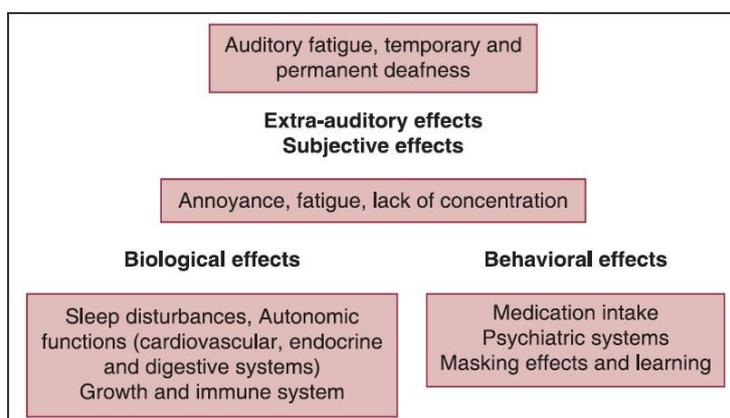
Among the topics covered in the research’s background material are smart cities, IoT, and machine learning (ML). In addition to vehicles, trains, and airport runways, there are many sources of noise pollution in the form of household and industrial activities. [1] Noise pollution increased along with urbanization and industrialization, as people migrated from smaller to bigger dwellings. The disruption of social connections that environmental noise causes may result in a variety of health problems, both mental and physical. Noise levels between 85 and 90 decibels have the potential to damage hearing and alter threshold sensitivity (dB). Discomfort reactions are closely connected to the number, variety, and intensity of daily activities. Table 1 summarizes some typical levels of background noise. Ecological breaks might be ascribed to street transportation commotion, which is to a great extent made by frictional contact among vehicles and air, between tires on street surfaces, or the moving clamor of a motor at speeds over 50 kilometers each hour for traveler vehicles.

Cafés, cafeterias, discos, as well as games, jungle gyms, vehicle leaves, homegrown creatures, as well as ventilation frameworks, office hardware, and family devices like TVs and radios, are possible wellsprings of commotion in the home. Many sorts of modern commotion might be upsetting to the work environment, including clamor made by apparatus, high-velocity dull movements, stream actuated endlessly commotion delivered by hardware including warmers, generators, and electromechanical frameworks (EMS). Table 2 shows the most extreme reasonable sound level (LAeq) given the getting zones. The well-being effects of commotion contamination are displayed in a pyramid in Figure 1. Also, there are plenty of countless, wide, tenacious, combined, and expanding synergistically and inimically inconvenient results.



**Figure. 2 World Health Organization pyramid of health effects**

Increases in blood pressure (hypertension), peripheral vasoconstriction (swelling), and cardiovascular illness have been associated with exposure to ambient noise, according to research (hypertension). [2] According to the findings of some scientific studies [3], chronic exposure to the noise of airplanes may harm children's reading comprehension and long-term memory. Furthermore, excessive noise levels in industrial environments have been linked to nausea, headaches, argumentativeness, and the modulation of mood and anxiety. It has been shown via epidemiological study that a level of irregular traffic noise equal to or more than 45 dbA is disruptive to day-to-day activities such as sleeping and relaxing. Additionally, it changes the blood's composition and decreases tolerance. [4] Hearing loss, gastric discharge, pituitary/adrenal stimulation, suppression of immune response, and difficulties with female reproductive health and fertility are all potential side effects of anxiety brought on by exposure to road traffic. According to the findings of scientific research, the cumulative impact of several noises is greater than the total effects of individual stressors, such as sustained sympathetic arousal or emotions of helplessness. This is the case when comparing the two.”



**Figure. 3. Auditory and extra-auditory effects of noise**

**TABLE 1:  
SOME NOISE LEVELS COMMONLY OBSERVED IN THE DAILY LIFE**

“Noise Level (dBA)	Activity
0	Threshold of hearing
38	Library
40	Living Room
58	Conversational Speed
66	Business Office
80	Average Street Traffic
100	Pneumatic Chipper
125	Firecrackers
140	Jet take-off (25m) and threshold of pain”

**TABLE 2:  
THE MAXIMUM PERMISSIBLE SOUND LEVEL (L<sub>AEQ</sub>) ACCORDING TO  
RECEIVING ZONES**

Category	Noise Level, L <sub>eq</sub> (dBA)	
	Daytime	Night-time
Noise sensitive area, low density residential institutional (school, hospital) worship areas	50	40
Suburban residential. Medium Density Areas, Public Spaces, Parks, Recreational Areas	55	45
Urban Residential, high-density areas, designated mixed development areas (commercial)	60	50
Commercial Business zones	65	55
Designated Industrial zones	70	60

Ten million adults and five million children in the United States have permanent hearing loss due to environmental noise, according to World Health Organization (WHO) estimates, and 250 million people worldwide are exposed to harmful levels of environmental noise every day [5]. Despite the well-documented disruption caused by environmental noise, these noise concerns, particularly in Malaysia, have long been taken for granted in developing nations. Therefore, this narrative evaluation aims to evaluate the dynamic pressure, significant issues, and relevant mitigation strategies of Malaysian noise control approaches. Noise monitoring and modeling are explained in this approach. In addition, the conservation program and control mechanisms for the promotion of the best noise management practices are specified. Analysts have taken a gander at the issues brought about by long-haul openness to traffic clamor at the Sungai Besi Toll Collection Plaza, a cost assortment office in Seri Kembangan, Selangor, by a workforce of the expressway cost square, street groups, and an interstate investigator. [6] Over five days, 20 tollgates were exposed to clamor openness testing utilizing sound level meters and commotion dosimeters by the word related openness inspecting methodology manual and ISO 9612 Acoustic Guidelines [6-7] created by the National Institute of Occupational Safety and Health (NIOSH). One hundred and seventy-one employees took part in the survey, which was separated into four sections: demographics,

workplace data, perceptions of noise, and symptoms of possible NIHL. The findings showed that most toll takers were at high risk of NIHL and discomfort as a result of long-term exposure to noise levels that were potentially harmful to their hearing. It was found that the average continuous equivalent level of noise exposure was 79.2 dBA, with the highest level of noise exposure being 107.8 dBA and the peak level being 136.6 dBA. Hearing protection devices (HPDs), monitoring programs, training, and audiometric testing were all recommended, as were engineering and administrative controls, as well as enforcing regulations governing Environmental Quality (Motor Vehicle Noise). Other toll plazas with a large amount of traffic and risk of noise exposure might benefit from the results of this study.

