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IoT-based Smart Traffic Cone System to Avoid Traffic Congestion and Improve Road Safety

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ABSTRACT: Chain-reaction automobile accidents are a common occurrence, especially on freeways. Several reasons can lead to these collisions, such as speed, failing to see stop signs for oncoming traffic, and unforeseen road conditions. The Internet of Things (IoT)-Based Smart Traffic Cone System is created as a solution to these problems. It makes use of a variety of sensors and IoT technologies that are elegantly incorporated into the traffic cone's design. It is a solar-powered smart portable device in the shape of a traffic cone. Particularly on two-way roads, the traffic cones are positioned strategically in the median of the road. In addition, a traffic display panel is placed near the signal to make necessary adjustments before encountering traffic jams. A Bluetooth system is used to alert the drivers inside their vehicles about the road conditions. This initiative is aimed at the VISION 2040 of Oman, which emphasizes the creation of smart and sustainable cities with advanced IT infrastructure. The smart traffic cone represents an innovative solution developed after long research and with the recommendations and guidance of the Royal Oman Police (RoP) for the advancement of smart city development. Through continued research and development efforts, the functional prototype of the Traffic cone system has been successfully developed.

1. INTRODUCTION

Road accidents are bound to happen, every day we hear about road accidents, whether it is from the news or on social media networks. On a normal day going to work, you may have seen a crowded road due to a traffic accident been in an accident yourself, or witnessed one happening. It has become a common phenomenon due to many reasons including heavy congestion, speed, weather changes, recklessness, violation of rules, and failure to understand signs. As a result, many people get seriously injured or even lose their lives. Approximately 1.3 million people die around the world each year.

According to the National Center for Statistics & Information (Oman) in 2021, traffic accidents caused 1621 injuries and 434 deaths, and speed was the largest cause of accidents, as the number of traffic accidents reached 820 due to speeding, and it accounted for 53.3% of the total traffic accidents [1]. The data will show a positive correlation between the number of added increased population and the total number of road traffic accident deaths, to conclude there are many intelligent systems widely used, and research has been done to control roads and lanes using several methods and technologies, “IoT-based Smart Traffic Cone” play a vital role in reducing Accidents caused by traffic congestion and rainy weather to make the transportation more easier and safer.[2] As per the VISION 2040 of OMAN Smart and sustainable cities are to be built with advanced IT infrastructure. This project is designed to

develop a solution to reduce the chain reaction accidents in our roads [3].

2. PROBLEM STATEMENT

Population growth is related to traffic congestion, as more people move to cities, the number of vehicles on the road rises. [4] Climate change in rainy seasons can also raise the water level, which increases the risk of a driver losing control of their vehicle. Additionally, poorly designed roads (In terms of capacity) make mobility difficult. 80–90% of road accidents may be caused by human error [5], such as making poor decisions when under time pressure, according to a study. This includes both causing an accident and failing to maintain a safe space between two vehicles.

Inventing IoT scenarios to improve transportation and reduce traffic accidents.

It aims to optimize traffic flow and reduce traffic accidents by helping the drivers to know that the highway road traffic is stopped and they need to slow down so that they avoid any accident caused by the busy traffic, also it has another function which is to inform the drivers that the road is full of water and they have to be careful while they driving.

Specific objectives are as follows:

A. Reduce traffic congestion.

B. Prevent continuous road accidents and the death

C. Manage the flow of vehicles to ensure smooth traffic.

D. Helping drivers to avoid chain reaction accidents.

E. Reducing the multiple vehicle collisions.

F. Enhance driver Experience.

G. Improving Safety.

H. Live monitoring of roads using the camera

To get maximum efficiency out of the existing road network while minimizing the negative impacts of traffic, the Internet of Things has the maximum potential to create a new wave to transform the transportation industry by providing connectivity, security, analytics, and monetization to enable smarter transportation strategies.

3. PROJECT DESCRIPTION

The IoT-based smart traffic cone will be placed on the median of the highway between the ingoing the outgoing roads and it will sense the road using an infrared sensor (IR sensor) if the road is stopped for a few seconds it will light the ORANGE LED which is in the top of the traffic cone that will inform the driver at the back that the road is stopped and they need to decrease their speed. If the traffic is stopped the RED LED on top of the cone will start flashing. A moisture sensor is used to check if the road is affected by the water if it's raining, or by any other condition.

