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IoT Carbon Monoxide Detector with Monitoring System for Car: A Design and Development for Safety Awareness

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Abstract

Carbon monoxide is a gas that is colourless, odourless, and tasteless. It may experience partial combustion. Carbon monoxide has long been recognised as a silent killer. Enclosed areas or idling vehicles in garages can lead to elevated carbon monoxide levels in automobiles. The aim of this study is to develop a gas sensor capable of detecting carbon monoxide in vehicles and integrating it with the Internet of Things (IoT). This sensor can transmit data to other devices or systems and link to technologies via the Internet and sensors. The system utilises the MQ-7 sensor as a carbon monoxide detector, which the gas sensor employs to detect notifications. The Arduino IDE facilitates a connection between hardware and software through data transmission. The study uses the Blynk application to detect carbon monoxide levels on a smartphone. The smartphone's alarm will trigger to notify the user if the CO (Carbon Monoxide) concentration is above 50 ppm. It will remain inactive if the value is beneath the threshold. Drivers can use the device as a safety measure to identify the presence of carbon monoxide in their automobiles. Conducted a test on the carbon monoxide detector to evaluate its response to an increased CO concentration of 100 ppm. Nonetheless, the objectives in this case are to guarantee their functionality and ability to detect and provide alerts that offer reliable protection against carbon monoxide exposure. This study utilised diverse systems and approaches, including Kansei Engineering (KE) and User Center Design (UCD), to determine user preferences for carbon monoxide devices during the development phase. Therefore, anticipate that the standard design process will give practitioners, especially product designers, more guidance in creating design specifications. Furthermore, it broadens the theory's relevance to product design and development.

Keywords

Carbon Monoxide Detector, Internet of Things, Gas Sensor, Monitoring System, Product Design and Development

1. Introduction

Carbon monoxide is a chemical compound that is a combination of a carbon atom and one oxygen atom. This carbon monoxide can be dangerous if people are exposed to it in the long term, which can be dangerous because it can attack the breathing system inside our bodies. Among them are common causes, including vehicle exhaust, fire smoke, and inadequately maintained heating systems [1]. The cases involve inhaling the excessive carbon monoxide that can kill due to the failure of the air conditioning system that gas is emitted into the atmosphere via the exhaust pipe. For example, the four young women were suspected to have inhaled carbon monoxide while resting in their vehicles at the parking lot of a petrol station in Sama Gagah on mainland Penang on 17 September 2020 [2]. Only one survivor remained in critical condition at a hospital in Kuala Lumpur.

Treatment that is suitable for carbon monoxide exposure, such as carbon monoxide poisoning, is initiated with supplementary oxygen via a non-rebreather mask and vigorous supportive treatment [3]. Then, to prevent the incident of carbon monoxide poisoning, install the carbon monoxide detector to detect the presence of carbon monoxide. The purpose is to detect and give a warning if the carbon monoxide is surrounding before it reaches a dangerous level. To effectively detect this harmful gas, it is crucial to identify the optimal material and technology [4]. Researchers try to improve the carbon monoxide detector from every aspect to develop the quality of detection of the gas itself.

A carbon monoxide detector is a device that can detect the presence of carbon monoxide in the area that approaches the device. Gas sensors' primary performance factors include selectivity, sensitivity, reaction time, working temperature, limit of detection, stability, reversibility, energy consumption, humidity dependence, and cost of production [5]. The usual function of a carbon monoxide detector is to detect the existence of carbon monoxide while notifying people using an alarm so that people are alert to carbon monoxide exposure. It can be a preventative step against carbon monoxide poisoning. There are types of carbon monoxide detectors which are malfunctioning with humidity and functions. So, the power source of carbon monoxide also has a variety which can operate with a battery or using the plug-in type. The recommended placement of carbon monoxide detectors is typically installing the detectors in bedrooms, kitchens, and any rooms with fuelburning appliances.

A study on developing the carbon monoxide detector can be easier to use if the carbon monoxide detector can suit the environment and be accurate. These days, a wide range of instruments and processes are employed to identify hazardous gases, including gas chromatography, optical devices, semiconductor sensors, and acoustic sensors [4] [6]-[8]. By using the electrochemical sensor, it can provide fast, precise, and non-destructive analysis for targets [9]. Also, photoelectric sensors can detect light rays reflected from a target [10]. Sensors which are gas sensors (MQ7) can help to detect the presence of carbon monoxide if it exists surrounding the sensor. It can help people know the presence of gas such as carbon monoxide, which is dangerous for air pollution if the exposure is too much. Furthermore, the carbon monoxide detector has two types which are for home usage or car usage. The device for car usage is more compact and portable than for home usage. It is also different because the car is more dangerous than at home due to the space that requires a detector to detect the presence of carbon monoxide.

However, there are many cases basically from the carbon monoxide itself, which is from the incomplete combustion of carbon-based fuels from anthropogenic sources, such as engine exhaust, fires, and gasoline-powered tools, producing CO at dangerous levels [10]. The carbon monoxide detector is a device that can be a preventive step for people, notifying them of carbon monoxide exposure. The usage of devices can be important due to the accuracy of detecting the type of usage. Features such as digital displays that can show the value of carbon monoxide can help people know the real-time situation of the place. The development of carbon monoxide detectors can also record the past of carbon monoxide values that can be easy to monitor [11].

Addressing this issue would necessitate breakthroughs in sensor technology, integration with vehicle systems, regulatory mandates, and improved public awareness. Overcoming these problems allows us to drastically lower the risk of carbon monoxide poisoning in cars while also improving overall road safety. Implementing accurate CO detection equipment in automobiles is critical for avoiding these tragedies and ensuring the safety and well-being of all vehicle occupants [12].

The objective of this study is to develop an IoT carbon monoxide detector with a monitoring system for car design that considers the user influences. To achieve this objective, this paper is divided into three sections. The first section concerns the existing study review of carbon monoxide detectors with monitoring systems and designs. In this phase, the importance of each aspect is identified. The second section discusses the potential correlation between user influences and carbon monoxide detector with monitoring system attribute preferences. In this section, the elaboration of preferences on carbon monoxide detectors with monitoring system design is elaborated, and the carbon monoxide detector with monitoring system design specifications are generated. The last phase concerns the carbon monoxide detector with a monitoring system sketch, a 3D design model, and the testing of the prototype. The conclusion section also explains the potential contribution of knowledge and practices.

2. Materials & Methods

This study involves 4 steps as shown in Figure 1.

