Real Life Pollution Measurement of Cairo

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Abstract: Today, the cost associated to the significant growth in the transportation field is air and noise pollution. According to the World Health Organization (WHO), an estimate of seven million people worldwide die every year due to breathing bad quality air, in addition, morbidities such as high blood pressure, heart disease, sleep disturbances and stress might be linked to noise pollution. In this context, many researchers have done efforts in measuring air and noise pollution to be fully aware of the areas that have a negative impact on human health. In this paper an intelligent transportation system is proposed which uses a low-cost sensor device and a mobile application to monitor air pollution and noise pollution in Cairo, Egypt successively.

1 INTRODUCTION

The increase of vehicles with the existence of other factors that cause a significant increase in the pollution level has become a serious issue. Due to the deficient urban planning of the city in the past, homes, universities, schools, offices, hospitals, and other community buildings were routinely built close to the main roads to be easily accessed without giving attention to whether this zone is a safe or an unsafe area for these sites. With the wide use of the internet of things **(IoT)** technology nowadays, intelligent transportation system **(ITS)** is developed to make positive changes in the transportation system by providing the user a safer and healthier environment. In our project, we are examining the potential of ITS towards the pollution issue by pointing out the measurement of noise and air pollution to inform the user about the pollution levels in any chosen area. Our aim is to develop a way to monitor a real-time air and noise pollution measurement using low cost sensors in order to detect the areas that have the most negative impact on human health, and to generate a dataset documentation for each pollution type. An IoT device is developed consisting of an *MQ135* sensor, which is responsible for measuring the air quality, and a *GP2Y1010AU0F* dust sensor, to measure the PM10 in the air.

A mobile application is developed to record sound levels using the built-in microphone sensor and calculate noise pollution in decibels **(dB)**. The application accesses the location to spread awareness for the individuals. Based on the results that are collected and using machine learning, a predictor model was used to predict the level of noise and air pollution whether it was in general or specific areas and chosen timeframe. This project is a part of a bigger project which aims to reduce traffic air and noise pollution inside urban cities. To fulfill this, pollution produced by cars as well as the desired city pollution levels are measured, and accordingly cars are being routed inside the city; If either the city's noise or air pollution level is more that the set threshold, or if the car itself is polluting enough to make the pollution level exceeds the set threshold, so this particular car will be routed in a way to minimize its traveling distance inside the city (Zaky and Soubra, 2021).

2 LITERATURE REVIEW

Air and noise pollution measurement is considered a serious concern covered by several studies, in this section previous studies done in measuring air and noise pollution will be discussed. (Gryech et al., 2020) in Morocco have used an approach to identify areas with poor air quality. PM10 concentrations exceeded the limit only in the presence of some vehicles otherwise PM2.5 remained low and stable. The results of this paper show how efficient their strategy to identify areas with low air quality. In (Chiang et al., 2020), They carried a device for monitoring air quality on a motorcycle and moved through a chosen route inside the