The motion sensor will be used to monitor if someone is standing in the median for crossing the roads and alert the driver by showing an orange light in the traffic cone. During night a green LED is lighted at the top of the cone to show the median of the road.

This data is sent to other traffic cones wirelessly so that all the traffic cones in that line will also light up until the traffic signal. The traffic signal will also light up as per the cone status. A Bluetooth system is used to alert the driver in their vehicles about the road conditions when they come near to the traffic signal. The traffic cones will be of maximum 105 m distance from each other, the cone will consist of 3 sensors on each side. if the roads are affected by the rain or floods, the BLUE LED light will start flashing as the ROP suggested which will represent the water issues in the road. Using solar energy for the entire working of the project renewable energy production.

A traffic display panel will be placed before the traffic cone so that the drivers can take action before they get to the place where there is a traffic jam. The distance between the cone and the wireless display panel is 20 meters. Another Buzzer will also be activated and the Red LED light will be turned on in the LED Display panel. The ROP (Royal Oman Police) can monitor the status of the smart traffic cones and can activate/deactivate the system remotely using an application through the internet, and if two to three sensors detect an issue on the road it will inform the ROP controller. RoP can monitor the road status and the surroundings of the cones using a camera.

4. METHODOLOGIES USED AND SYSTEM REQUIREMENT SPECIFICATION

4.1 Purpose

Methodology is like an instructional manual or guide to effectively oversee the completion of the project. A project team must have a set of defined processes to

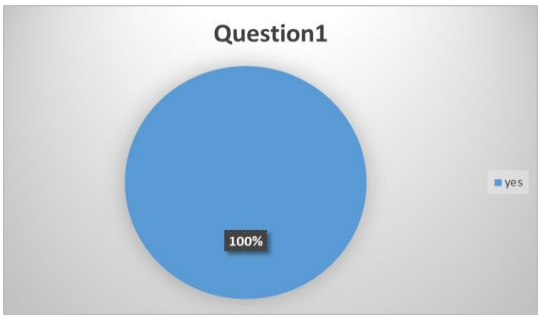
follow to initiate, plan, and, execute the project. Common project management methodologies include waterfall, agile, and scrum. [6]

The methodology used is the waterfall approach.

4.2 Requirement gathering

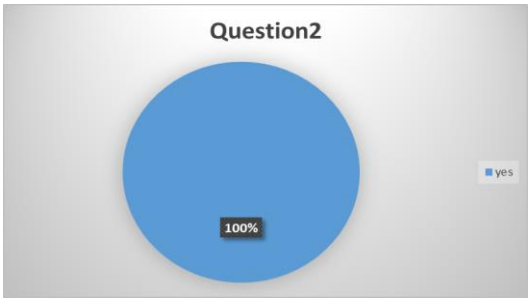
In this phase, we gathered information using a questionnaire/interview, and the questionnaire was as follows:

Q1: Do you think ROP needs to use an IOT-based device that reduces accidents caused by busy traffic?



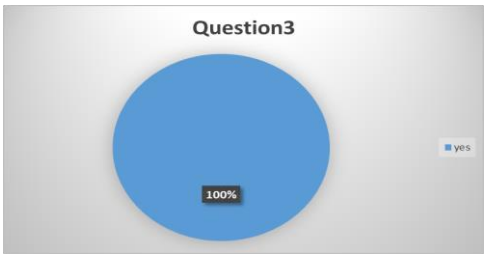
Yes (100%), No (0%), others (0%)

Q2: Do you think that an accident on the highway can lead to more accidents?



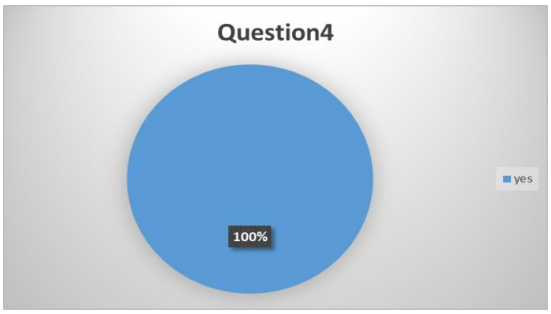
Yes (100%), No (0%), others (0%)

Q3: Dose it considered to find a solution for managing the traffic during a car accident in the middle of the highway?