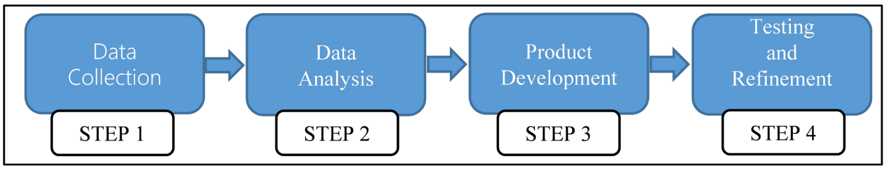


Figure 1. Process flow of the study.

2.1. Step 1: Data Collection for Features of Carbon Monoxide Detector

The first step is data collection, where all the data collected consist of methods that relate to this study. 24 units of existing products of carbon monoxide detectors have been benchmarked and analysed according to their features, functionality, design, size, and capabilities to know the user needs by using the market positioning, specification analysis, and position map. Product features are important to help the user to know more details, including the purpose of why the features exist in that product. The size of the product is also an advantage for the product because the usual carbon monoxide detector mostly is not lightweight. It can be hard to attach to any surface. The height and width of the product make sure that the device is handheld, compact, and easy to attach to any surface. Then, the other features, such as the LCD display, can make it easy for people to know the real time of carbon monoxide values. The battery level can also be seen due to the period of usage as shown in Figure 2. The difference between the usual carbon monoxide detector and the bulkier design is that the latter is also not as aesthetic as the handheld carbon monoxide detector because of the sensor, buzzer, and alarm at the back of the product, which is more compact. Refer Table 1 for details of features.

Furthermore, it is impossible if the sensor is not included together in the carbon monoxide detector. Also, the alarm light is an additional feature that is quite good for carbon monoxide detectors to give a signal for carbon monoxide detection. Moreover, this part is the most important thing of carbon monoxide detectors to increase the productivity of the product while giving a good appearance for the usage of the device. This part also can influence the usage of the carbon monoxide detector that is different from other carbon monoxide detectors which are not portable and lightweight. Next, the alarm light and saved max light are additional to attract the user to use that detector. By combining all these components, it can boost the functioning of the carbon monoxide detector, and it can be a user-friendly carbon monoxide detector. Lastly, the most important part of this device, which is the sensor and buzzer, must be suitable for the size and functionality.

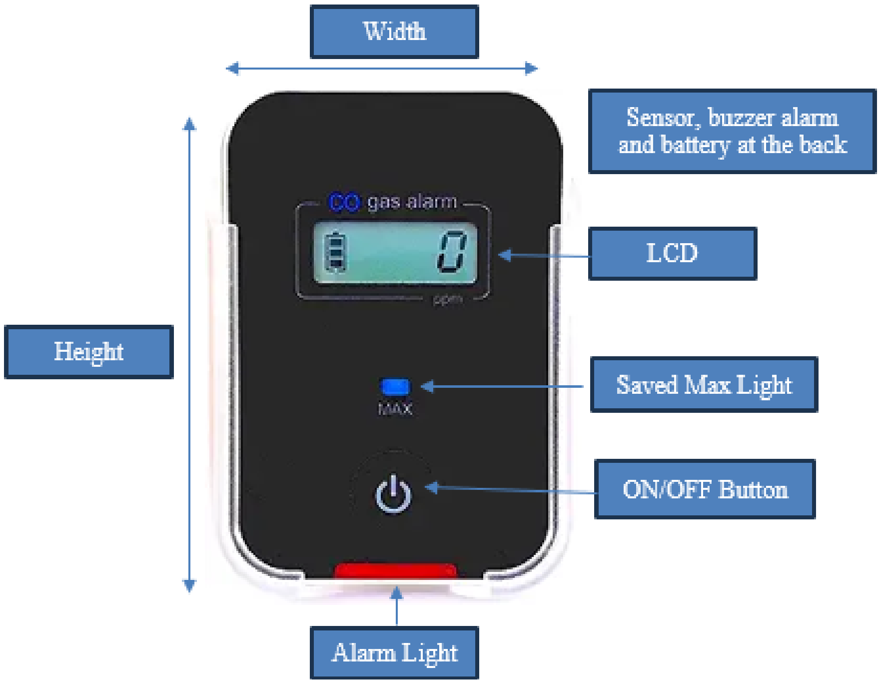


Figure 2. Features of carbon monoxide detector.

Table 1. Details of features.

Item	Description
Height and width	Used to make sure that the size of carbon monoxide detector is suitable for its usage
Sensor	The most critical component that used for detection process
Buzzer alarm	Used to notify the user when the sensor is trigger
Battery	The battery is needed for carbon monoxide detector usage
LCD	To show the level of carbon monoxide values
Saved max light	To save the maximum data of carbon monoxide level
ON/OFF button	The button to ease the people to open and close while using the device
Alarm light	The light will open if there is carbon monoxide in existence

2.2. Step 2: Data Analysis for User Preferences of Carbon Monoxide Detector

The second step consists of data collection that is already analysed by categorising the features that are suitable for user needs and can satisfy the user instead of just developing the product without using any guide. There is a questionnaire that involves the emotional aspect due to the features that are needed in a carbon monoxide detector. Kansei methods that are always related to the emotional reactions of the user according to the product, which can define user needs. Kansei engineering is a methodology that is suitable to guide the product development or improvement of products that can involve the emotional responses of customers into design elements and features of the product. This is frequently referred to as the customer's unspoken needs or "voice". It is inherently vital and sensitive for users or consumers; once fulfilled, it can result in great satisfaction and loyalty [13]. The words "kansei kougaku" in Japanese refer to the emotional or effective engineering due to the user experience.

Based on Figure 3, the concepts of KE refer to the feelings and emotions of the customer towards the product. The product's quality includes visual appeal, tactile sensations, sounds, and even smells. Products describe the emotional responses or feelings that are gathered from users through surveys or interviews. The KE also involves data collection with various methods, which are surveys, interviews and observation that can be qualitative and quantitative. After collecting the data, the data will be interpreted to identify the patterns and correlations between design and emotional users. It can give analyses such as statistical and factor analyses and neural networks. By converting the data to the Kansei analysis, it can visualise the specific design elements and features that are suitable for product development. The prototypes will show the functionality or design based on the design that was collected. Moreover, the product design can ensure that the emotions of the user are achieved. This method can also facilitate easy adjustments.

