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Methodology for Monitoring Toxic Gases Internet of Things (IOT) Technology

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Abstract

The objective of this paper is to build a cost-effective instrument that can monitor toxic gases in real-time utilizing IOT. The instrument consists of an Arduino board, shield communicator, and MQ-7 sensors. Python language is used to program the Arduino board. The computer is used as a base station, using IDE Arduino software. The model will be deployed in an indoor parking garage to sense Carbon Monoxide (CO) emitted from cars. The main contribution is to build an affordable device which utilizes IOT technologies to monitor toxic gases.

Keywords—Monitoring, Toxic Gases, Internet of Things (IOT).

1 Introduction:

1.1 Internet of Things (IOT):

In the last few years, modern technologies have been born, grown fast and then distributed within a short period; IOT is one of them. IOT is an incredible technology which was developed a few years back. It is the technology that has found a place among larger competing technologies. Day after day, IOT is proving to be an easy, smart, cheap, and fast technology. [1] [2] [3] Many scientists and engineers believe that IOT is the best technology available today to improve people's traditional daily lives, making them "smarter." IOT is easily adapted to the skills of users, and it can be deployed in different locations and environments. Equipment used for IOT is inexpensive and has enormous reliability; therefore, machines or devices with IOT will not be much higher priced than traditional technology. IOT can be applied to most physical objects to turn them into smart objects: a smart house, a smart office, a smart car, etc. Moreover, new smart cities are being designed and constructed utilized IOT to coordinate their infrastructure. Moreover, there are multiple uses for IOT in the industry; It can distribute supervision and collect data in real-time with low cost and minimum maintenance. It will enhance industrial operation and flow. It can reduce industrial production losses and energy consumption and will increase communication between humans and machines; therefore, the presence of IOT in the industry is highly recommended. IOT is a new and unique technology that will work to change our lives for the better. [4] IOT has been attracting researchers from all sectors in recent years because it is the technology that can establish one platform to control many different objects in separate places performing various tasks. IOT, without doubt, is a technology with a bright future.

[5] Pollution monitoring is one technology that benefits from the application of IOT; it monitors air pollution in real-time. [6] Health care is another major sector that will benefit from IOT, creating a new generation of medical services. Devices will connect wirelessly to monitor patients' current health status all day in real-time, as well as providing other services that can be delivered wirelessly such as emergency alerts. [7] IOT can monitor elderly or chronically ill patients to make their families feel more confident knowing they are constantly monitored in real-time wherever they go. Monitoring patients' health status outside the hospital 24/7 is easier and more economical with IOT.

[8] Agriculture is a large sector that always needs improvement; applying IOT to agriculture will improve production by monitoring climate change and rainfall wirelessly. [9] Ideal plant growth can be achieved by adapting irrigation to rainfall. Thus farmers will not provide more or less water than plants need, as long as water flow is monitored 24/7 by few clicks using IOT applications.

1.2 IOT Hardware:

Hardware used for IOT is inexpensive and can last a long time with no major issues. For instance, [10] Arduino is one of the most popular control boards on the market; it can be used as a controller for a variety of IOT models. It can be connected to the internet via WIFI or GSM by using a compatible shield. Arduino is an inexpensive open source hardware platform, which is very easy to acquire and work with; [11] it is one of the most reliable open source hardware platforms available. Arduino is a high-performing platform which provides a strong base for hardware and software. It is compatible with all big operation systems (Windows, MAC, Linux), and with common programming languages such as C++, Python, and others.

1.3 Carbon Monoxide (CO):

One of the main sources of world pollution is automobile exhaust, and one of the worst chemical gases is carbon monoxide (CO). Indoor parking garages are one example of the many areas which are contaminated by CO. [12] CO is a gas which can’t be seen, smelled, or tasted by humans. Breathing small amounts of CO can cause symptoms of dizziness, vomiting, headache, or nausea; breathing larger amounts can cause suffocation, then death within a few minutes. [13] Scientists call it the “Silent Killer.” Keeping cars running inside enclosed areas is dangerous to human health. Indeed, it can be fatal. [14] The Center for Disease Control and Prevention estimates that CO poisoning kills about five hundred people a year, and forces another fifteen thousand to visit emergency rooms with a headache, nausea, or fatigue every year. Children and pets are more easily affected by less concentration and have more risk of dying faster than adults. Hence, the ventilation system is a must in indoor garages to increase air circulation and reduce toxic gases. CO danger is the reason why many states like California have passed laws to limit CO levels in all car parking garages.