TRS is an incessant methodology of making street clients aware of a roadway-changing climate by delivering over-the-top vibration, beating, or rash commotion that sounds like a sled being thumped, fireworks, or a blast. Hence, in Kg. Batu 30 of Pengkalan Raja, Pontian, Johor, Haron, et al. [1] investigated the outer clamor made by the establishment of thunder strips in a provincial settlement region with a populace of 60 local residences and anticipated the aggravation response because of TRS establishment. Pulsar sound level meters and sound level calibrators were utilized all through the request to screen commotion levels at the two locales where TRS was introduced and where it was not. The factual levels L10, L50, and L90, which address percentile levels outperforming 10%, half, and 90% of the passed time, were applied to the drive or fluctuating commotion level, and the relating ceaseless equivalent energy level (LAeq) was estimated. With the expansion of TRS, the LAeq, L10, L50, and L90 dBA levels noticed were 82, 78, 73, 54, and 67 dBA, separately, as indicated by the outcomes. Nearby neighbors made a move and voiced their dismay with the establishment when the outcomes were unveiled.

The table below summarizes the impact of traffic noise on traffic staff and neighboring inhabitants. In the light of this research, there is an urgent need to raise awareness, understanding of OSH, attitude, and practice about PPEs. It was also recommended that a noise monitoring program be put in place as well as training, audiometric testing, technical and administrative controls, and the enforcement of environmental quality rules. The installation of rumble strips and the development of the airport have brought attention to the exterior aggravation they cause. As a result of these discoveries, society and individuals may better arrange road traffic so that the most vulnerable members of society are kept as safe as possible. Noise Control Act, Aircraft Noise Policy, and Aviation Noise Abatement Policy were all established in the United States to reduce traffic and construction noise. The  $L_{Aeq}$  of 67 dB was set to protect local people during peak traffic hours. The European nations and urban areas have applied different mandates in regards to commotion outflows from different sources, like engine vehicles, railroad frameworks, airplanes, domestic devices, and outside hardware, to draw vital clamor maps for the appraisal of commotion from significant transportation foundations and networks with more than 100,000 occupants. There are natural quality guidelines for a wide range of traffic commotion in Japan, as well as ecological principles in Australia that determine the greatest clamor levels for different classes of engine vehicles, as well as the testing philosophies. Many nations' commotion regulations and

overall clamor guidelines still can't seem to be refreshed to incorporate stricter measures and commotion impediments. Because of a rising populace, traffic, and residents' craving for superior personal satisfaction, the diminishing in a street vehicle and airplane clamor has not been reflected by the drop in beneficiary commotion levels. The safety, health care, and well-being of employees in the workplace are all addressed by occupational safety and health, which is a multidisciplinary field. There are several negative impacts of industrial and occupational noise, such as higher blood pressure, impaired performance, sleep problems and irritation and stress as well as tinnitus and NIHL. A study of public opinions and understanding of sewage treatment plant odor, noise, and the visual effect was conducted in selected regions of Selangor and the Federal Territory of Kuala Lumpur, according to the viewpoint. It took two weeks to survey 225 families in 22 housing estates, with the majority of respondents having at least elementary education and 84.9 percent having secondary education. Inquiries were made about the reasons why people are concerned about living near sewage treatment facilities. To get a better picture of the current situation, we spoke to several house developers. A significant psycho-environmental component impacting the public's acceptance of the sewage facilities was found to be industrial noise created by electrical motors and pumps, aerators, revolving discs, and the splashing of water. 30 percent of those polled could not name sewage treatment systems, and an astounding 59% of them had no idea what a treatment system was supposed to do, according to the report.”

### **Previous Works**

For the German examination project named StadtLärm, Goetze et al. [8] present an outline of a stage for appropriated metropolitan commotion evaluation. An ARM BCM2837 quad-center SoC-based appropriated organization of sound sensors was utilized to accumulate metropolitan clamor signals, preprocess the got sound information, and convey it to a focal unit for information capacity and more elevated level sound handling. At long last, the web application was used to show and oversee both handled and crude sound information. To picture commotion contamination, a few specialists have utilized Ameba RTL 8195AM and Ameba 8170AF IoT frameworks. Remote-Invent hubs were analyzed as far as cost and common sense for surveying metropolitan commotion and estimating psycho-acoustic measurements utilizing Zwicker's disturbance model regarding cost and achievability in the review. As opposed to earlier work, our strategy centers on utilizing an IoT gadget to quantify commotion levels in decibels (dB) instead of a foundational model and perception.

[9] According to Moukas et al., their Automatic Noise Monitoring System is the industry's finest noise monitoring apparatus, and it can measure both the level of noise and the amount of time it lasts. Can be used to record the occurrence of sounds Often, their origins remain a mystery. They highlight research aimed at producing better instruments that can detect sound sources. According to Mudakam et al., technology advancement and progress may lead to major turning points [10]. In the early days following the entrance of IT and ITeS technologies, human everyday life and working circumstances in businesses undergo a sea shift. There has been a significant increase in the number of devices connected to the Internet of Things [IoT]. There are a lot of businesses that need to be studied and conquered.

[11] Neshwa Al. Bendari and her colleagues claim to have devised a method to cope with the notion of a smart network of sensors. It is also a new area of study that incorporates some of the issues raised in the problem statement. The fields of computer science, wireless communication, and electrical design face several difficulties. The use of wireless technologies to monitor noise levels in an industrial setting is of particular importance here. A complete evaluation of the hardware and its components is made using the Arduino UNO board, sensor, and its accompanying components.