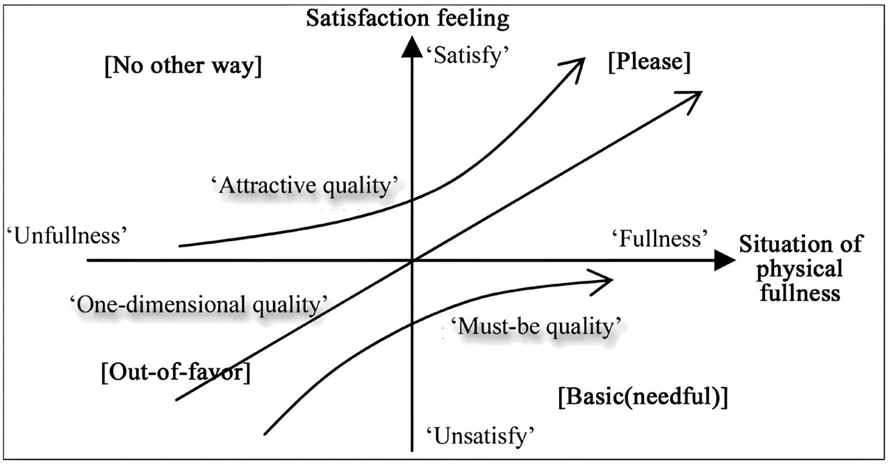


Figure 3. Kansei engineering method.

Kansei Engineering is a methodology that requires human emotions toward the product and gets the collected data to analyse the design's elements and features that are required to design a development product. It can also be used in various industries to ease the product or service. Then, KE can enhance the productivity and functionality of the product to improve its user experience.

This study provides a questionnaire survey that involved 51 respondents about their opinions on carbon monoxide detectors aligned with their preferences based on the appearance of the products. The Kansei method can be used to focus on questions related to appearance, including shape, size, and additional features. The questionnaire gathers Kansei terms that influence the user's selection of product features. The result can be to figure out the customer requirements. The questionnaire comprises three sections: A, B, and C. Section A provides general or basic topic information such as age, gender, and occupation, and it asks the user if they have a car or not. This type of question helps to understand how people are drawn to these studies. Furthermore, the device appeals to older individuals due to its ability to safeguard their families from carbon monoxide poisoning. The results from section A's general user information were collected to know who's the main target of this study.

The general knowledge of users regarding carbon monoxide detectors is discussed in section B. This section can ease the process of collecting the data of user preferences, such as the appearance of the carbon monoxide detector device. There are assorted designs of carbon monoxide detectors, such as for home users and for travel users, by prioritisation of the emotion of a carbon monoxide detector. The user also will ask about the preference of the factor to buy the carbon monoxide detector due to its functionality and appearance. Refer to **Table 2** and **Table 3** for the summary from the survey.

Table 2. Summary of section A (demographic).

Item	Percentage (%)
Gender (female)	70.6
Age (21 to 30 years old)	58.8
Education background (bachelor's degree)	49
Occupation (education sector)	34
Origin (middle of Malaysia)	60.8
Own the car (No)	51

Table 3. Summary of section B (general knowledge).

Item	Percentage (%)
Know about CO poisoning	Yes
Potential risk of CO poisoning	Worried
Having CO detector in car	Safety
Important to have CO detector	Integration with other car safety systems with minimal false alarms
Security when using CO detector	Immediate alerts
Potential installing CO detector	Neutral
Design of product	User friendly interface
Statement of CO detector	I would feel reassured if my car automatically contacted emergency services in case of high CO levels

Finally, the user in section C must choose the Kansei words. It can describe the feeling or emotional user towards the carbon monoxide detector suitable with the Kansei method [13]. The result of the survey is summarised in **Table 4**. According to the survey results, it can gather all the information that can be helpful in the development process. Thus, the questionnaire surveys can include every kind of person with diverse kinds of opinion.

Table 4. Summary of section C (user preferences).

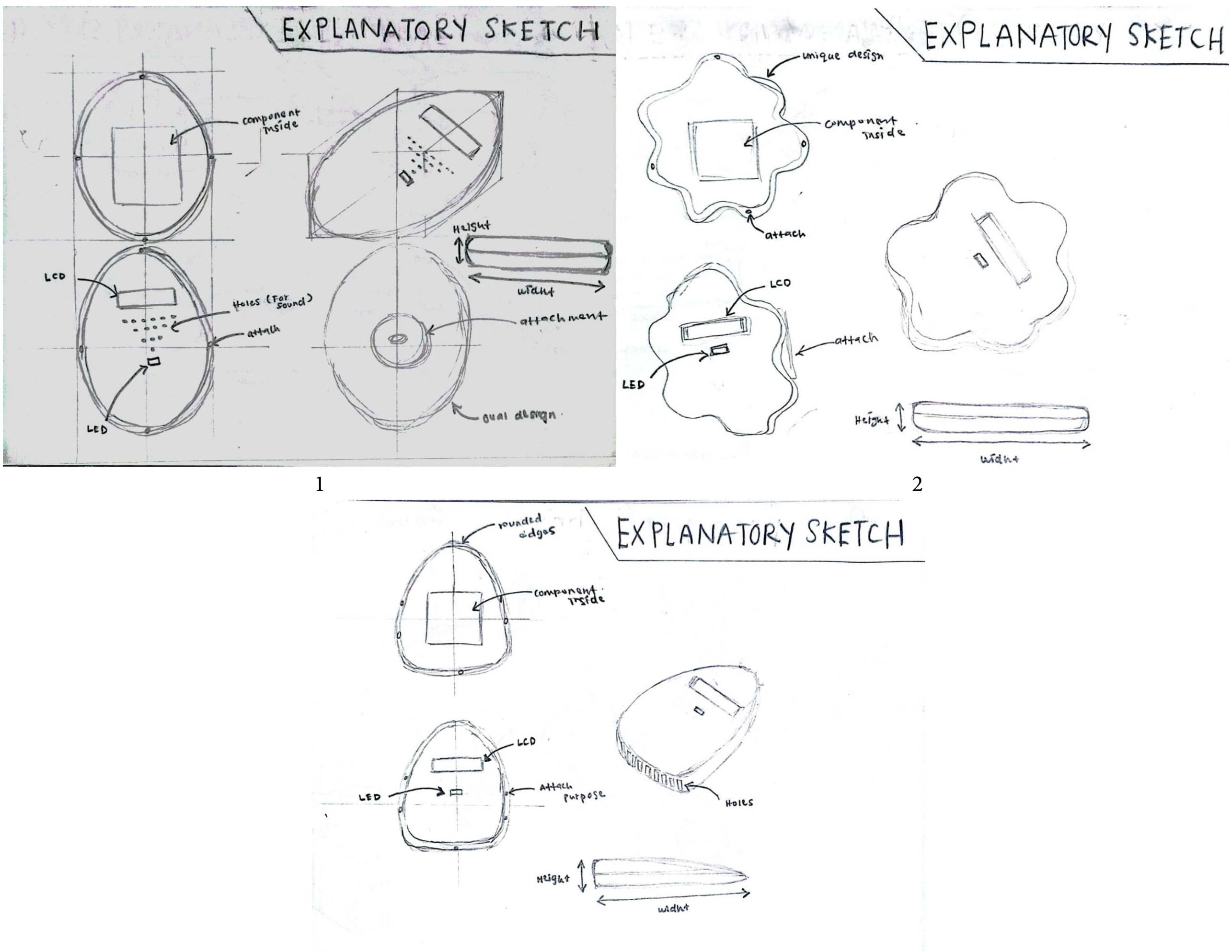
No	Criteria	Percentage (%)
1	Real time location detection	58.80
2	Easy maintenance	56.90
3	User friendly interface	52.90
4	Automatic emergency notification	49.00
5	Lightweight	49.00
6	Portable	47.10
7	Customizable alerts	47.10
8	Audible alerts	45.10
9	Battery backup	45.10
10	Easy to assemble	45.10
11	Unique design	43.10
12	Practical design	43.10
13	Push notifications for high CO levels	43.10
14	Real time CO level monitoring	41.20
15	Mobile app connectivity	41.20
16	Visual alerts	39.20
17	Data logging and history	37.30
18	Cloud storage for data	33.30
19	Aesthetic Design	33.30