[15] The table below explains the health effects from CO in PPM:

Level of CO	**Health Effects, and Other Information**
0 PPM	Normal, fresh air.
9 PPM	Maximum recommended indoor CO level (ASHRAE).
10-24 PPM	Possible health effects with long-term exposure.
25 PPM	Max TWA Exposure for 8-hour work-day (ACGIH). **Pocket CO TWA warning sounds each hour.**
50 PPM	Maximum permissible exposure in the workplace (OSHA). **First Pocket CO ALARM starts (optional, every 20 seconds).**
100 PPM	A slight headache after 1-2 hours.
125 PPM	**Second Pocket CO ALARM starts (every 10 seconds).**
200 PPM	Dizziness, nausea, fatigue, headache after 2-3 hours of exposure.
400 PPM	A headache and nausea after 1-2 hours of exposure. Life-threatening in 3 hours. **Third Pocket CO ALARM starts (every 5 seconds).**
800 PPM	A headache, nausea, and dizziness after 45 minutes; collapse and unconsciousness after 1 hour of exposure. Death within 2-3 hours.
1000 PPM	Loss of consciousness after 1 hour of exposure.
1600 PPM	A headache, nausea, and dizziness after 20 minutes of exposure. Death within 1-2 hours.
3200 PPM	A headache, nausea, and dizziness after 5-10 minutes; collapse and unconsciousness after 30 minutes of exposure. Death within 1 hour.
6400 PPM	Death within 30 minutes.

12,800 PPM	Immediate physiological effects, unconsciousness. Death within 1-3 minutes of exposure.

1.4 Problem statement:

The purpose of this research is to design and develop a cost-effective instrument to monitor toxic gases. There are three components: hardware development, communication, and evaluation of results. The model will utilize IOT Technology to transmit data from CO sensors in indoor parking garages through an Arduino board to a base station in real-time. The model will consist of MQ-7 CO sensors, an Arduino board as a processor, and a computer as a base station.

1.5 Significance of the study

The objective of this study is to show that it is possible and economical to use IOT to capture and transmit data from sensors and then monitor it at a base station. This study will focus on CO concentrations in parking garages, but the objective is to demonstrate the efficacy of IOT technology in the transmission of data. Also, it will develop a way of monitoring toxic gases, thereby improving public health and safety.

According to [12], [13], [14], CO is a very dangerous gas, threatening human health, nature and the environment. By designing and developing a cost-effective, modern instrument utilizing IOT technology to monitor CO, this research will be focusing on making sure that indoor parking garages are safe for humans, issuing alerts if the presence of toxic gases is higher than normal. The model will reduce fatalities and illness in garage users.

2 Literature Review:

2.1 IOT in Monitoring Air Quality:

In [2], IOT technology was used to build an urban climate monitoring model in India to monitor the city environment. One of the major concepts which were approached in their model is to create a low cost, IOT based, a monitoring system for urban climates. Raspberry Pi is the processor for this system. It functions as a mini-computer programmed using the python language library. It receives climate data from sensors and then sends that data to the user in real-time. The sensors connected directly to Raspberry Pi are DHT22, which senses humidity, a BMP180 sensor which provides air temperature and pressure, and a BH1750 sensor, which captures light intensity levels. Arduino Nano is implemented in the system and connected to Raspberry Pi by USB to read CO data coming from the MQ-7 sensor, and the MQ-135 sensor measuring air quality. The model utilizes an external Wi-Fi module to transmit data from sensors to users; all data can be displayed on a computer, smartphone or tablet in real-time.

In [5], the authors used IOT technology to monitor vehicle-produced pollution in real-time. They placed two types of sensors to monitor Carbon Dioxide (CO_2) and Sulfur Oxide (SOx), which are two major toxic gases produced by gasoline-powered vehicles which cause air pollution. A Radio Frequency Identification (RFID) reader system is used in this model to detect cars passing on the road. It is connected to Arduino which is utilized in the system as a controller to receive data from sensors and the RFID reader. The Arduino then sends all input data to the server. The system analyzes any data coming from vehicles; if any pollution is detected, the system will send an alert message to the user immediately.