Yes (100%), No (0%), others (0%)

Q4: If the system is developed do you think that it will make a big difference to the safety of the road?



Yes (100%), No (0%), others (0%)

4.3 Design

We designed the project after we had the requirements. This level does not include any coding. When the design stage is complete, the design will be transformed into a physical design using real devices and software.

4.4 Implementation/Development

When the design was complete, technical implementation started. This stage includes coding. We used the knowledge gathered during the design phase to create a working product. If significant changes are required during this stage, this may mean going back to the design phase.

Below are some key technical aspects and components typically involved in our system.

IoT: The Internet of Things, or IoT, is a system of interrelated computing devices, mechanical and digital

machines, objects, animals, or people that are provided with unique identifiers (UIDs) and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction. [7] The different sensors used in the system are IR sensors These sensors detect any impact or movement of the traffic cone, indicating potential changes in the road environment. Motion sensor which is used to monitor any person standing in the median which will falsely trigger the traffic cone. Water level sensor to check the level of water in the road to identify whether a vehicle can pass through that road.[8] We used four Communication Protocols in our project The first is the LoRa WAN transceiver for communication between the traffic cones. The is a half-duplex wireless serial communication module with 100 channels in the 433.4-473.0 MHz range that is capable of transmitting up to 1 km [10] and second the RF transmitter and receiver for the communication between the traffic cone and traffic display panel. Third, the Bluetooth transmitter broadcasts data to the nearby vehicles, and the fourth cellular network does the control and monitoring of the traffic cone. The microcontrollers used in our project are Raspberry Pi 4 for the effective working of the Traffic cone and node MCU ESP8266 for the working of the traffic display panel Microcontrollers. Solar Panel: A solar panel, also known as a PV panel or module, is a device that collects sunlight and converts it into electric current. [9]. For the sustainable and continuous power for the working of the traffic cone, we used a 50-Watt 6 Volt Monocrystalline Semi-Flexible Bendable solar panel for the cone so that it will fit with the shape of the cone and 6V 4Ah Lead Acid battery and placed in the bottom of the cone so that the weight of the battery keeps the cone intact during the wind and flood. A BMS which was available with the solar panel charging circuit ensures the efficient use of power and will monitor the battery health. The data collected using the different sensors are available in the cloud system for the AI system to check and make changes in the traffic signal lights. This data is also used to identify the heavy traffic time and plan for expansion. The database and our system are protected with endpoint security and can be accessed only using a special key which will be with the RoP. Users can monitor and manage the smart traffic cone system through the dedicated Cayenne mydevices application and can use the web browser which provides real-time information and control features. We have minimal use of AI to analyze sensor data to predict when high traffic is occurring. Buzzer: An audio signaling device like a beeper or buzzer may be electromechanical piezoelectric or mechanical type. [11]

4.5 Software Requirements

a) Operating system- Raspbian OS

b) Cloud API - Cayenne, Cloud database

c) Programming API- Python 3 IDE

4.6 Operating Environments

a) Attempting to reduce chain reaction accidents

b) Attempting to reduce traffic congestion.

c) Provide Live monitoring of roads using a camera

d) Any issue detected will be informed to ROP

e) ROP can monitor the road status using a camera.

f) Activate/deactivate the system remotely using an application through the internet.

4.7 Design and Simulation using Block diagram:

This diagram below shows the simple planning of the traffic cone system. The system will use different types of sensors including IR sensors will sense the traffic movement, Moisture sensors that will be used to check the water level, LDR sensors is used to detect the

intensity of light, and Motion sensors To detect nearby people or objects that will start an alarm to inform them to stay away from the cone so that they will not affect the functions of the other sensors, also it has a camera for the ROP to monitor the road in case of any issues, and three LED that have three different colors, Red, Orange, and Blue, the Red-colored LED is to indicate that the traffic movement is stopped, the Orange colored LED is to indicate if the traffic movement is slow, and lastly the Blue colored LED is one when the water level is high, HC 12 transceiver that will be used to send and the receive the signal from different and to the display panel. The display panel will have three LEDs the same as the cones, and will receive the signal from the cones via the HC 12 transceiver. The cones will be installed with a GPS to track them, also an email service will be available in case anything happens in the road that causes the traffic to stop, the ROP will receive an email regarding the issue and it will contain the location of it and other additional information.