2.3. Step 3: Product Design and Development of Carbon Monoxide Detector

The third step is the product development process. The design element and finding of the research can be visualised in the real product with the development of the prototyping. Design development is developing innovative ideas to build the product based on their system and design [14] [15]. By focusing on the functionality, usability, aesthetics, and feasibility in detailing the product. In this topic, the preliminary design to create the initial sketches of the product and using the 3D models to define the product functionality. It also involves the material that is used in this product. Detailed design which involves precise measurements due to the initial sketches. It can also include the material specification and technical details, such as the CAD models, circuit diagrams, and systems that are used in the product. In this study, circuit diagrams are the most important to this study to test and validate this study.

An investigative sketch is the sketch that can create the visual of the product that can represent the idea and problem-solving phases. It also can guide the development process because the sketch includes the features, design, and functionality of carbon monoxide detectors. By exploring the design and functionality of carbon monoxide detectors that are able to suit this study. The multiple shapes can give an idea to improve the design to be more aesthetic and user-friendly interface. Explanatory sketches of the design ideas before creating the finalised sketch. It must be simple to help with brainstorming and visualising design ideas. By planning the layout of products that is done by the designer. This stage is most important to plan what kind of shape and design that suits this study. It can also guide the development of more designs.

Below is the explanatory sketch from the brainstorming ideas as shown in Figure 4. Explanatory Sketch 1 has an uncomplicated design with an oval shape that fits the component inside. The width and height are suitable for prototyping. Additionally, this design incorporates an attachment suitable for mounting on a car dashboard. The holes for this shape are due to sound alerts and LEDs for carbon monoxide detection at a high level. The LCD also serves as a monitoring tool. Explanatory Sketch 2 has a unique shape that distinguishes it from other sketches. The component can also fit perfectly due to this design. The height and width are also perfect for the prototype of the carbon monoxide detector. The LCD is required to monitor; the



1 2 3

Figure 4. Explanatory sketch 1, 2 and 3.

level will be shown at the display. Also, for this design, the LED will trigger when the carbon monoxide is at a high level. Attachment is important due to the car dashboard. Explanatory Sketch 3 has a minimal design and aesthetic design that can fit the component with a suitable width and height. It has holes that can provide sound detection of high carbon monoxide. Including the LCD is important due to the carbon monoxide level display and attachment purpose. The LED is also the same as the other design in that it triggers the high carbon monoxide level.

To select the final design, use the Pugh Matrix method to define the perfect design for this study. Pugh Matrix is a type of matrix design that can guide comparison of designs. The best design will be selected based on the established criteria. Analysing using the best weight based on the section C in **Table 4**, percentage from the questionnaire would be as follows. In this Pugh Matrix as shown in **Table 6**, it can categorise the weightage into five categories as illustrated in **Table 5**. Score 5 is the feature that more than 50% of users in Section C's survey results preferred. Then, scores of 4 and 3 are given to the features that are more than 45% to 50% and more than 40% to 45% of the preferred features by the users, respectively. Lastly, score 2 and score 1 are the percentages more than 35% to 40% and more than 30% to 35%, respectively, preferred features in section C. The score each feature by selecting a suitable design for the carbon monoxide detector. By using the score and weight, the final score for each sketch can be identified.

Table 5. Pugh matrix weight.

Item	Percentage (%)
5	≥50%
4	≥45%
3	≥40%
2	≥35%
1	≥30%

Sketch 3 was chosen due to the shape rarely used for carbon monoxide detectors. Also, the design has smooth, rounded edges for both safety and aesthetic reasons. It indicates that the equipment is intended to be portable or user-friendly. Inside the component space, all the sensors and components are indicated in rectangular space. A rectangular cut-out on one side identified as an LCD. This panel may display readings, settings, or notifications. On the side, little holes have been sketched for ventilation or sound output. This shows that the gadget may incorporate airflow-dependent components such as a buzzer, microcontroller, or sensor. A smaller labelled portion beneath the LCD suggests an attachment point for mounting the gadget on a surface or integrating it with other devices. The small profile and general design make it ideal for handheld or portable applications, emphasising both functionality and ease of use.

Table 6. Pugh matrix.