2.2 IOT in Wildlife Management:

IOT technology has been used in sectors other than gas detection systems. In [16], GPS-Arduino Based Tracking and Alarm System (GATA) is a model that can protect wildlife and humans from death or injuries; the system locates and tracks wildlife that travels from forests to residential areas. The model consists of a GPS module, Arduino, Accelerometer, Arduino WIFI shield, and receiver. The GPS Module locates the animals; Arduino is the open source hardware and the processor function of the model. The Arduino WIFI Shield is an internet connection antenna board consisting of IEEE 802.11 protocol, which is connected to Arduino to transmit all data to the base station. The receiver is the device that is located at the Base Station and is implemented in the system to receive all data from GPS through the Arduino shield using Wi-Fi internet connection. The accelerometer is applied to determine the movement of the animals; when no motion occurs, the GPS module stops working. If an animal strays outside its sanctuary zone, an alert sounds at the fixed base station. Catching and relocating the stray animal helps to avoid train and traffic problems and attacks to the local human population. GATA is a real-time system for people who live in forest areas to protect wildlife and themselves from death or injuries.

2.3 IOT in Smart Cities:

In [3], nowadays, many countries are thinking seriously about and preparing to build smart cities, which have better infrastructure, smart buildings, easy communication between people and government, and provide a superior lifestyle. The European Smart Cities Project (www.smart-cities.eu) is an example. Smart city developers have chosen IOT as the keystone of their project. It is the technology that connects everything to everything using the internet; hence, living in a smart city means anyone could be a few clicks away from any service. For instance, a house owner can unlock his front door, have full control of all appliances, as well as turn any light in the house on or off using a phone application. Smart cities are not only about smart houses but include all city management: hospitals, schools, public services, and many other things, all serving smartly. All these impressive services are gathered under one umbrella called IOT. The IOT umbrella continues to encompass more users; it is the modern and future technology.

Air-conditioning systems also benefit from IOT. In [17], a model was built to improve and retrofit air-conditioning systems in smart buildings by using IOT tools; the system reduces power consumption and improves air-conditioning performance by measuring the temperature of the interior and exterior of the building, using sensors for the outside which are connected to the network by a mesh based on Digi-Mesh protocol. Arduino is the platform that processes all data of the system.

2.4 IOT in Traffic Management:

In [18], IOT technology is used to create a low-cost model which can monitor a real-time high volume vehicle traffic flow in big cities. The model uses two Arduino boards. The first detects all cars passing over the system, and the second stores the number of cars detected every five minutes; then all data is sent to the user using a GSM Module, as shown in Figure 1.

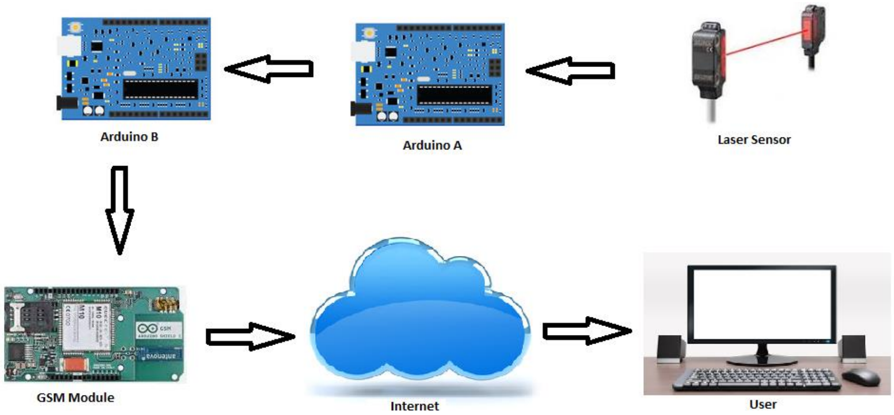

Figure 1: Hardware Architecture for Urban Traffic System Using GSM Technology

2.5 IOT in Agriculture:

IOT is also useful in monitoring agriculture. In [8], a model was build using IOT technology to convert classic agriculture to smart agriculture, resolving one of the biggest issues affecting agriculture for the past decade: climate and rainfall change. This model reduces risks in the agriculture sector. The subsequent ease of production has encouraged farmers who have quit farming to return to their fields. Solar panels are implemented in the system as a power supply for the outdoor sensors. This model helps agriculture to keep up with modern life, as it lets farmers have full control of their crops, watering by IOT technology using a computer or a phone application.