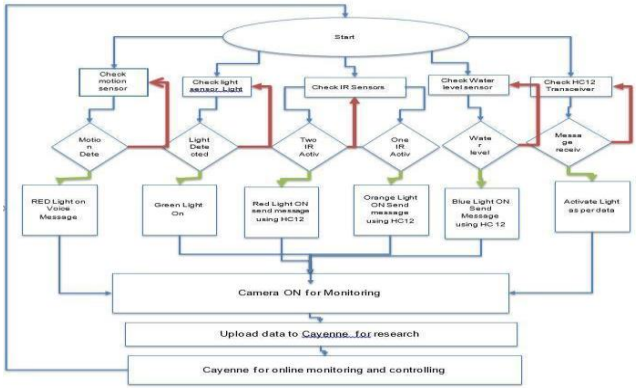


Fig 4.1: Flow Chart

4.8 Prototype Using Simulation Software

Simulation modeling is the process of testing the functionality of the system before it gets implemented physically. It is a logical design structure that helps to understand how the system will work.

In our project, the Cisco Packet Tracer with the version 8.2.0 is used for the simulation process. It is a tool designed by Cisco for visual simulation that has the ability to create network topologies and imitate modern computer networks. it gives the users the ability to simulate the configuration of different networking devices such as Cisco routers and switches using simulated CLI. The software can also be used to simulate IOT devices Configuration

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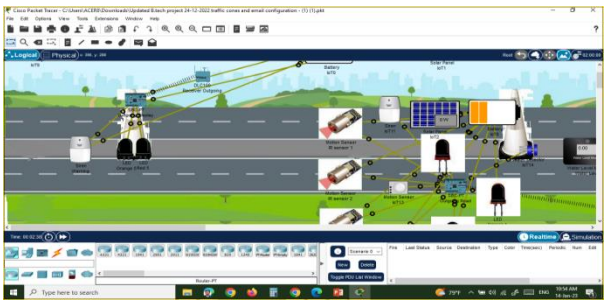
4.9 Prototype - Packet Tracer Simulation

Figure 4.2: Packet Tracer Diagram



5. NETWORK DESIGN, TESTING AND IMPLEMENTATION

5.1 Software of the project

We are planning to use the following software to implement our project:

Cayenne-IoT:

Cayenne is an IoT online dashboard platform that takes most of the complexities out of creating hardware-oriented programming [12]. We are using this to control the IoT devices from remote via mobile. You can send data to ThingSpeak from your devices, create instant visualization of live data, and send alerts. [13] Raspberry Pi OS (previously called Raspbian) [14] it is a Debian operating system based on Linux for Raspberry Pi. This OS was officially released by the Raspberry Pi Foundation it has been the primary interface for the Raspberry Pi family of tiny-sized computers since 2013. In addition, the latest version of Raspberry Pi OS was released on January 28, 2022. [15]

5.2 Network design steps

In our project we used 4 types of sensors. IR sensor to detect if the traffic movement is stopped or when it is slow, and we are using 4 sensors of this type to achieve this, two sensors on one side of the road. The second sensor is the water level sensor, which is used to sense the water level in the road. The third sensor is the motion sensor, which is used to detect the nearby people or objects to inform them to go away from the cone to not interrupt the functionality of the cone. The fourth sensor is the LDR sensor which will used to detect the intensity of light. Also, the system is using a camera to monitor the Roads. To transfer the signal between the cones we are using the HC12 transceiver. For

charging the cones, a Solar panel is used. To inform the drivers about the condition of the road different LEDs have been used Red, Orange, Blue, and Green, and LCD screens.