Criteria	Weight	Sketch 1	Sketch 1	Sketch 1
Aesthetic design	1	1	3	2
Unique design	3	3	5	4
Practical design	3	3	3	4
Portable	4	4	2	3
Easy to assemble	4	3	3	3
Lightweight	4	2	1	3
User friendly interface	5	3	3	4
Customizable alerts	4	2	3	3
Real time location detection	5	3	4	5
Real time CO level monitoring	3	3	3	4
Push notifications for high CO levels	3	3	4	3
Visual alerts	2	2	2	2
Audible alerts	4	3	2	3
Mobile app connectivity	3	4	3	4
Data logging and history	2	3	3	2
Cloud storage for data	1	2	2	1
Battery backup	4	2	3	3
Automatic emergency notification	4	3	4	3
Easy maintenance	5	3	1	4
Total		52	54	60

3D CAD can create the detailing of a product and precise product design by conducting the exact measurement and detailing of product design as shown in **Figure 5**. It involves the design that is selected from the explanatory sketch and also can apply the material that is suitable for product design. It can illustrate the details of the design of the preliminary sketch. Also, drawing can include the multiple views, which are front, side, top and isometric views. By using SolidWorks software to create the 3D model, you can view the design from the top, front, and side perspectives as follows. The dimension of this top is 120 × 120 × 22.50. This kind of shape is suitable for prototypes and includes 5 small pins that can attach easily with the bottom. The bottom dimension of the prototype is 120 mm × 140.01 mm × 22.50 mm. This kind of shape is suitable to place the component. It also has holes to give the sound of a buzzer when carbon monoxide is at a high level. The functional and ventilation elements also are shown to describe an ergonomic and visually appealing shape. By maintaining a lightweight design, the wall of this product is thin, not like the other parts. The isometric view also helps to provide a 3D perspective that can visualise the final product as shown in **Figure 6**. The design appears practical and functional for component placement, which has proper accessibility for user interfaces.

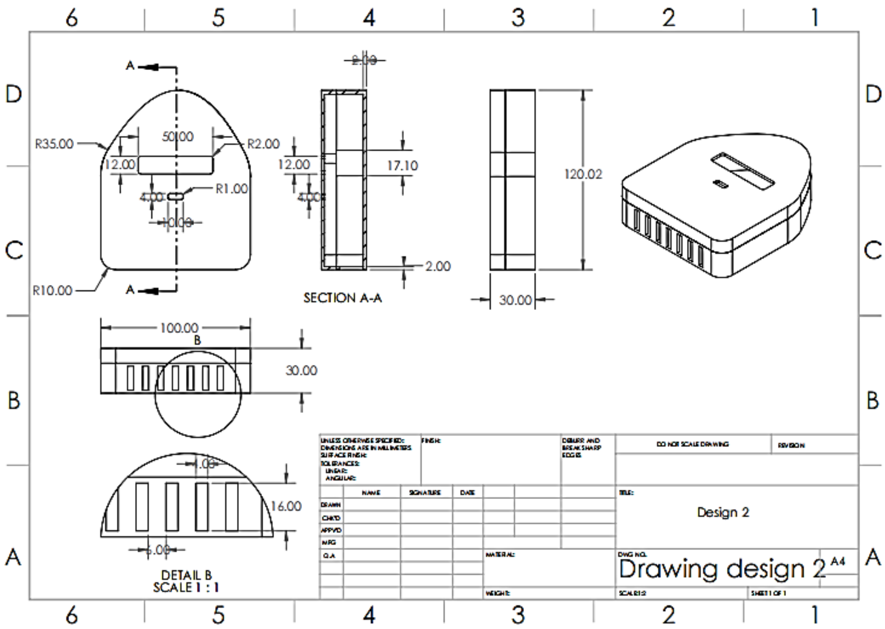


Figure 5. Drawing of the final design.

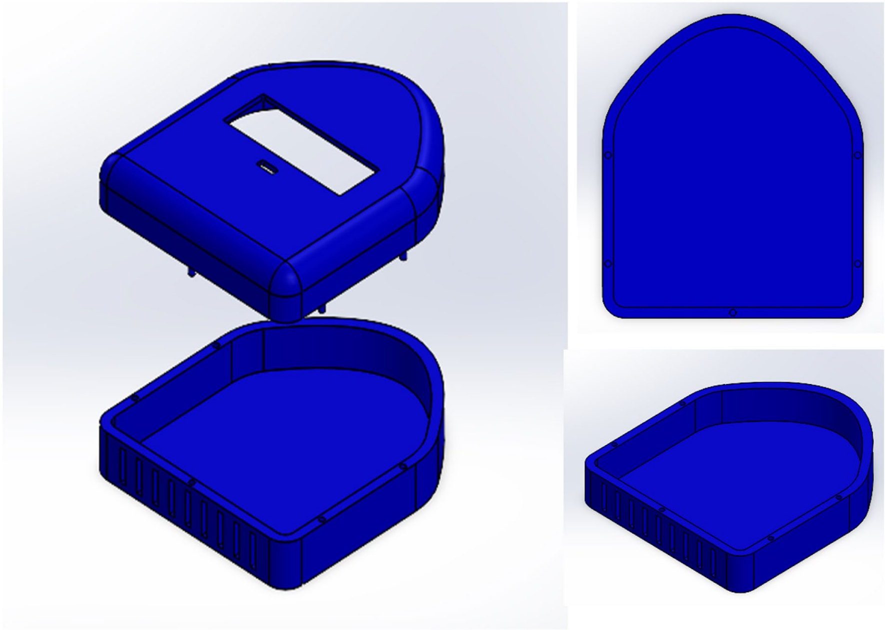


Figure 6. Views of the prototype.

3D printing allows for the creation of component casings according to the selected design. The two parts consist of completing the casing for the components. Plastic 3D printing usually uses material such as PLA (Polylactic Acid) or ABS (Acrylonitrile Butadiene Styrene), and it depends on which is suitable for printing. The finishing of the surface also has visible layer lines because of the typical quality of material. This 3D-printed enclosure is consistent with the previous sketch, implying that it is part of a prototype for an electronic device, such as a sensor or monitor. It works and shows how 3D printing can be used to make custom enclosures for electronics as shown in **Figure 7**. To develop the functional prototype, it will include the entire process to assess the design in the real world and identify the performance of product limitations. From this, it can know the efficiency of the product itself while maintaining the functionality and quality of the product. This area also allows for management of the product's capabilities.

Figure 7. 3D Printing of the prototype.