In [9], a soil moisture monitoring system was built to monitor any irregular rainfall in real-time, making sure that soil gets a suitable water supply so that plants grow in a perfect environment. This system gives an early alert to the farmer about any changes in the weather. It uses Arduino as a data processor and an external WIFI shield connected to Arduino to transmit data from sensors to the user. This model is an IOT system which would support farm owners in controlling moisture on their farms.

2.6 IOT in Healthcare:

Healthcare also benefits from the use of IOT. In [7], a heart rate detector model was designed to monitor patient heart rates in real-time. Arduino is part of this system as a processor for data coming from patient sensors to users; an external GSM shield is connected to Arduino acting as an SMS interface between the system and user; an alarm notifies users of any heart rate changes in real-time; this system demonstrates yet another use of IOT.

In [10], a model for measurement of respiration rate using a temperature sensor and Arduino mini-controller was created. The system is based on TMP102, which is a sensor for reading the person's temperature; it acts as a "slave" and is controlled by an open source hardware mini-controller (Arduino). The sensor receives all commands from Arduino. The user can see all monitored results via Arduino IDE software connected to the Arduino hardware platform by a USB cable.

In [6], a model was built with IOT technology for detecting Obstructive Sleep Apnea (OSA) which is the most common type of sleep-disorder. Normal OSA detection requires the patients to sleep in a specialized laboratory on the testing site. The purpose of this model was to find another procedure, applying IOT so that the patient can take the diagnostic test at home; the model would help many patients that don't feel comfortable sleeping in hospital beds. This model is more practical than building specialized laboratory rooms with beds for patients.

2.7 IOT in Measuring CO:

The research on the topic of IOT is huge as it is used in many different sectors. Many researchers prefer IOT technology in building their models that monitor climate or specific gases. In [19], an IOT system was built that can monitor CO in any industrial area in real-time. The system consists of nodes, routers, and a base station; nodes are the CO sensors in the system; routers are the WIFI connection in the system. The routers transport data from sensors to the base station. The base station is the user in the system. It can be a computer or a mobile application. This model works as a prediction system which can send early alerts to users. [20]Another system utilizes an MQ-7 semiconductor sensor to monitor CO, an MQ-4 semiconductor sensor to sense methane (CH_4), and an LM-35 semiconductor sensor to sense the room temperature; together, these three sensors work as an Air Quality Prediction system which can control the environment regarding CO and methane. A Raspberry Pi (B+) board is the processing unit for this model; all sensors are connected to it. Raspberry Pi was chosen for this model because it is one of the least expensive and most reliable boards that can do all processing work for the system. An ADC MCP 3208 chip is applied in the system to read analog output voltage data coming from sensors using python script; data travels from sensors to the ADC MCP 3208, to Raspberry Pi, to the base station (user) as shown in Figure 2.