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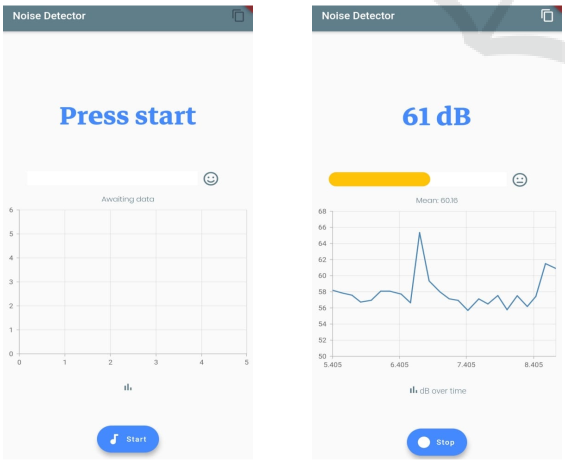
city on six main roads, the results shows that their proposed system can effectively monitor PM2.5 concentrations while moving. In Zagreb, (Marjanović et al., 2017) conducted a study using the carry of air monitor wearable devices following a predefined route. The predefined route was chosen to include 2 major roads with heavy traffic, a park, a residential area, and a business area. it was concluded that air pollution is strongly depending on the traffic exposure. Some studies have done the experiment on one road to measure and evaluate the pollution produced by traffic. In (Moutinho et al., 2020), measurements were taken along a highway in Atlanta.The results obtained were compared to measurements that were taken in an urban area around Atlanta, observing that the concentrations of CO and NO2 in the highway were 35% and 57% higher than the urban background concentrations, respectively. In Pakistan, (Aamer et al., 2018) conducted a data-set containing around 25000 samples during a month in a road segment between 2 cities. It was observed that humidity and temperature are negatively correlated against NO2 and inherently affect the NO2 balance in air. Other studies have taken their measurements from fixed locations either on long or short term. (Gunawan et al., 2018) developed a portable device placed in three different locations, a hostel, a university, and a roadside. The obtained results were compared to a dataset generated by air quality monitoring station at the same time of the experiment, showing that different places can have different AQI value even though they are nearby to each other. (Spandana and Shanmughasundram, 2018) took place in Amrita University, India, to determine the pollution level inside the campus and also in a metro city (Bengaluru). The results indicated that the university atmosphere is less polluted than Bengaluru. (Duangsuwan et al., 2018) measured the AQI in just 2 points (Bangkok Yai district, and Pathumwan district, Bangkok.) from Oct. 7 to Oct. 13, 2017. The results showed that the AQI level has not exceeded 100, making it a safe zone for people. An Android-based application was implemented by (Ghosh et al., 2019) that uses the built-in microphone sensor to capture ambient noise levels and the GPS sensor for identifying the location, and for validation they compared the data collected by the application with sound level meter (Meco-970P 3). The outcome of this test was illustrated, and the variation of the application results compared to the sound meter was in the range of ±3 dB, which clarify the efficient of the mobiles' microphone sensors for detecting noise pollution. (Marjanović et al., 2017) proposed a real-time system to monitor air and noise pollution. They implemented a mobile application which uses mobile phone's microphone to collect noise data and converts the recorded sound pressure to dB and shows the equivalent sound pressure level for each second in dB. The results showed that the average noise level is higher 3dB at the rush hours due to the increasing numbers of vehicles. AQI is the unit or the way of communication between the institutes responsible for calculating air pollution level and the public. AQI is targeting many gasses and sources of air pollution like (Carbon Monoxide, Lead, Nitrogen Oxides, Ozone, Particulate matter including PM2.5 and PM10 and Sulfur dioxide). Air quality standards were set by the US Environmental Protection Agency (EPA) and were divided into two parts (epa,); Primary standards, which were set for the public health protection, as protecting the health of "sensitive" groups such as asthmatics, children, and the elderly people, and the secondary standards, which provide protection to the public welfare, this includes preventing reduced visibility and damage to animals, crops, vegetation, and buildings. Parts per million by volume (PPM), parts per billion by volume (PPB), and micro-grams per cubic meter of air µg/m3 are the units of AQI measurement. For noise levels, the WHO set guideline values based on specific environment and large health impacts (Berglund et al., 2000). The guideline values are presented taking into consideration all harmful health effects identified in a particular environment. The negative effects of noise exposure refer to temporary or long-term impairment of physical, psychological, or social functioning. Decibels (dB) is the unit of measuring sound or noise level. No study was found to monitor air or noise pollution in Cairo, Egypt. All the devices located in Cairo are stationary with a high cost and only one that is a real-time device, but it only monitors and measures Pm2.5 concentration in the air from Katameya Heights in New Cairo city(cit,). Only one study took place in Egypt for monitoring noise pollution, particularly in Alexandria in 2009, (Ghattas, 2009). The literature has proven that no data was collected in a city-scale. It's either collected indoors or in specifically selected regions inside the cities. In this paper, we aim to generate a dataset for both air and noise pollution, as it will be the first dataset documentation for these types of pollution inside Cairo. Our approach will be as follows; regarding air pollution measurement we are measuring the concentration of Carbon Dioxide and Nitrogen Oxide as they are the common gasses that are emitted from vehicles on the road. In addition of the concentration of PM10 in air, this will be done inside New Cairo City in 2 locations. For noise pollution measurement, a mobile application was developed and distributed among the public. The application will have access to the mobile microphone sensor and the GPS sensor. It will help the user to be informed by the amount of noise pollution in their area by calculating a real-time noise intensity value. A noise pollution dataset will be collected from selected main roads and a comparison of the values in peak-hours and off-hours as well as on working days and weekends will be made.