2.4. Step 4: Testing and Refinement of Carbon Monoxide Detector

Finally, step 4 is testing and validation of the product that collected the feedback from users about the product, such as the functionality of the product and the design of the product being suitable for the market. The refinement product needed to improve the process by using the Kansei Engineering (KE) and User Center Design (UCD) methods combined to get the product that follows the user needs. By using the UCD method, it can guide the prototype according to the functionality of the product, which can be an important aspect due to the carbon monoxide detector that consists of the user characteristics and priorities that can be included in this study. It also contributes the user preference that can assess the product to collect feedback that can be an optimal way for usability tests. The UCD methodology as shown in **Figure 8** is the process create the product based on the preferences and limitations of the end user, which is to give the design and development of the process easily to process. UCD also is the sustainment, which is a process of rebuilding the world and humanity to generate new opportunities for environmental sustainability and ensure the product is high quality and satisfies the functionality of the product [16]. This method also can be used to involve the product through the design and feedback of the product. It can also assist in the product development process by identifying the needs, limitations, and preferences of the end user. The aim of this method is to conduct testing and refinement based on the product's requirements [17].

There are benefits which are the usability of products improved by leading to higher adoption rates and user satisfaction. Every product must match the suitable features that can fulfil the user satisfaction. User feedback can enhance the product to meet user needs and expectations, ultimately leading to user satisfaction. Also, the design process can save time and resources by identifying and addressing usability issues to reduce the development cost. The challenges of the UCD method required the method with time-consuming conduct of the testing and research that was required due to the project development. Then, the developer will face the technical constraint and business goal to balance the stakeholder needs. Other challenges include the evolving preferences and needs of users, which can change over time and require updates and ongoing research in design development. The UCD method can ensure that the product will be designed according to the end user preference to be a more functional and useful product following the user preference. Understanding user emotions and experiences, such as those studied in Kansei Engineering (KE), is also important for knowing the design process.

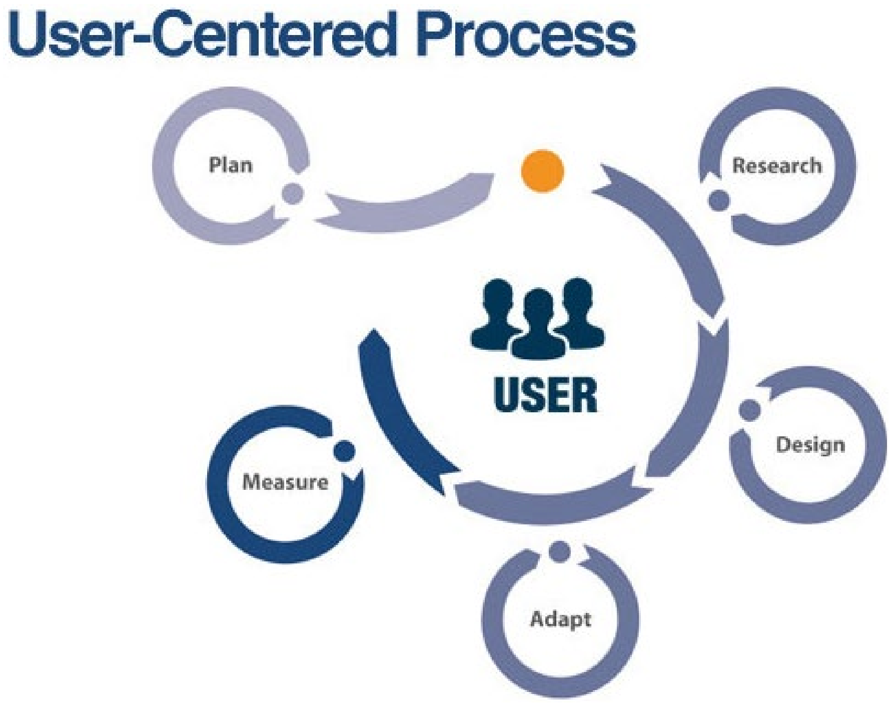


Figure 8. UCD process.

3. Results

Three systems pertinent to this investigation are employed for the detection of carbon monoxide in vehicles, as shown in Table 7. Various types of connections yield distinct outputs. This can serve as a guide to enhance the development process by increasing the efficacy of carbon monoxide detectors in automobiles. Numerous individuals utilise IoT in conjunction with applications to facilitate monitoring.

Table 7. Table comparison of system.

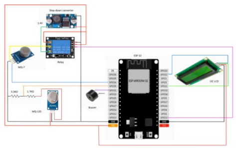
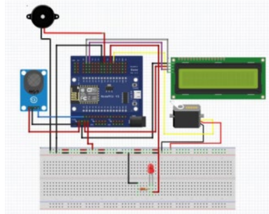
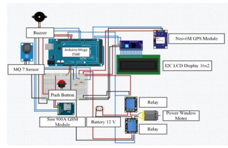
Items	Carbon dioxide and carbon monoxide detection system for cars	IoT-based carbon monoxide (CO) real-time warning system application in vehicles	IoT based carbon monoxide monitoring and warning system application in vehicles
Schematic diagram			
System	-Carbon dioxide and carbon monoxide detection -Real time result	-Carbon monoxide detection -Real time result -Warning alerts	-Carbon monoxide detection -Real time result -Real time location -SMS
Monitoring	-LCD display -Blynk apps	-LCD display -Blynk apps	-LCD display -Thingspeak
Hardware	-ESP 32 -MQ7 and MQ135 -Buzzer -Relay -Step-down	-ESP 8266 -MQ9 -Buzzer -LED -Resistor -Motor	-Arduino mega -MQ7 -Buzzer -Sim module -GPS module -Relay -Push button -Battery

Figure 9(a) is the schematic diagram used in this study. The diagram illustrates the actual configuration of the circuit. The Arduino Uno is crucial for this study as it serves as a microcontroller to regulate the input and output processes. GPS modules are employed to ascertain the device's position via interfacing with the Arduino. The LCD in this study utilises the I2C module to display the carbon monoxide level. The alarm buzzer will activate upon reaching a high level. Additionally, establish a connection between the transistor and resistor to provide optimal connectivity between the components.

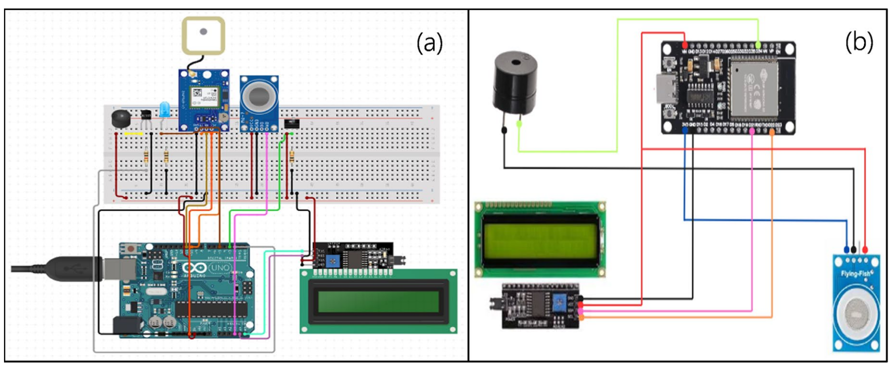


Figure 9. (a) Schematic diagram, (b) Improvised schematic diagram.