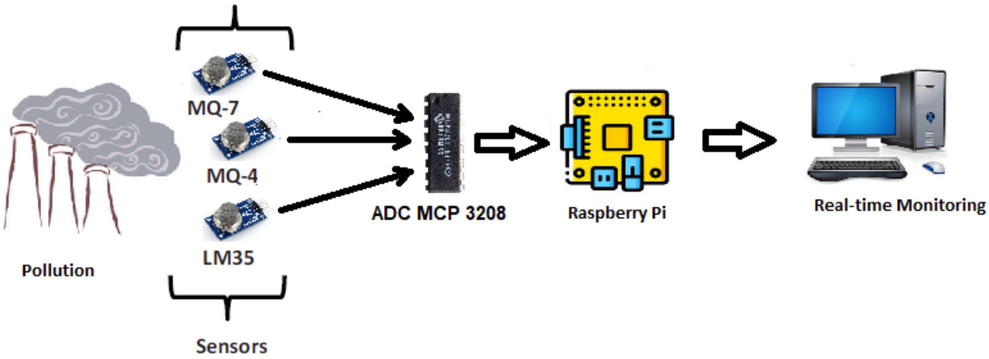

Figure 2: Functional Block Diagram of a CO Monitoring System

In [21], a model with MQ7 sensors was deployed in Sao Paulo's Metropolitan area (SMA) in Brazil to collect CO data to monitor and control pollution in the environment. All monitoring data was analyzed and stored using the Big Data Tool. The model involves a real-time collection process, distributed storage manner, analytic data processing, and analyses visualization. An ESP8266 Arduino module is part of this system, which has a TCP/IP protocol; it can receive CO data from the sensor, and then transmit it through a WIFI connection to an Application Programming Interface (API) user. An MQ-7 sensor capable of working with various programming languages, such as R Studio, was used for this model. This model was an example of the use of IOT in monitoring CO; it is a low-cost monitoring device that helps the Sao Paulo Metropolitan Area (SMA) to control the environment.

2.8 Threats to IOT

[22] Based on reports by The US Federal Trade Commission, by 2020, fifty billion sensors will be deployed to serve IOT technology. Gartner Inc.'s "Hype Cycle for Emerging Technologies, 2015" forecast that IOT will control the entire electronic market in 2025 or before. IOT technology connects all sensors, gateways, and all different data analytics models into real-time decision making. The number of sensors deployed has a direct relation to some threats and attacks to the network. The more sensors, the more threats, and attacks will occur; they are both growing fast. Therefore, work on securing IOT data is an important component of building an IOT network. We must prevent any loss of privacy, which is the biggest priority to users. Thus, IOT technology is a double-edged sword. It is flexible and can gather a variety of services in one place; however, at the same time, it is risky because it might disclose personal information if data is not encrypted.

3 Proposal:

The purpose of this research is to design a model using IOT technology to transmit data from CO sensors in indoor parking garages through Arduino to a base station in real-time. The model consists of MQ-7 (CO sensors), an Arduino base as a processor, a shield board as a connection part, and a computer or phone application as a user.

3.1 Hardware Architecture:

This IOT model consists of the following major parts:

3.1.1 Microcontroller Board (Arduino Uno R3):

[23] Arduino Uno R3 board is used for the system as a microcontroller to process the data. The operating voltage is 5V; input voltage limitation is 6-20V; however, the recommended input voltage limitation is 7-20V. It has 14 digital I/O pins and six analog input pins. DC current per I/O pin is 40mA, and DC current for 3.3V pin is 50mA. Arduino has 32 KB of the flash memory of which 0.5 KB is used by a bootloader. It has 2 KB of SRAM, 1 KB of EEPROM and 16 MHz of clock speed. Arduino Uno R3 can be powered by connecting it to a computer via USB or by an external power supply. An AC-to-DC adapter or battery can be as an external power supply for Arduino. A 2.1mm Center-Position Plus is available for the board for an external power supply. 6-20 volts are the only limits to external supply.

Figure 3: Arduino Board (Front)

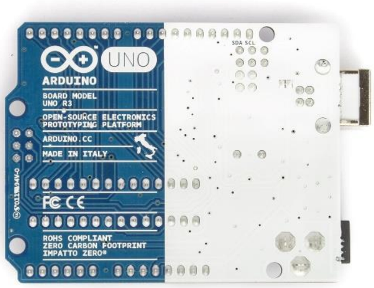

Figure 4: Arduino Board (back)

3.1.2 Sensing unit (MQ-7):

[24] MQ-7 gas sensor is the sensing unit of the system; it is a CO sensor which will be connected to the Arduino. It will utilize the power from the Arduino and send the data to the system. The sensor is composed of a sensitive layer, micro AL2O3 ceramic tube, Tin Dioxide, measuring electrode and heater which are fixed into a crust made of plastic, and

stainless steel net. Six pins are on this sensor, four pins for fetching signals and another two for providing heating current. The MQ-7 has a long life: it can usually last five years with no issues.