3 METHODOLOGY

The data is received by NodeMCU which is programmed to transfer the data and send it to ThingSpeak using its built-in Wifi Chip. Every data received consists of 7 fields; a unique ID to the record, the time and the date of the reading, the location, current AQI value, temperature, humidity, and the PM10 value. Arduino MEGA is added to the device connecting to it the 3 sensors, and serial communication is established between the Arduino Mega and nodeMCU. The user should press on button "Start" to begin the recording, once the user clicks it, the application measures the noise level in dB and starts recording for 10 seconds. Unless the user clicks the stop button, the application will keep saving data in Firebase every 1 minute. If the dB value exceeded 80dB the record is saved in Firebase. The data collected consists of sound level in decibels, the date of the reading, and the phone's location. Figure 1 shows screenshots from the application before and after the recording starts.



(a) Before clicking Start (b) During recording

Figure 1: Screenshot of the Mobile Application.

Regarding the air pollution monitoring, complications were found with being able to station the device for days, which made it difficult to measure the air quality all over Cairo. Hence, we down-scaled the region of measuring air pollution to be done in New Cairo city, It is one of the cities that were built in recent years, it lies east of Cairo and has 3 main areas; the first, third, and fifth settlements. The city has a good transportation network of buses and micro-buses that makes it easy to be reached from any other city in Cairo. The most famous and most populated district in New Cairo is the 5^{th} district, 90^{th} Road is considered as the main entrance to the 5^{th} district. Heavy traffic can be observed on the 90^{th} road and it is one of its major issues due to the huge amount of services located around it.

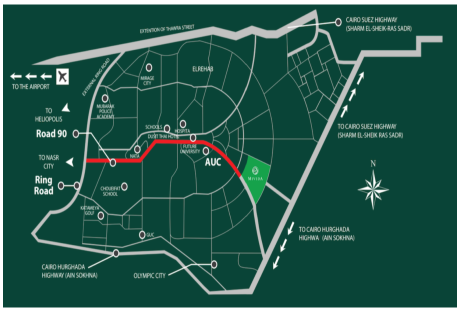


Figure 2: 90^{th} Road on the map.

The device has been stationed in 2 locations around the 90^{th} St. in New Cairo as shown in Figure 3, the first location is a building that is located approximately 250 meters far away from the 90^{th} street. The device is set to be 8 meters above the ground and placed in a terrace of the building facing the street. The other location is about 100 meters away from the 90^{th} street. The device also placed in the terrace of the building as well at height 4 meters above the street.

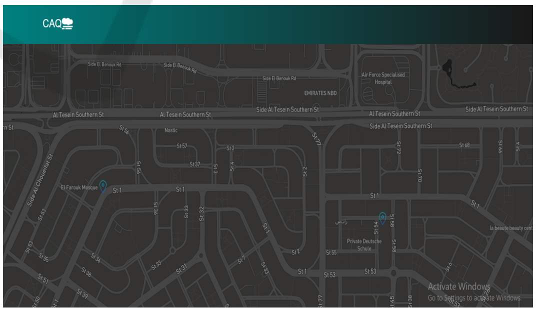


Figure 3: Both locations on the map.

3.1 Noise Pollution

The application is distributed among volunteers to measure noise levels all over Cairo to help in obtaining the most number of records and to be able to measure noise pollution in many areas. Besides that, 3 main streets were chosen in different regions in Cairo that are popular of being crowded in the peak hours.