The refined schematic diagram with the ESP32 to reduce the number of components and improve the system's performance, tackling various challenges and errors resulting from the limited skills. The transition from the Arduino Uno to the ESP32 enhanced the system performance by integrating Wi-Fi and Bluetooth capabilities, thereby simplifying IoT implementation and eliminating the need for external communication modules. This reduced the overall component count, improved reliability, and enabled more efficient real-time data transfer to the Blynk platform [8]. The inputs and outputs may also differ from the initial schematic diagram. This procedure ensures the product operates efficiently and mitigates risks associated with the system's connectivity. The homemade device has the capacity to detect carbon monoxide and can produce concepts. **Figure 9(b)** shows the improvised connection to the system.

Coding is a crucial procedure as it provides instructions to the microcontroller to operate the device. Utilising the Arduino IDE software to understand the relationship between the sensor and other components. This code utilises the interface between hardware and Blynk applications to facilitate the monitoring of carbon monoxide effectively. This code reads the gas sensor value by connecting the sensor to the analogue input, which activates a buzzer when the gas level exceeds 50 ppm, accompanied by a warning message that states "Warning!" The maximum threshold of 100 ppm can notify users of the presence of carbon monoxide within the vehicle as shown in **Figure 10(a)**. If the gas value is below 50 ppm under typical conditions, the buzzer will not activate, and the LCD will display "Normal" as shown in **Figure 10(b)**.

```
//Get the ultrasonic sensor values
void GASLevel() {
  int value = analogRead(sensor);
  value = map(value, 0, 4095, 0, 100);

  if (value >= 50) {
    digitalWrite(buzzer, HIGH);
    lcd.setCursor(0, 1);
    lcd.print("Warning!  ");
    WidgetLED LED(V1);
    LED.on();
  } else {
    digitalWrite(buzzer, LOW);
    lcd.setCursor(0, 1);
    lcd.print("Normal    ");
    WidgetLED LED(V1);
    LED.off();
  }
```

(a)

```
//Get the ultrasonic sensor values
void GASLevel() {
  int value = analogRead(sensor);
  value = map(value, 0, 4095, 0, 100);

  if (value >= 50) {
    digitalWrite(buzzer, HIGH);
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    lcd.print("Warning!  ");
    WidgetLED LED(V1);
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  } else {
    digitalWrite(buzzer, LOW);
    lcd.setCursor(0, 1);
    lcd.print("Normal    ");
    WidgetLED LED(V1);
    LED.off();
  }
```
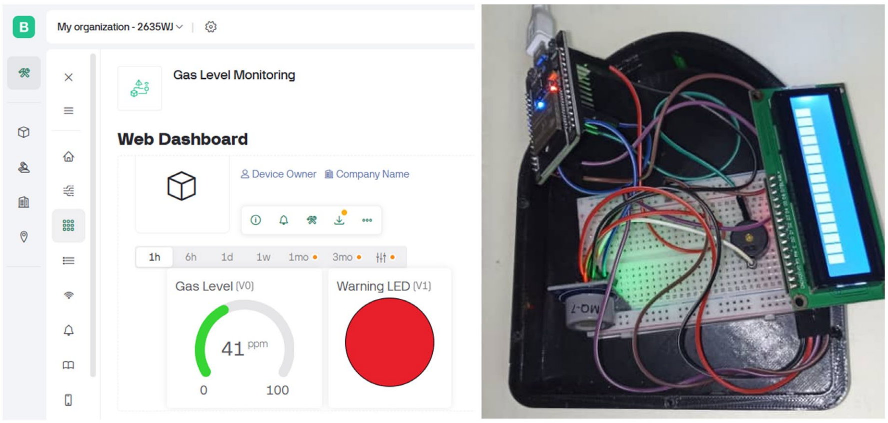

(b)

Figure 10. (a) Condition if the gas level is high; (b) Condition if the gas value is normal.

The code pertains to the Blynk applications, which are significant as they provide users with notifications regarding carbon monoxide levels. The Blynk applications can improve usability and create an effective interface for the detecting process. **Figure 11(a)** illustrates the Blynk dashboard used to monitor carbon monoxide levels. These applications may ascertain the real-time sensor data and transmit instructions to regulate the components. The warning also addressed specific occurrences, such as elevated levels of carbon monoxide. The dashboard incorporates a gauge and an LED widget to display values and provide a warning signal for the presence of carbon monoxide. The device can seamlessly function between hardware and software to fulfil the study specifications.



(a) (b)

Figure 11. (a) Blynk dashboard; (b) Hardware setup and testing.

The schematic diagram guided to conduct the real component connection to fulfill the requirements of this study. Figure 11(b) shows the hardware setup suitable for a gas detection system which uses the MQ7 to detect the carbon monoxide level and sends the signal to the microcontroller ESP32. Then, this setup is using the breadboard due to ease the study because not using any soldering method and good for testing component due to reusable. The connection between positive and negative also provided to this hardware setup. From the testing result, the components have a good connection between them. Then, the microcontroller can send the data into Blynk apps and monitor the level of carbon monoxide gas through smartphones. This result is achieved the project objectives and can solve the problem statement of this study. The device was calibrated to display a maximum value of 100, which was selected as conservative short term action threshold. This decision is consistent with established occupational safety and health guidelines, where concentrations in the range of 90-100 ppm are recognised as critical short term exposure levels associated with accurate health effects [18]. In this system, the serial monitor continuously transmits carbon monoxide data to the Blynk application, enabling real time visualization of concentration levels on a smartphone dashboard. An LED indicator within the applications is automatically triggered when the gas concentration exceeds 50 ppm, a threshold aligned with the current Occupational Safety and Health Administration (OSHA) permissible exposure limit (PEL) for carbon monoxide, which is set at 50 ppm as an eight-hour time weighted average in occupational settings [19] [20].

The results of this study were collected in a variety of settings, including ambient air, a car with an open window, a car with a closed window, a car with the air conditioner on, and smoke that is produced from the combustion of the car exhaust. Table 8 displays all results that have been gathered in the various situations that have been specified.