The standard measuring circuit of the sensor MQ-7 consists of two parts:

- The heating circuit has a time control function, which means, the high and low voltage can be working in the circuit alternately.
- The signal output circuit can accurately respond to changes in surface resistance of the sensor. These circuits are shown in **Error! Reference source not found.**.

The surface resistance (Rs) of the sensor will be obtained through affected voltage signal output of the load resistance (RL). The formula below describes the relationship between them:

$$R_s/R_L = (V_C - V_{R_L})/V_{R_L}$$

Error! Reference source not found., is an example of (RL) signal output which comes in an alterable situation, measured by using the circuit output signal at the same time as the sensor shifting from an area with no CO gas to an area with CO gas and then going back to an area with clean air.

Figure 5: MQ-7 Sensor for CO.

3.1.3 User unit (Base Station):

The system can process data using more than one mechanism: the base station can be a computer receiving analyzed data via a computer application or email. The base station can also be a smartphone using a smartphone application or a phone text.

3.2 Software Architecture:

The Arduino board can be programmed using Arduino IDE software which can be downloaded free of charge from the official Arduino website, as shown in Figure 6.

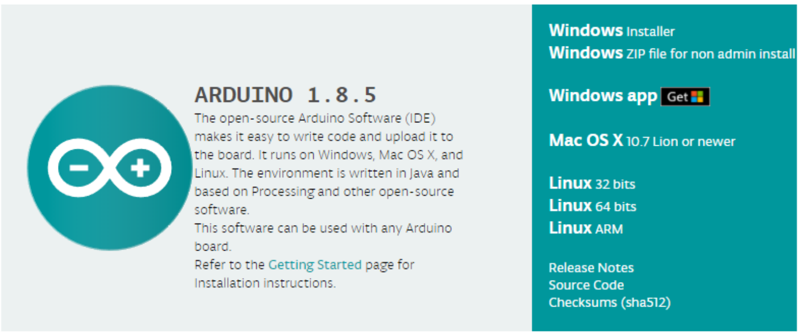

Figure 6: Arduino IDE Software.

Several languages that can be used to program Arduino; however, Python language is the library used for this system; Python is an open source programming language that can be used in any operation system. IDE software can be downloaded in Windows, Mac OS, and Linux Operating systems. It is available at (https://www.arduino.cc/en/Main/Software).

3.3 Experimental Field:

The model was deployed in a private car garage in a house with a car inside of it.

3.4 Workflow:

An MQ-7 sensor is connected to a programmed Arduino board, which is connected to the computer by a USB connection. IDE Arduino software will be used to read the data input from the MQ-7 sensor. Thus, the system is ready to sense CO. The model will be taken to a running car, and the sensor will be placed near the car exhaust. At this point, the system will start reading the CO of the exhaust.

4 Preliminary result:

4.1 Result:

A preliminary model was built by connecting one MQ-7 sensor to a programmed Arduino board then connecting the Arduino board to a computer using a USB connection. IDE Arduino software is used in this model to read data coming from a sensor as shown in **Error! Reference source not found.**, **Error! Reference source not found.**.

Max reading: 85.69 PPM

Min reading: 3.77 PPM

4.2 Results Analysis:

The graph below displays preliminary results which were collected in the garage of a private home. The results were collected over a two-hour period. It is evident that when the sensor is closer to the car's exhaust, more CO is detected.