[12] As per Martina Marjanovic and associates, the exploration is centered on growing fine-grained guides of contaminations and clamor to distinguish metropolitan regions that impact human wellbeing. From sensor adjustment through information gathering and handling, we show how a genuine framework is conveyed. Hearing loss, stress, blood pressure fluctuations, migraines, sleeplessness, nervous system disorders, productivity restrictions, mental health issues, and other challenges are some of the negative health effects of noise pollution. A system for detecting noise pollution and keeping tabs on its impact on human health that combines a Wireless Sensor Network (WSN) with a Body Access Network (BAN). Using the WSN and BAN networks, scientists may learn about the dangers of excessive noise and how it affects people's health.

[13] A new technology developed by Kulkarni Chaitanya et al. can identify dangerous chemicals and loud noises. Air and sound pollution may also be detected using this technology, which is a brand-new idea. This system's primary function is to monitor the environment. MQ135 and a microphone sound sensor are the sensors that we're utilizing in this application. An air quality sensor called Sensor MQ135 is used to detect NH<sub>3</sub>, CO<sub>2</sub>, and SO<sub>2</sub> as well as other dangerous gases. The MQ135 sensor picks up on the situation and sends a signal to the control unit.

[14] Internet of Things-based solutions has been presented by Piyush Patil to address these issues. Because our system keeps track of vehicle pollution and noise levels, those that go beyond a preset limit are immediately reported to the appropriate authorities, including the traffic department and environmental organizations.

[15] A smart city has been suggested by Dr. A. Sumithra and others. Using sensors and modules, they were able to monitor a wide range of environmental conditions. The data is monitored and sent to the cloud server using air and sound sensors. Cloud storage is responsible for storing and analyzing the data that is collected.

To help potential homebuyers, Thomas Zimmerman and Christine Robson have come up with a noise model and data visualization tools. The Resident's nighttime noise is represented as an ambient sound source, and researchers are attempting to determine the extent of its influence. After then, the phase's final execution attempts to notify users through SMS. Additional functionality has been added to this system. A quantitative study of the noise environment is provided by the noise analysis output supplied through SMS text messages when the peak value is reached. The noise model has been implemented via the creation, calibration, and verification of a device. The physical propagation model is the first approach

for predicting noise from a distance, using the distance between the sound source and the predicted noise location point as well as the physical qualities of the sound source. Several industrialized nations have been doing extensive research on airport noise control since the 1960s, including the FAA's Integrated Noise Model (INM), UK's Aircraft Noise Contour (ANCON) model, and Switzerland's Fluglaerm (FLULA) program. Predicting ambient noise has necessitated research on the spatial propagation of noise. It is possible to design a noise distribution by using the propagation model of noise attenuation [16]. There have also been investigations on the most effective locations for noise monitoring stations [17]. Physical propagation models are seldom used in investigations looking at the temporal variance of urban noise.

The factual methodology is the second sort of clamor forecast strategy. Indeed, even after only a couple of long periods of information, Kumar and Jain [18] proposed an autoregressive incorporated moving normal (ARIMA) model for traffic commotion time series expectation. Furthermore, a bigger time skyline is demonstrated to be ideal while investigating the time series. An examination of long-haul information from clamor checking led by Garg et al. [19] demonstrated that the ARIMA approach is solid for time series displaying of traffic commotion, albeit different situations need changing fundamental boundaries. As per Gajardo et al. [20], a Fourier examination of the traffic commotion of the two urban areas of Cáceres and Talca, bigger occasional parts and plentifulness values are comparable in various examples no matter what the estimation climate of the city and the relating traffic stream, which shows that metropolitan traffic clamor can be anticipated. Relapse models have additionally been utilized to anticipate the level of commotion in bound modern conditions through the ruling recurrence limit." The machine learning approach falls under the category of noise prediction methods. When simulating traffic noise, [26] used a backpropagation neural network. Wind turbine noise was predicted using a random forest regression approach by Iannace et al. [21]. Using feature extraction and machine learning approaches, Torija and Ruiz [21] were able to accurately estimate the level of ambient noise. It's difficult to arrange the data since there are 32 input variables and the difference between them is subtle.

Several factors go into predicting ambient noise, including historical and real-time monitoring data. Frank et al. [22] found that integrating the rules or patterns extracted from monitoring data with the acoustic theoretical calculation model improves the prediction accuracy of noise significantly. Based on concerns about conserving resources and increasing data gathering efficiency, certain sampling procedures have been proposed to better represent regional noise levels. Considering the time savings and the accuracy of the findings, Giovanni et al. [23] observed that a non-continuous 5- to 7-day noise observation is adequate for long-term noise prediction. Controlling urban noise may have a scientific foundation if its temporal volatility can be predicted. Using sound level meters and sensor networks, ambient noise data has grown exponentially in recent years, thanks to these advancements. Although noise measurement, prediction, and control have been studied in the past, most of the study data is small. With this newfound motivation came the idea of reconsidering environmental noise prediction, specifically whether or if there are better models and ways for processing

large amounts of noise data. A more efficient method is needed to forecast noise in the temporal domain. Despite this, few studies have examined and forecasted the variance in noise over a single day. [24]

Recent years have seen the fast development of deep learning and its effective use in a wide range of fields [25]. As a result, they may identify a vast number of structures in a dataset by using multiple-layer structures or deep architectures [26]. As a result of the research into artificial neural networks, deep learning has been developed. Multiple-layer perceptrons, convolutional neural networks, recurrent neural networks, and so on are the most prevalent models of neural networks. [27] Using RNNs for time series is a common method for describing hidden states and capturing data properties. Simple RNN, on the other hand, has issues with long-term dependency and is unable to efficiently use past knowledge collected over extended intervals. LSTM networks have been developed to solve the gradient disappearance problem, and they have been used for a variety of applications including stock price forecasting [35], air quality monitoring [28], sea surface temperature monitoring [29], flight passenger count monitoring [30], and automatic speech recognition. The model's performance was shown to be good, as shown by the outcomes.