A graph of time sampling every 5 seconds for 12 times against PPM is depicted in Figure 12 for each situation. These results unequivocally demonstrate that the haze generated by fuel combustion at 5 cm and 30 cm exhibits higher readings than in other scenarios. Consequently, this investigation is highly beneficial for resolving this perilous circumstance and minimising the number of fatalities resulting from CO toxicity. The instrument employed in this investigation is capable

Table 8. Condition and output for every situation.

Situations	CO level (PPM)	Condition	Output
Ambience air	1 - 10	Normal	No action
In car with open window	1 - 10	Normal	No action
In car with close window	2 - 8	Normal	No action
In car while the air conditioner is turn on	2 - 9	Normal	No action
Smoke that are produce from fuel combustion of the car exhaust (distance 5 cm)	60 - 95	Abnormal	Buzzer active, LCD display "Warning!" and Blynk apps
Smoke that are produce from fuel combustion of the car exhaust (distance 30 cm)	15 - 45	Normal	No action

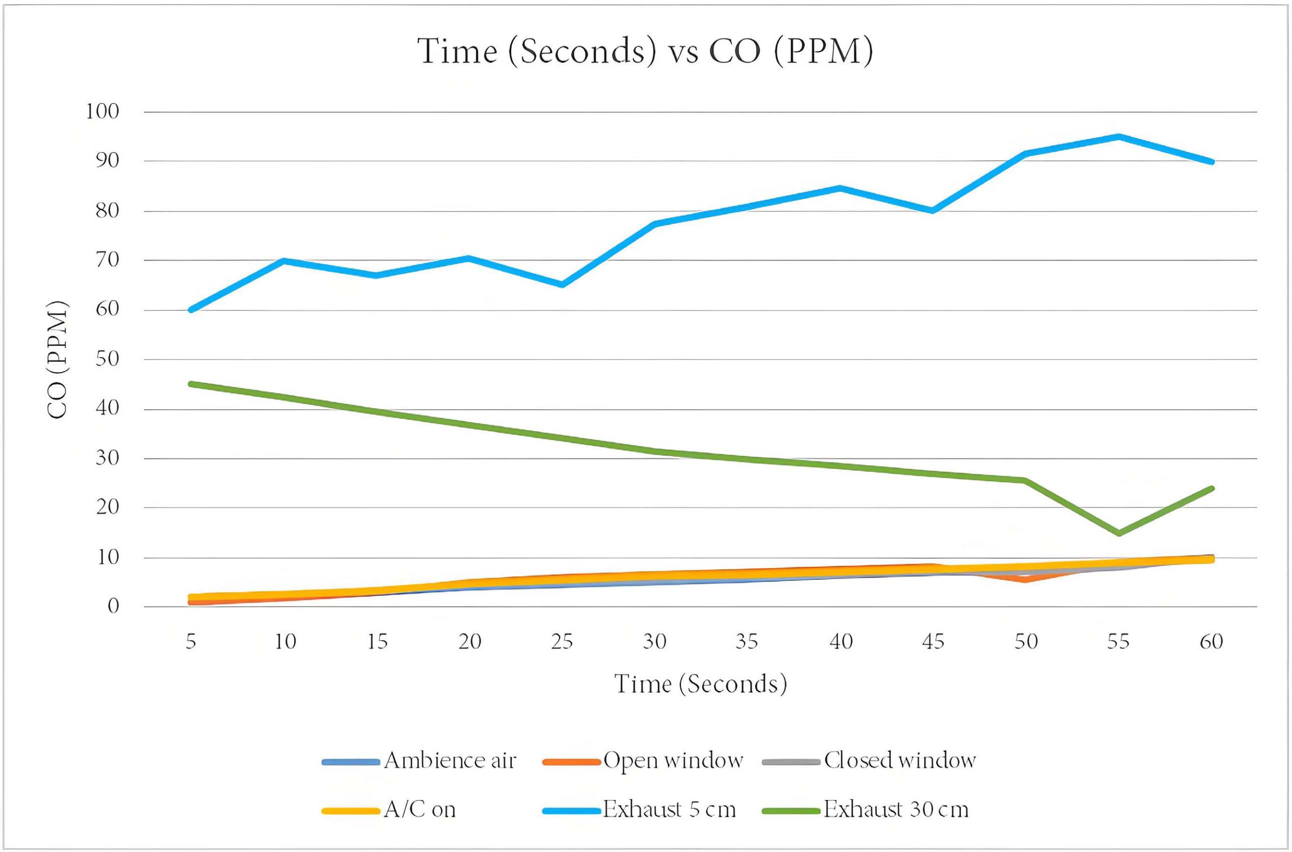


Figure 12. Graph of time sampling vs PPM for every situation.

of detecting and informing users of the CO level. In this scenario, the system will transmit a signal to the alarm (buzzer) to activate it. Additionally, the alarm system has the potential to draw the attention of those in the vicinity to the situation. This procedure will facilitate the assistance of others in the event of a hazardous situation, such as the driver collapsing, sleeping, or drowning in the vehicle. This study employs the Blynk application to warn parents or other family members. Therefore, their parents or family members can monitor the CO level to determine whether it poses a threat to their lives. This capability is one of the advantages of the IoT-based system used in this study, which integrates the devices and the system through the Internet.

4. Using Conclusions

0The current study has proposed a new product design and development of an IoT carbon monoxide detector with a monitoring system for cars. The performance of the developed system has been tested and evaluated by the kansei engineering (KE) and user-centred design (UCD) methodologies in order to create user-friendly and emotionally engaging products. It is because of the different people's interests that they can request the IoT carbon monoxide detector for cars with numerous parameters. It is extremely difficult to create products that can align with the perspective to satisfy everyone's desires. As a result, the strategy is useful for promising and raging client requirements for specific populations to ensure the effectiveness and feasibility of its development. It has approved its efficacy and reliability in solving the problems that were associated with the current vehicle's detector device and improved its performance and functionality through.

a. Improvement of carbon monoxide detector devices with the addition of the monitoring system via the embedded IoT system.

b. Provides a systematic approach to efficiently guide designers/fabricators in making selections and achieving the goal or design and development solution.

Although the prototype shows potential as a preventive safety device for detecting carbon monoxide in vehicles, this study has several limitations. The use of the MQ-7 sensor may introduce cross sensitivity issues, while testing was restricted to controlled laboratory condition. In addition, system dependence on IoT connectivity, lack of battery performance evaluation, and limited user testing reduce the generalizability of the findings. Future studies should address these aspects to ensure robustness and practical applicability in real world environments.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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