The 3 streets that have been chosen are 90^{th} Street in New Cairo, Abbas Al-Akkad in Nasr city, and 9^{th} street in Al-Mokkatam. Al-Mokkatam district is a famous neighborhood in Cairo. 9^{th} Street is the most famous and exclusive street in Al-Mokkatam city, as it is the main and the only entrance for this area and goes through the neighborhood.

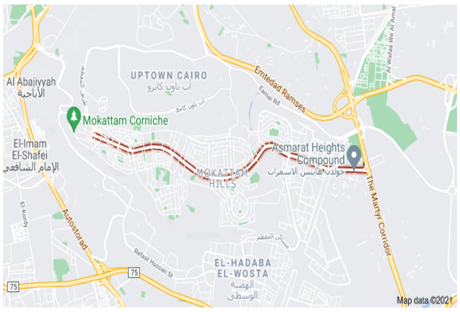


Figure 4: 9^{th} street on Google maps.

Nasr City is another one of the famous districts in Cairo. It's also known for various landmarks and is mostly crowded. Abbas Al Akkad street, shown in Figure 5, is considered as the backbone of Nasr City, it's one of busiest shopping streets in Cairo.

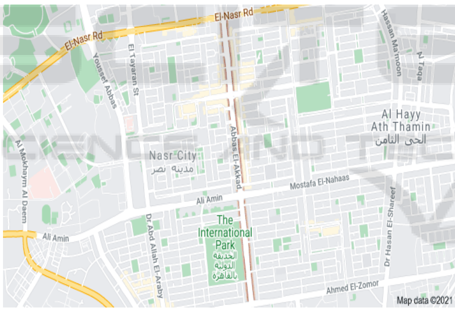


Figure 5: Abbas Al Akkad street on Google maps.

4 RESULTS

Air Pollution. Air pollution measurement has been done in 2 locations in exact locations "Building 130, St. No.54, First New Cairo, Cairo Governorate" and "Building 241, St. No.55, First New Cairo, Cairo Governorate" gathering around 3307 samples from both locations. The data-set obtained contains 6 fields, AQI value, Pm10 concentration, Temperature, humidity , the ID of the location (Latitude , Longitude) that generated automatically by MongoDB, and the date of the record. All the data represented in this section is just a subset of the full dataset. The experimental setup of the project is as follows.

Computing Unit. A NodeMCU ESP8266 module is used along with its ESP-12E module containing an ESP8266 chip having Tensilica Xtensa 32-bit LX106 microprocessor. The data and programs are stored in 4MB of Flash memory. We also used an Arduino Mega 2560 board.

Sensors Unit. The sensors used for data acquisition are as follows:

1. MQ135: used in measuring AQI and to detect and measure the concentrates of NH3, NOx, Alcohol, Benzene, Smoke, CO2 in air.
2. DHT11: it is an ultra-low-cost digital temperature and humidity sensor.
3. GP2Y1010AU0F: especially effective in detecting very fine particles like cigarette smoke and dust, and is commonly used in air purifier systems.

First Location. As this location is in front of a famous PlayStation & Cafe and a big mall, the weekend days are the peak days in which the cafe receives the most number of customers, and the peak hours of these days would be at night; the time that the cafe is in full capacity, and the off hours would be at any other time in the day. However, in the working days peak hours would be in the morning and afternoon and the off-hours would be at night as regular, as the cafe and the mall are almost empty in the working days. At this location, samples were taken within a period of 8 days from $09-07-2021$ to $16-07-2021$. A total of 1784 samples were taken at different times in all the days monitoring the AQI in PPM, temperature in Celsius, humidity as a percentage and the concentration of PM_{10} in µg/m^3. We discuss the results for the following 3 scenarios:

- A scenario is represented within the peak hours on the weekends which is consider the worst-case scenarios.
- A scenario within an off-hour in a weekend.
- An exceptional case occurred during a working day due to being the same day as the EURO 2020 final game that played on $11-07-2021$.