## ENVIRONMENTAL NOISE MODELING AND MONITORING

As sound and noise sources, collectors, and forecast models get more refined, improving general wellbeing and personal satisfaction is turning into a more troublesome undertaking because of the developing requirement for computational observing and reenactment. The utilization of clamor expectation models is basic in assessing current traffic, rail, air terminal, industry, and metropolitan arranging configuration plans. A concentrate by [3] in Lahad Datu analyzed the degree of foundation commotion and the essential wellsprings of clamor in a few Malaysian areas, including JanaManjung, Perak, Tangga Batu, Melaka, Terengganu, and Lido, Johor, which address West Peninsular Malaysia, Mid-West Peninsular Malaysia, the East Peninsular Malaysia, and South Peninsular Malaysia, individually.”

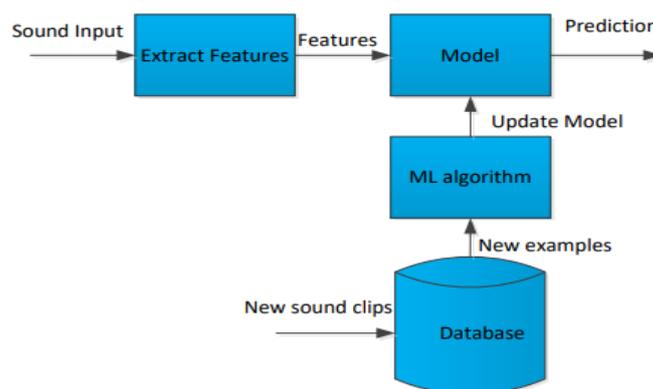


Figure. 4. ESR System

Gauge sound levels were estimated throughout the constantly during two separate times, and commotion descriptors like L10, L90, and Leq were recorded for every period. Perak, West

Malaysia, Tangga Batu, Melaka, and Mid-West Malaysia, all recorded the most minimal constant time Leq upsidings of 75.5 dBA, separately. As a source of perspective and rule for a future regulation on commotion constraints in Malaysia's metropolitan districts, these measurements may be significant. Scientists and policymakers at Malaysia's Department of Environment who manage commotion contamination in natural effect appraisals (EIAs) may significantly profit from this review.

Models of noise nuisance are used to determine the level of noise that will be generated by a planned road or highway or rail line, airport, industry, or settlement. Models for predicting single-vehicle sound pressure have been developed since the 1950s using speed measurements to estimate traffic noise. The Handbook of Acoustic Noise Control published the first model for reducing noise pollution caused by automobile traffic. A noise exposure map may be created with the use of computer graphics applications to show the projected noise levels."

To simulate outdoor noise propagation from sources with varying shapes and power distributions, two researchers adopted an adaptive three-dimensional Gauss-Legendre Quadrature approach based on the diffused-field theory. To match the shape of the sound source with the created shapes, the geometry of the sound source has been taken into consideration. Lines, planes, and three-dimensional blocks are just a few of the many possible shapes and sizes that may be used to represent the noise sources in an array. To most people in the real world, an average loudness variation of 1.2 decibels (dB) is considered realistic. Many EIA studies in Malaysia have used this mathematical technique, all of which came up with positive results.

The mathematical formalism does not support the assumptions made about the link between noise and productivity based on genuine surveys. A need to model the links between noise and operating efficiency has evolved. Long-term health impacts of noise pollution may be predicted utilizing the noise intensity, exposure time, and operator age in combination. The noise level of a lawn trimmer, a common piece of equipment used in Malaysia to maintain grassy fields, was tested. At 2, 5, and 8-hour intervals, a total of 300 workers were observed and their ages, exposure durations, tasks completed, and overall performance were recorded. It was proposed that the modeling system use an IF-THEN rule set divided into four stages: identifying input and output variables, selecting input and output variables, determining functions for input and output variables, and creating the ruleset. An exposure limit for industrial employees was set based on the results. The data reveals a link between working time and noise level, with the decline happening between 85 and 115 dBA showing a logarithmic decrease in working efficiency. Systems for noise monitoring and modeling are critical in predicting the effects of noise pollution and generating valuable real-value outputs from on-site monitoring data, as these studies demonstrated. This was made possible by the use of noise monitoring and modeling techniques.

## MATLAB RESULTS

MATLAB stands for Matrix Laboratory which is open-source software. Open-source software means that a user doesn't have to buy the software, rather than that the user can easily develop and run the code.

### RESULTS OF MONITERING THE NOISE POLLUTION SAMPLES

Table 3 shows the samples of sounds that have been captured in several places in Malaysia at different times during the day hours using the noise capture.

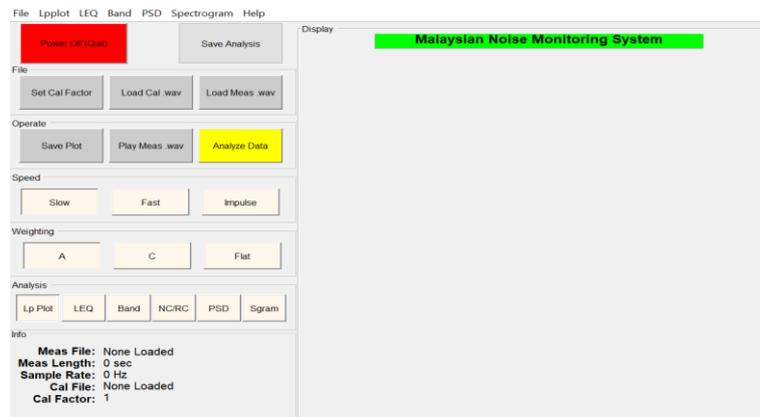
**TABLE 3 SAMPLES OF SOUNDS**

No	Class	Sample	Duration (Min.)
1	Johor_mall	44	128
2	Kedah_beach	39	44
3	Kelantan_Police Headquarters	9	28
4	KualaLumpur_Sea waves	23	73
5	Labuan_wind	35	93
6	Melaka_RESTAURANT	22	43
7	Negeri Sembilan_usine	13	78
8	Pahang_stade	71	49
9	Perlis_birds	45	78
10	Perak_cars	32	95
11	Pulau Pinang_hotel park	56	61
12	Putrajaya_rain	98	102
13	Sarawak_reaver	76	88
14	Selangor_forest	54	87
15	Trengganu_thunder	43	72
16	Sabah_airoport	213	4322

For a noise-monitoring system, a detailed algorithm is developed. Firstly, a GUI is developed. The GUI consists of various buttons. The first button is to power/switch OFF the GUI and goes to the main page. Another button is to add the .wav (waveform audio file) to the MATLAB and then the algorithm will work on it to identify the noise level ( $L_{eq}$ , etc.). Moreover, the noise can also be played in MATLAB.