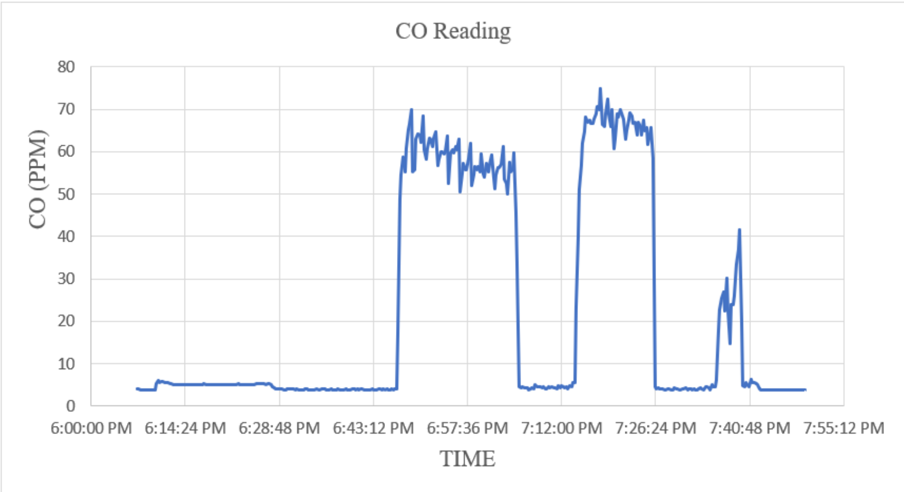

Figure 7: the graph shows CO reading VS Time

4.3 Calculation:

- **[25]** The equation needed to convert Voltage (V) reading to Part Per Million (PPM) is
$$\boldsymbol{PPM = 3.027e^{(1.0698 * V_{RL})}}$$
- The relation between Voltage readings and PPM in graphic form:

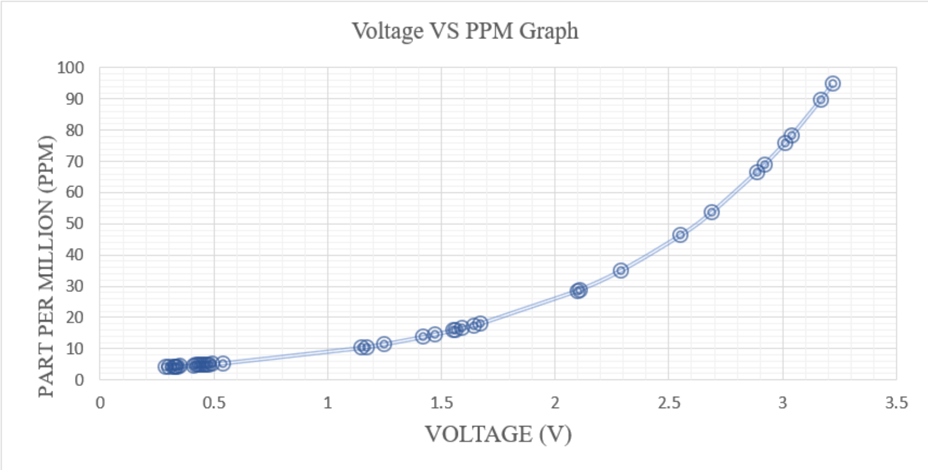

Figure 8: Voltage VS PPM Graph.

5 Conclusion:

The purpose of this research is to build a model that can measure and monitor CO in car exhaust in the FIT indoor parking garage. This smart system will give an early alert to avoid any injury or death from CO; the model consists of low-cost parts and low power consumption, as well as ease of use and speed in functioning with high performance. The system uses modern technology, IOT, an important new technology. It is hoped that in the future, the system will contribute to the health and safety of society and the world.

References

[1] O. Vermesan and p. Friess, Internet of Things: Converging Technologies for Smart Environments and Integrated Ecosystems, Aalborg, Denmark: River Publishers, 2013.

[2] R. Shete and S. Agrawal, "IoT Based Urban Climate Monitoring using Raspberry Pi," in *International Conference on Communication and Signal Processing*, India, 2016.

[3] A. Zanella, S. Member, IEEE, N. Bui, A. Castellani, L. Vangelista, S. Member and M. Zorzi, "Internet of Things for Smart Cities," *IEEE INTERNET OF THINGS JOURNAL,* vol. 1, p. 11, 2014.

[4] S.-M. Chun and J.-T. Park, "A Mechanism for Reliable Mobility Management for Internet of Things Using CoAP," p. 12, 8 November 2016.

[5] R. Rushikesh and C. M. R. Sivappagari, "Development of IoT based Vehicular Pollution Monitoring System," in *IEEE*, Noida, India, 2015.

[6] C.-T. Lin, M. Prasad, C.-H. Chung, D. Puthal, H. El-Sayed, S. Sankar, Y.-K. Wang, J. Singh and A. K. Sangaiah, "IoT-Based Wireless Polysomnography Intelligent System for Sleep Monitoring," *IEEE Access,* vol. 6, no. IEEE, p. 11, 2017.