5.3 Fritzing implementation

a) Fritzing Circuit Diagram

Fig.5.1 Fritzing Circuit Diagram

b) Fritzing Schematic Diagram

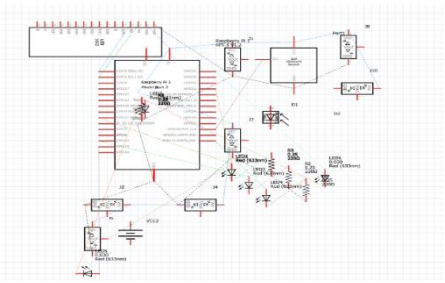


Fig 5.2 Schematic Diagram

5.4 Raspberry Operating system

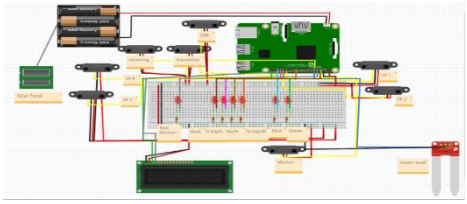
Interacting with a Raspberry Pi requires an operating system called Raspberry Pi OS, which is an operating system with graphical interfaces. It is installed by using the Raspberry Pi Imager. Raspberry Pi Imager is a quick and easy way to install an operating system. The first step is to download the Raspberry Pi Imager file on a computer with an SD card reader and store the downloaded operating system file in the SD memory of at least 8GB (16GB recommended), finally, we will install the memory in the Raspberry and boot the Raspberry Pi with Imager file from the SD memory which will become the main storage for the Raspberry Pi OS boot on the device.

5.5 Preliminary Circuit design using Fritzing

Fritzing is open-source software that supports designers, engineers, and academics in creating electronic projects as creative prototypes, and those interested in experimenting with interactive electronics by including devices, sensors, circuit design, and electronic connections for their project. Where we helped the program understand the necessary connections to the components of our electronic project. We created our circuit on the breadboard and started connecting the pins from our IoT components to the controller.

5.6 Integration of devices to SBC (Raspberry Pi)

The SBC used is a Raspberry Pi 3. The sensors that will be used in this project are: IR sensor that will detect the movement of the traffics, water level sensor which will measure the water level in the roads, motion sensor that will detect the nearby people or object, LDR sensor which will detect the intensity of light, in addition to a camera for monitoring the roads, and a buzzer and LCD are used when something happened in the road to inform



the drivers about it, LEDs also will serve the same purpose, Red is when all sensor is detecting, yellow if one, Blue is when the water level is high, and green is when the light is detected. SBC is connected to the power supply and also to WiFi. The SBC connects to the monitor using an HDMI cable and also to the USB keyboard and mouse. To the different GPIO pins, we connect different sensors and actuators.

6. SUMMARY AND CONCLUSION

6.1 Summary

The IoT-based smart traffic cone system is an innovative project that aims to reduce the Chain reaction accidents. The device is portable and solar powered so can be placed anywhere. The traffic cones will be placed in the middle of the highway each cone will be from 50 cm to 100 M distance from each other. is a smart cone with 4 types of sensors IR sensor, water level sensor, motion sensor, and Light sensor. if one IR sensor detects the traffic movement is stopped or slow (orange colored LED) if two IR detect (red colored LED). the water level sensor to check the water level (blue colored LED), motion sensor to check if someone is standing in the median and may cross the road(red colored LED). The light sensor is used to illuminate the traffic cones at night providing Live monitoring of roads using cameras and using solar energy for clean energy production.

A traffic display panel will be placed before the traffic cone so that the drivers can take an action before they get to the place where there is a traffic jam. The ROP (Royal Oman Police) can monitor the status of the smart traffic cones.

6.2 Conclusion

To sum up everything that has been stated so far, Innovating an IoT smart cone system to improve transportation and reduce traffic accidents.by managing traffic flow and reducing traffic accidents by helping drivers know that traffic on the highway is at a standstill and that they need to slow down in order to avoid any

accident caused by heavy traffic, and it also has another function which is to inform drivers that the road is full of water and they should Be careful while driving. To get the maximum efficiency out of the existing road network while minimizing the negative impacts of traffic, the IoT has the potential to create a new wave to transform the transportation industry by providing connectivity, security, analytics, and monetization to enable smarter transportation strategies.

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