After that, the GUI is divided into two different weightage categories i.e., time-weightage and frequency weightage). The waveform file can also be displayed as graphs of A-weightage, C-weightage, and Impulse weightage. In addition to this, the waveform can also be generated as slow and fast.

A complete GUI is developed which is shown as under:

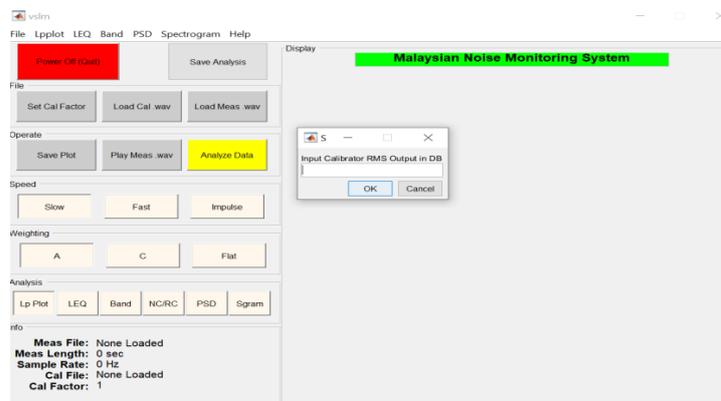


**Figure. 5. Graphical User Interface” GUI” Simulation Result**

At the last, analysis buttons are used to perform an analysis of the noise. 6 different types of analysis are performed. Lp Plot, LEQ, Band-width, NC/RC, PSD and Spectrogram are the analysis that can be performed by this system. The plot axis and calibration factor can be adjusted from the top bar. Lp Plot is used to figure out the noise levels (decibels) at different points and plot a graph. LEQ is the equivalent continuous sound level. NC/RC is the Noise Criteria to Room Criteria. PSD is the noise density of the waveform. PSD Plot is power spectral density. It is mainly used to specify the average power of noise at several frequencies. The spectrogram plot identifies the time, frequency, and amplitude of the sound in one plot and it is seen in colors. The red color shows that it is a loud noise and the green color tells that the noise is fine. The plots can be saved on any folder as well.

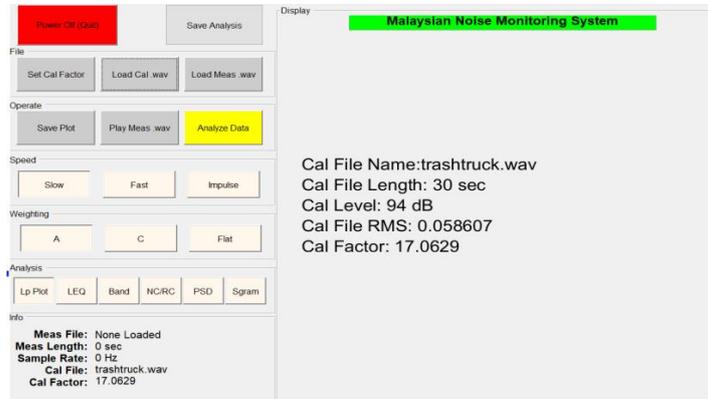
Each button has its callback function generated by MATLAB in the code. The three main parameters of the callback function are object, event-data, and handles. All of these help to maintain the data, store the data and then display the data in the form of figures and graphs.

In this part, the GUI is simulated and results are performed. 1-2 waveforms are implemented in the GUI and six different analyses are performed three main results are stated above.



**Figure. 6. Setting calibration level**

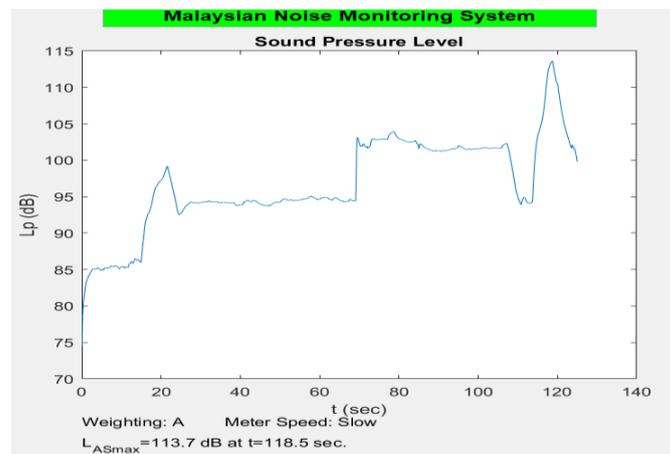
The calibration level is set to 94dB. Usually, it is between 94 to 114 dB.