[7] R. S. B. Rosli and R. F. Olanrewaju, "Mobile Heart Rate Detection System (MoHeRDS) for Early Warning of Potentially-Fatal Heart Diseases," in *International Conference on Computer & Communication Engineering*, Kuala Lumpur, Malaysia, 2016.

[8] K. A. Patil and N. R. Kale, "A model for smart agriculture using IoT," in *IEEE*, Jalgaon, India, 2017.

[9] S. Athani, C. H. Tejeshwar, M. M. Patil, P. Patil and R. Kulkarni, "Soil moisture monitoring using IoT enabled arduino sensors with neural networks for improving soil management for farmers and predict seasonal rainfall for planning future harvest in North Karnataka - India," in *IEEE*, Palladam, India, 2017.

[10] R. Patel, S. Sengottuvel, K. Gireesan, M. P. Janawadkar and T. S. Radhakrishnan, "Extraction of breathing pattern using temperature sensor based on Arduino board," in *AIP*, Kalpakkam, India, 2015.

[11] A. Nayyar and V. Puri, "A review of Arduino board's, Lilypad's & Arduino shields," in *IEEE*, New Delhi, India, 2016.

[12] N. E. P. Health, "Carbon Monoxide Poisoning," *https://ephtracking.cdc.gov/showCoRisk.action,* p. 1, 26 October 2016.

[13] Helmenstine and A. Marie, "What Is Carbon Monoxide Poisoning?," *https://www.thoughtco.com/carbon-monoxide-poisoning-4048941,* p. 1, 24 January 2018.

[14] R. Albinger, "Monitoring and Control of CO Emissions in Parking Structures," *https://www.parkingtoday.com/articledetails.php?id=735,* p. 1, March 2009.

[15] Detect Carbon Monoxide Website, "CO Knowledge Center".*https://www.detectcarbonmonoxide.com/co-health-risks/.*

[16] M. Gor, J. Vora, S. Tanwar, S. Tyagi, N. Kumar, M. S. Obaidat and B. Sadoun, "GATA: GPS-Arduino based Tracking and Alarm system for protection of wildlife animals," in *IEEE*, Dalian, China, 2017.

[17] B. E. Medina and L. T. Manera, "Retrofit of air conditioning systems through an Wireless Sensor and Actuator Network: An IoT-based application for smart buildings," in *IEEE*, Calabria, Italy, 2017.

[18] H. Nugra, A. Abad, W. Fuertes, F. Galarraga, H. Aules, C. Villacis and T. Toulkeridis, "A Low-Cost IoT Application for the Urban Traffic of Vehicles, Based on Wireless Sensors Using GSM Technology," in *IEEE*, London, UK, 2016.

[19] J. Yang, J. Zhou, Z. Lv, W. Wei and H. Song, "A Real-Time Monitoring System of Industry

Carbon Monoxide Based on Wireless Sensor Networks," p. 12, 17 November 2015.

[20] S. Karamchandani, A. Gonsalves and D. Gupta, "Pervasive monitoring of carbon monoxide and methane using air quality prediction," in *IEEE*, New Delhi, India, 2016.

[21] M. A. Borges, G. M. F. Correia, M. d. O. Igarashi, P. B. Lopes and L. A. Silva, "an Architecture for the Internet of Things and the Use of Big Data Techniques in the Analysis of Carbon Monoxide," in *IEEE International Conference on Information Reuse and Integration (IRI)*, Sao Paulo, Brasil, 2017.

[22] D. Puthal, S. Nepal, R. Ranjanl and J. Chen, "Threats to Networking Cloud and Edge Datacenters in the Internet of Things," *IEEE Cloud Computing,* vol. 3, no. 3, p. 8, 2016.

[23] ." WECL،"Arduino Uno ،WECL Electronic Specialist

[24] Research Design Lab, "Carbon Monoxide Sensor MQ-7," Balmatta, Mangalore, India.

[25] jenfoxbot, "Hazardous Gas Monitor".*https://learn.sparkfun.com/tutorials/hazardous-gas-monitor/calculate-gas-sensor-ppm.*