Results

- **Peak hour on a weekend.**

  Figure 6 shows 12 out of 56 total readings taken for both PM_{10} and AQI on a weekend. A maximum AQI value 214.096 PPM and minimum value 33.00 PPM, and a maximum concentration of PM_{10} 159.27 µg/m^3 and minimum 23.97 µg/m^3 were measured.

Table 1: First location Air pollution measurement Table.

Air Pollution measurements				
Scenario	Time	Average AQI value	Average PM10	Figure
Peak hour in the weekend	08:47PM - 09:50PM	136.88 PPM	70.07 μg/m^3	6
Peak hour in the weekend	10:20PM - 11:20PM	145.19 PPM	44.91 μg/m^3	7

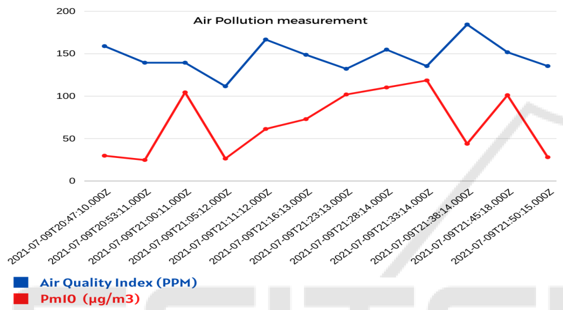


Figure 6: Graph of Air pollution measurement on 09-07-2021.

- **Off-hour on a weekend.**
  Figure 7 shows 10 out of total 45 readings of PM_{10} and AQI taken on an off-hour on a weekend. A maximum AQI value 171.568 PPM and minimum value 45 PPM, and a maximum concentration of PM_{10} 147.65 μg/m^3 and minimum 23.97 μg/m^3 were found.

  Figure 8 shows 25 readings out of total 218 samples of both PM_{10} and AQI taken within 4 hours at the same time as the EURO 2020 final game between England and Italy and as stated above, the device is located in front of a famous cafe, which lead to a traffic increase in front of the building. The game started at 9:00 PM (GMT+2), extra 45 minutes were added; so the whole game took around 3 hours. So the 4-hour period of the graph can be divided into 3 parts. First part during the game (10:40 PM - 12:00 AM), and after the game (12:00 AM - 1:00 AM) in which people started leaving, last part after the ceremony (01:00 AM - 2:40 AM) in which the rest of the people left. During the game, 68 samples were taken with an average AQI equals to 217.898 PPM with maximum value 299.775 PPM and minimum value 153.724 PPM, and an average concentration of PM_{10} equals to 85.888 μg/m^3 with maximum value 113.62 μg/m^3 and minimum value 62.16 μg/m^3. In time right after the game finished and during the ceremony, 54 samples were taken with an average AQI equals to 153.91 PPM with maximum value 229.328 PPM and minimum value 53.86 PPM, and an average concentration of PM_{10} equals to 83.1559 μg/m^3 with maximum value 115.28 μg/m^3 and minimum value 53.86 μg/m^3, in the last part, 78 samples were taken with an average AQI equals to 51.157 PPM with maximum value 96.34 PPM and minimum value 18.005 PPM, and an average concentration of PM_{10} equals to 82.143 μg/m^3 with maximum value 126.07 μg/m^3 and minimum value 48.87 μg/m^3.

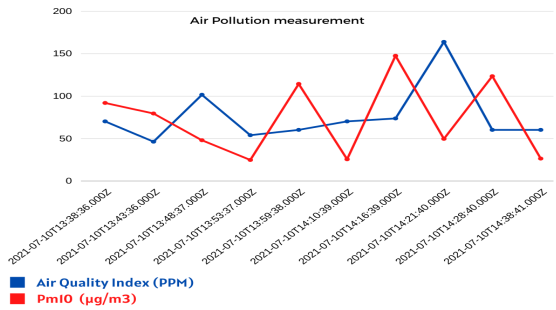


Figure 7: Graph of Air pollution measurement on 10-07-2021.