**Figure. 7. 94dB Calibration level**

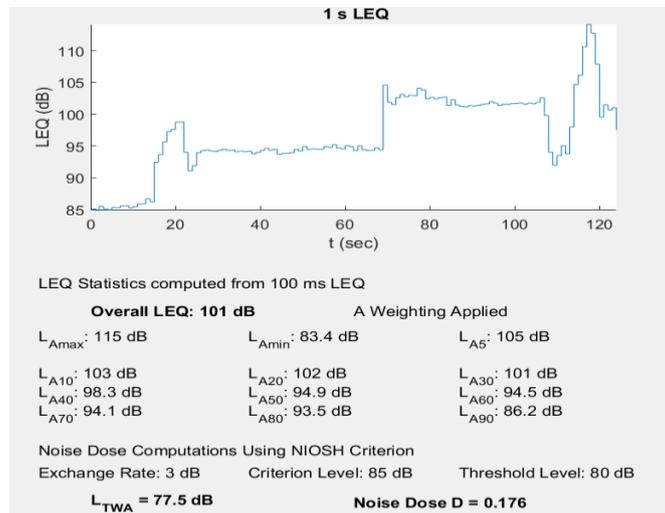
### Lp Plot

The above truck data is analysed and the Lp Plot was selected from the above GUI. Lp is also known as SPI in noise monitoring. It is a function of the source and its surroundings and is a measure in decibels of the total instantaneous sound pressure at a point in space. The SPL can vary both in time and in frequency. The result of the Lp Plot is as follows:



**Figure 8. Lp Plot (Slow)**

Lp Plot results were determined by the system. The maximum noise level was 113.7dB at 118.5 sec. The lowest level was 75 Db at the start of the sound. After that fast data set was selected. In fast response, the data is monitored at a faster rate and in depth as well which gives clearer results. The maximum level noted was 114.8 dB.

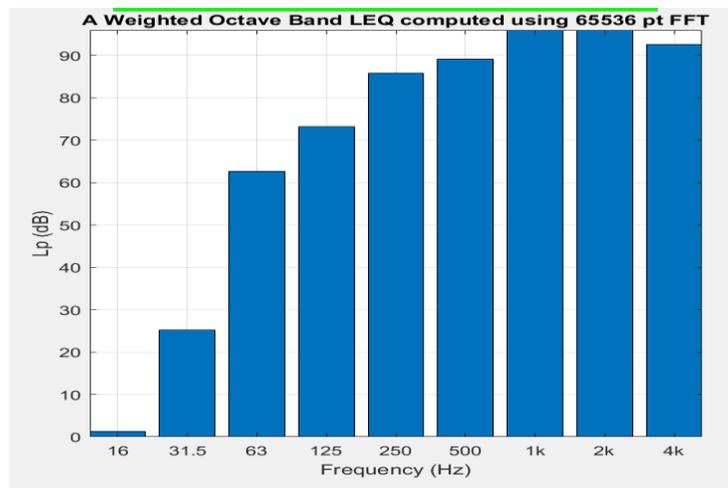


**Figure. 9. LEQ Plot**

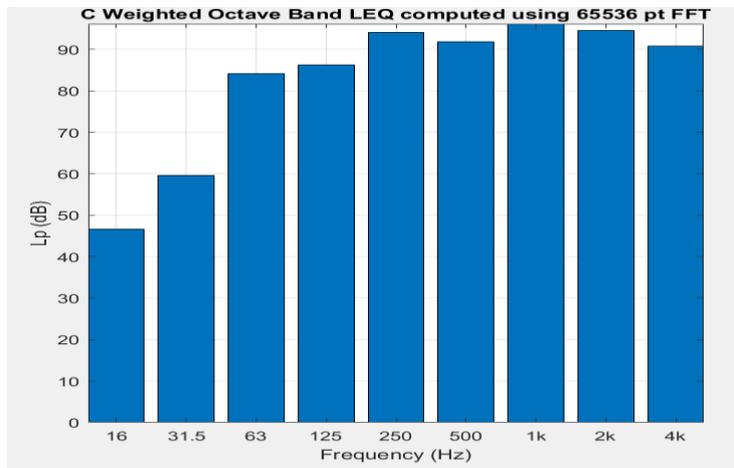
LEQ Plot shows noise levels at different seconds and calculates the average. The average of the above sound came out to be 101 dB. Maximum and Minimum levels were 115 dB and 83.4 dB respectively.

**Band-Levels**

Band levels are basically the histogram of Lp Plot versus frequency of noise. Band levels for the A and C weightage plots are as follows:



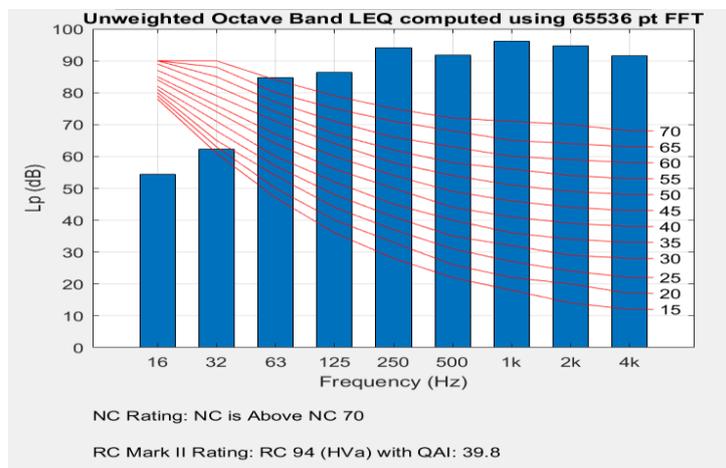
**Figure. 10. Band-Levels for A weightage**



**Figure. 11. Band-Levels for C-weightage**

The above results showed that there is only a slight difference between A and C weightage plots on some frequencies. For A weightage plot, the maximum Lp was recorded as 100 dB at 1k and 2k Hz frequencies. For C weightage plot, the maximum Lp was recorded as 100 dB at 1k Hz frequency.

**NC/RC Plot**

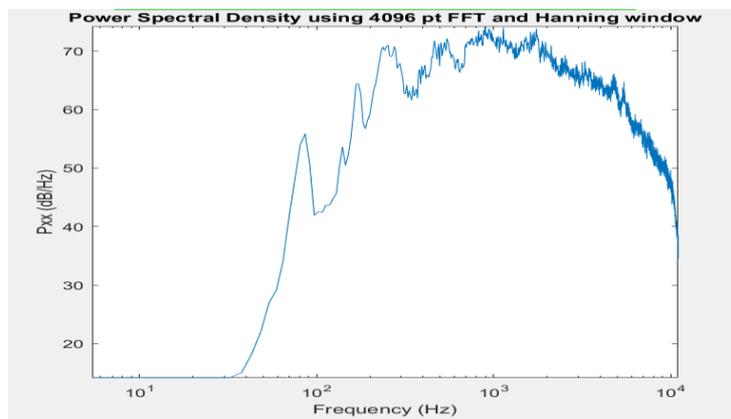


**Figure. 12. NC/RC Plot**

The Noise Criteria (NC) defines the maximum noise levels that can be present in each octave band of noise in order to meet a certain Noise Criteria. For frequencies spanning from 16 to 4000 Hz, the Room Criteria (RC) is used to measure background noise in buildings. Room Criteria (RC) is a noise measurement system that evaluates background noise in buildings at frequencies ranging from 16 to 4000 Hz. So, NC is divided by RC to get NC/RC Plot for the monitoring system. In this noise case data, NC/RC is above 70.