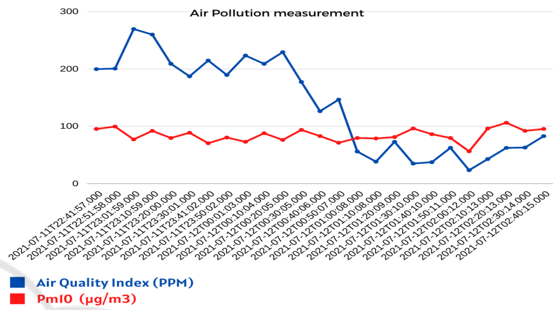


Figure 8: Graph of Air pollution measurement on 11-07-2021 / 12-07-2021.

Second Location. Being a regular location with no popular places around, peak hours will be as usual in which traffic exists; from 7:00 am to 10:00 am and from 3:00 PM to 6:00 PM as people going or coming from their daily destinations (work,universities,etc.) in the working days from Sunday to Thursday, as Fridays and Saturdays are the weekend in Egypt. Samples were taken within a period of 5 days from 25-07-2021 to 29-07-2021, in the meanwhile a total of 1523 samples were taken at different times in all the days monitoring the AQI in PPM, temperature in Celsius, humidity as a percentage and the concentration of PM_{10} in µg/m^3. Below we are representing 3 scenarios in a working day:

- After midnight of a working day.
- Within a peak hour of the same working day.
- Within an off hour of the same working day.

Air Pollution measurements				
Scenario	Time	Average AQI value	Average Pm10 Concentration	Graph
After midnight (working day)	12:00AM - 01:00AM	62.79 PPM	120.83 µg/m^3	Fig 9
Peak hour (same working day)	09:49AM - 10:59AM	142.26 PPM	148.26 µg/m^3	Fig 10
Off hour (same working day)	07:00PM - 08:00PM	101.71 PPM	127.979 µg/m^3	Fig 11

- **After midnight of a working day.**

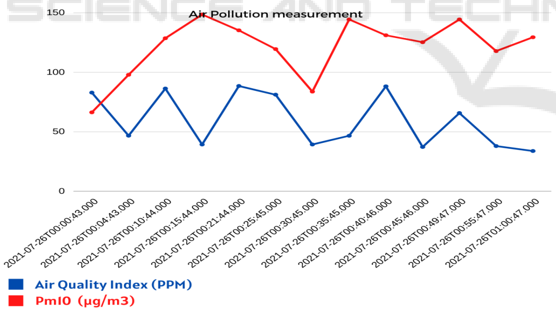


Figure 9: Graph of Air pollution measurement on 26-07-2021.

In figure 9, 12 out of total 48 samples are shown of both PM_{10} and AQI during midnight of a working day. A maximum AQI value 169.672 PPM and minimum value 20.86 PPM were measured, and a maximum PM_{10} value 148.48 µg/m^3 and minimum value 63.82 µg/m^3 were found.

- **Peak hour of a working day.**

Figure 10 shows 12 out of 57 total samples of both PM_{10} and AQI measured during a working day. 231.728 PPM and 33.7 PPM were the maximum and minimum values found for the AQI. For

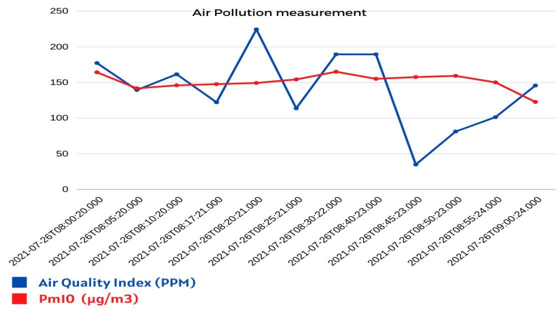


Figure 10: Graph of Air pollution measurement on 26-07-2021.

the PM_{10} concentration. 181.69 µg/m^3 and 87.89 µg/m^3 were its maximum and minimum values.