## PSD

A significant approach for identifying harmonics and electromagnetic emissions in a circuit is noise power spectral density (PSD) analysis. PSD denotes the power of noise signals spread out over a frequency range. By dividing the noise power by the measurement bandwidth, which is the noise equivalent power (NEP) bandwidth of the bandpass filter around the noise frequency, the noise power spectral density (PSD) is derived. By monitoring power/ground noises, PSD plots conserve signal/power integrity in circuit architectures.

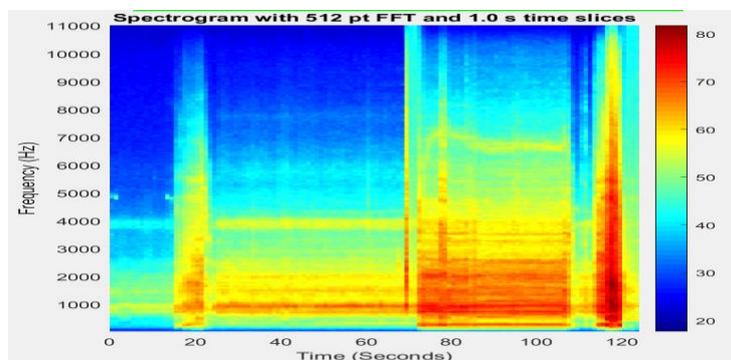


**Figure. 13. PSD Plot**

For above PSD Plot, the maximum Pxx is around 80 dBHz at around 103 Hz frequency.

## Spectrogram

Music, linguistics, sonar, radar, speech processing, seismology, and other fields rely heavily on spectrograms. Audio spectrograms can be used to phonetically detect spoken words and examine animal noises. A spectrogram is a visual representation of a signal's signal strength, or "loudness," across time at different frequencies in a waveform. The spectrogram is as follows:



**Figure. 14. Spectrogram (Slow and A-weightage)**

So, the above spectrogram tells that 80 is red color and is harmful to a person whereas 20 is the lowest level and ideal for hearing.

## **RESULTS OF TRAINED DATA USING ML IN MATLAB**

In the above case, the noise for a particular data was monitored. In this step, the data was taken from Noise Capture App available in Playstore. The data was downloaded for Malaysia. After that, geojson file was converted to readable file for noise classification model in MATLAB. Results of the samples that have been monitored can be now classified using our Machine learning on MATLAB as the following:

### **Prediction model**

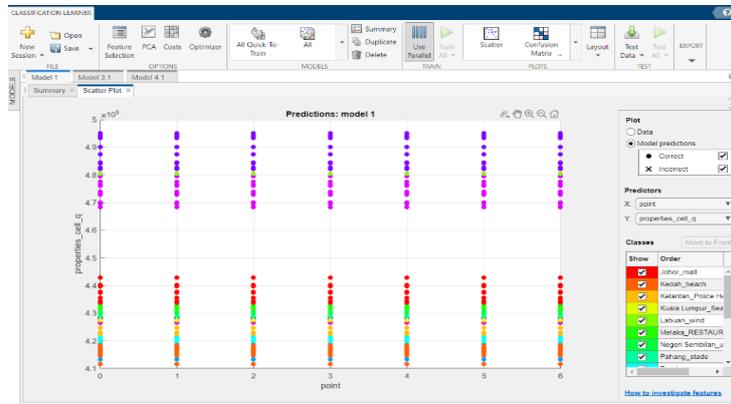
Predictive modelling is a mathematical procedure that analyses patterns in a set of input data to anticipate future events or outcomes. It's an important part of predictive analytics, a sort of data analytics that forecasts activity, behavior, and trends using current and past data.

Traffic noise prediction models are used to aid in the planning of highways and other roadways, as well as to assess current and anticipated changes in traffic noise conditions. They are frequently required to anticipate sound pressure values set by government bodies in terms of L10, etc.

The steps performed by the prediction model were as follows:

- Remove outliers and address missing data to clean up the data.
- Determine whether to utilize a parametric or nonparametric predictive modelling technique.
- Pre-process the data to make it acceptable for the modelling algorithm you've chosen.
- Specify a subset of the data to be used in the model's training.
- Model parameters are trained, or estimated, using the training data set.
- Check model adequacy using model performance or goodness-of-fit tests.
- Validate the accuracy of predictive modelling on data that was not used to calibrate the model.

This prediction model, firstly classified all the sound files and divided them into the relevant area from where they were heard i.e., Johor Mall, Kedah Beach, Kuala Lumpur and many more.



**Figure. 15. Prediction model**

This model predicted the noise levels at different locations. Most of the noise was heard at Johor Mall which is depicted in red color and the lowest noise level is in blue color. This model proved very helpful as it first classified the data of different locations and then arranged them in ascending order.

### Validation ROC Curve

The Receiver Operator Characteristic (ROC) curve is a binary classification issue evaluation metric. It's a probability curve that displays the TPR against the FPR at different threshold levels, thereby separating the 'signal' from the 'noise.' Furthermore, ROC curves are widely used to depict the relationship/trade-off between clinical sensitivity and specificity for each feasible cut-off for a test or a set of tests in a graphical format.

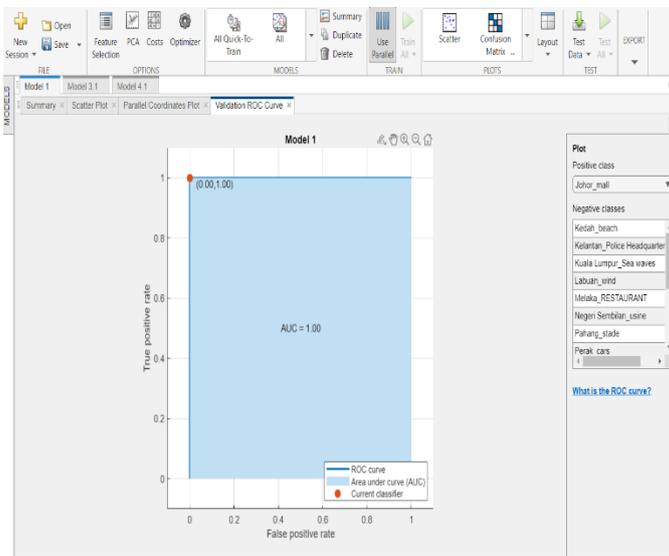
When  $AUC = 1$ , the classifier is capable of successfully distinguishing between all Positive and Negative class points. If the AUC was 0, however, the classifier would expect all Negatives to be Positives and all Positives to be Negatives.

When the AUC reaches 0.5, there is a good likelihood that the classifier will be able to tell the difference between positive and negative class values. Because the classifier can recognize more True positives and True negatives than false negatives and false positives, this is the case.

The classifier is unable to distinguish between Positive and Negative class points when  $AUC=0.5$ . For all of the data points, the classifier is either predicting a random class or a constant class.

As a result, the higher a classifier's AUC score is, the better it is at distinguishing between positive and negative classes.

Same is the case in the AUC-ROC curve modelled in MATLAB.

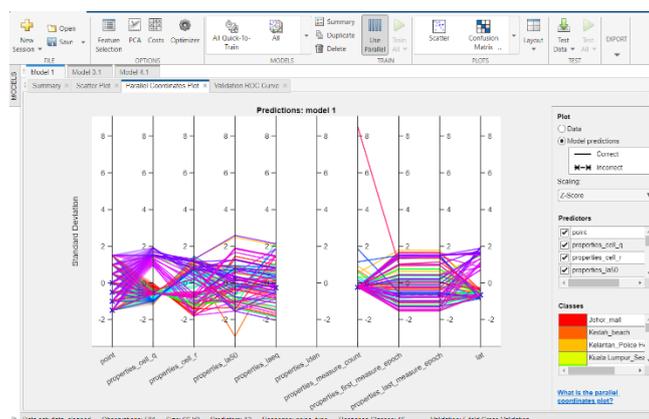


**Figure. 16. Validation ROC Curve**

### Parallel Coordinates Plot

Parallel Coordinates Plots are great for comparing multiple variables and visualizing their relationships. Each variable has its own axis in a Parallel Coordinates Plot, and all of the axes are parallel to each other. Because each variable uses a distinct unit of measurement, each axis can have a separate scale, or all the axes can be normalized to keep all the scales uniform. The data is represented as a set of lines that connect all of the axes. This indicates that each line is made up of a collection of points on each axis that have been linked together.

In addition, to evaluate multivariate numerical data, a Parallel coordinates plot is employed. It allows for several numerical variables to be compared between samples or observations. A separate axis represents each feature/variable. The axes are all evenly spaced and parallel to one another.



**Figure. 17. Parallel Coordinates Plot**

This plot also predicted the parallel coordinates of each of the noise data. It basically showed that the standard noise level for each of the location should be generally a particular value. Standard deviation tells that how much the noise data deviated from its normal noise level.

### Validation Confusion Matrix

A confusion matrix is a method of summarizing a classification algorithm's performance.

If we have an unbalanced number of observations in each class or if your dataset has more than two classes, classification accuracy alone can be misleading.

Calculating a confusion matrix can help to figure out what the classification model is getting right and where it's going wrong.

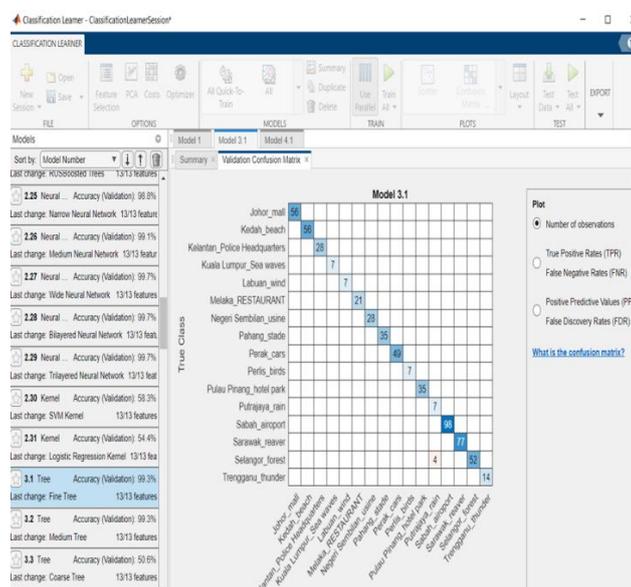


Figure. 18. Validation Confusion Matrix

## CONCLUSION

In this research, we have presented an ML approach to monitoring and classifying noise pollution. Both methods of monitoring and classification approaches have been successfully completed. MATLAB coding has been generated to monitor all the types of noise pollution from the Data which have been collected, while Machine learning was trained to classify these Data. ML algorithms showed promising performance in monitoring the different sound classes such as highways, railways, trains and birds, airports and many more. It is observed in the study that all data which have been gotten using both methodologies (Monitor and classification) can be used to control the noise pollution levels and data analytics will be used to help decision-making processes and policymaking by stakeholders such as municipals, housing agencies and town planners in smart cities. The findings indicate that the Machine

Learning “ML” may be utilized effectively in monitoring, and measuring, and also improvements can be obtained by enhancing the methods used to collect the Data. This is intended to result in the development of more ML platforms from which to construct a relevant environment with less noise pollution.

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