- **Off hour of a working day.**

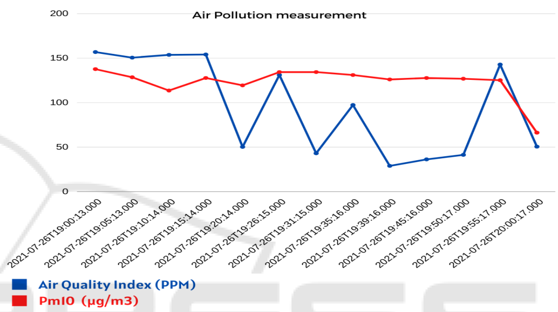


Figure 11: Graph of Air pollution measurement on 26-07-2021.

Figure 11 shows 13 out of 50 total samples taken during a working day evening. A maximum AQI value equals to 193.289 PPM and minimum value equals to 26.731 PPM were found, and maximum PM_{10} concentration 156.78 µg/m^3 and minimum 66.31 µg/m^3 were found.

4.1 Noise Pollution

Noise Pollution measurement has been done by 2 methods, getting readings from particular main streets in different areas in Cairo, each street of them has its own features that make it differs from the others as stated in section 3.1 taking into consideration to take readings in the peak and off-hours in each street, the second method is done by distributing on the public to get readings in random places with different time inside Cairo city. All the readings are combined in one data-set consists of 5 fields; location address name, location coordinates, DB value, the date and time of the sample, Running on (the device in which the application is running on). Below we are introducing a heat map for each street of the following streets (90^{th} St, Abbas Al-Akkad St.) in addition to a heat map for all the readings that are taken inside Cairo. All the data represented in this section is just a sub data from the full data set.

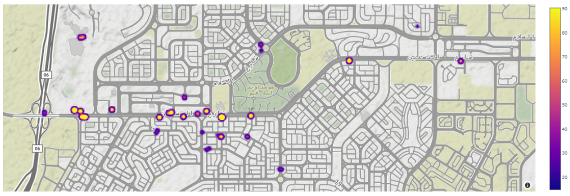


Figure 12: Heat map for 90^{th} St.

As the 90^{th} road is a very busy road almost all the time of the day, so comparing the peak hours with the off hours will be in this case not convenient enough to show the difference between them, definitely, there will be a difference between the average dBs taken under a certain period (1 hour for example) in the peak hours comparing with the average dBs taken under the same period in the off-hours, however, it will be a slight difference that will not show the huge effect of vehicles on raising the noise level, however, by representing the heat map shown in Figure 12, we can observe that as we got closer to the 90^{th} street the plots are getting more yellowish as the most yellowish ones that indicate higher noise levels are located on the 90^{th} street and as we go further the plots are heading to be more blueish as the noise levels decrease.

Figure 13: Heat map for Abbas Al-Akkad St.

The heat map of Abbas Al-Akkad street as shown in Figure 13 clarify more how main roads can raise the noise level due to the traffic on them, we can observe that all the yellow plots are located on the street itself showing the increase in noise level there, and the same as 90^{th} street, as we go further from the street the noise level decreases as the plots trends to be more blueish.

Figure 14 represents all the readings were taken either by taking it in particular streets or by distributing the app to take readings from random locations in Cairo, a total of 558 samples were taken inside Cairo, divided into 106 samples on the 90^{th} street, 71 samples on Abbas Al-Akkad street, 77 samples on 90^{th} street, and 304 samples were taken in random locations at a different time inside Cairo.

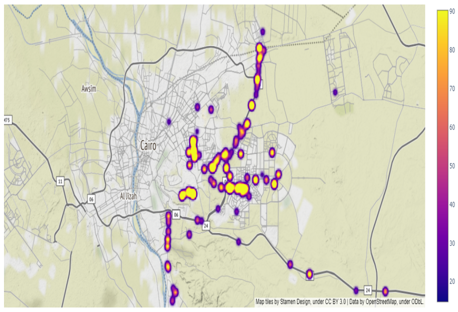


Figure 14: Noise Pollution readings in Cairo.

Predictor Model. The predictor model is a created model to predict whether pollution levels are more than the required threshold or not. For such, a basic model with two fully connected hidden layers is implemented. For both networks a train-test-split of 0.2 is used, with Adam optimizer and trained for 100 epochs. The results of the models is as follows. The air pollution network takes as input a feature vector of Time, Date, Temperature, and Humidity, and classifies the pollution in three categories (good, moderate or unhealthy). The model achieved 69% accuracy and an crossentropy loss of 0.7058 on the test set.

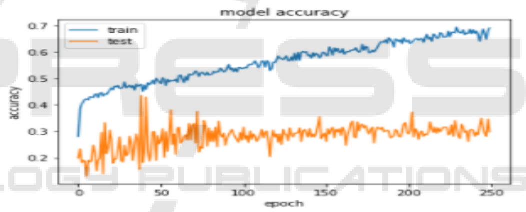


Figure 15: Graph of model accuracy and the validation accuracy against Epoch.

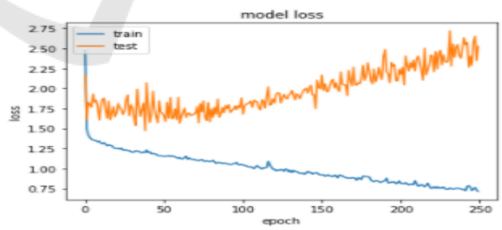


Figure 16: Graph of model loss and the validation loss against Epoch.

The noise pollution network takes in a location and time as input and predicts whether the db value would exceed 80dB or not. The model achieved an accuracy of 87% with a crossentropy loss of 0.2782.

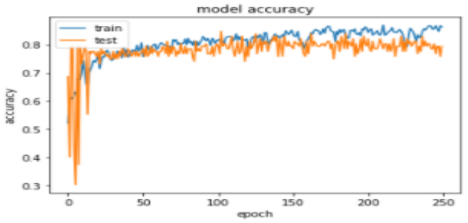


Figure 17: Graph of model accuracy and the validation accuracy against Epoch.

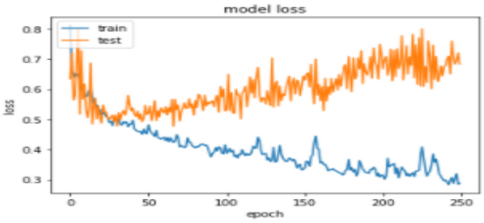


Figure 18: Graph of model loss and the validation loss against Epoch.

5 CONCLUSION

In conclusion based on the above results, regarding the air pollution measurement we could gather a total samples of 3307 samples in 2 different locations inside New Cairo district. Air pollution monitoring was done by measuring the concentration of PM_{10} in the air using GP2Y1010AU0F dust sensor and measuring the AQI using MQ135 sensor. The results obtained by the air pollution measurement shows how the AQI and PM_{10} behave within the peak and off hours, as shown in the EURO final game example. Also, it shows how the PM_{10} concentration was relatively high in the second location as it is located in front of an empty land full of dust and smog. Regarding the noise pollution measurement we have introduced a mobile application that measures a real time noise level in dB, we have concluded from the results that as we get closer to main roads the noise level increases due to the vehicles passing through the main roads as they are a main source of noise pollution. The monitoring of accumulated data in the cloud storage helps to analyze the various patterns in the environmental parameters and accordingly implementing a predictor model using machine learning to be able to early notifying the public about the changes in the pollution in different areas.

Limitations: Setting up the air pollution measurement device in main roads is not easy in Egypt, facing this limitation lead to setting the device up inside balconies of buildings near the main road. For the noise pollution measurement, the application doesn't get readings above 90.30dB which is a very high value that we can barely reach.

Future Work: It is planned to locate the air pollution measurement device in more locations inside Cairo, with the addition of measuring $PM_{2.5}$ for more efficiency. More data of noise levels is planned to be taken as well, for more accuracy to the predictor model.

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