Carbon Monoxide Gas Leakage Detection System Prototype: A Medium Class Car Passenger Compartment

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Abstract*: The purpose of this research is to design, develop and test the functionality of the carbon monoxide gas leak detection system prototype. Carbon monoxide is a tasteless, colorless and odorless gas produced by running engine, the accumulation of carbon monoxide caused by leakage from exhaust system to a car cabin compartment reduces the oxygen levels unnoticeable. Absence of detector system in the consumer vehicle might cause a fatal incident to driver and passengers in the worst case. Based on design thinking steps, this prototype was developed using NodeMCU ESP8266 as a microcontroller to assists users by displaying current readings of carbon monoxide gas and warns users about the leakage of carbon monoxide gas is on risk level. Analysis shows that this prototype capable of detecting the presence of carbon monoxide gas based on three stages; first (151ppm - 400ppm), second (401ppm - 800ppm), the LED will turn on and the LCD will display readings, third, if the gas exceeds 800ppm, the LED will be lit, the buzzer will mark a sound for 10 seconds and the LCD will display the current reading of carbon monoxide gas. After 10 seconds, if the prototype not be turned off by the users, the information will automatically be sent to the Department of Fire and Rescue Malaysia Twitter account.

***Keywords*: Carbon monoxide, gas leaks, detection system.**

I. INTRODUCTION

According to the Environmental Quality Act (1974), pollution is defined as any direct or indirect change to the physical properties of heat, chemistry or biological of any part in the environment by releasing, removing or putting hazardous substances on it. Pollution or waste that can affect any beneficial use causes a condition which is dangerous or potentially harmful to the health, public safety, animals, birds, wildlife, fish or aquatic life and plants [1]. Environmental pollution is divided into four types of pollution: water pollution, air, soil and noise. Malaysia is one of the countries that have no exception in experiencing environmental pollution problems [2].

Air pollution has direct impact on human especially on cardiovascular and respiratory system, consequently a more chronic health downturn [2-3]. Generally, two main sources of the air pollution were local and external sources. The most significant local resources include motor vehicles, landfills, industrial plants and agricultural sites [4]. Outsourcing means the movement of pollution sources across Malaysia's boundaries and creates ephemeral haze episodes, especially near coastal and lowland areas. Based on the Malaysian Air Quality Monitoring System, the air quality classification index according to IPU is 0-50ppm (good), 51-100ppm (moderate), 101-200 (unhealthy), 201-300 (very unhealthy), 301-400 (dangerous), 401-500 (very dangerous) and more than 501 (curfew and emergency) [5]. If the air quality is within an alarming or gross stage, it will jeopardies the world ecosystem.

Air pollution has two types: open air pollution and closed air pollution [6]. Open air pollution is involving open disclosure in airspace by micro particles. For examples, the micro fine particles generated by fuel or fuel combustion such as charcoal and petroleum used for vehicles and energy generation, open burning of cigarettes, greenhouse gases such as sulfur dioxide, carbon dioxide, carbon monoxide and others. On the other hands, closed air pollution is an indoor exposure that is carried by air in closed or dusty areas [6]. Examples of closed air pollution are the effects of gas such as monoxide, dioxide and others, building materials such as asbestos and lead, cigarette smoke and gas leaks in a confined space. Open air pollution can also penetrate indoor airways through windows, doors and spaces allowing air flow. Open air pollution also contributes to the possibility of air pollution in confined space, especially in a car compartment.

II. RELATED WORK

Carbon monoxide is a silent killer since it does not smell or have any color or taste. Thus, carbon monoxide poisoning causes more than 50% of all types of fatal poisoning in most industrialized countries [7-9]. In Taiwan, the annual rate of death due to carbon monoxide poisoning has increased significantly from 0.1% to 5.1% per 100 000 current population from 1998 to 2010 [10]. The pattern of carbon monoxide poisoning has also changed in many other Asian countries, with the rise in death-related deaths containing carbon monoxide gas from the charcoal burning process, as well as vehicle-related suicide in the other parts of the worlds, especially in western countries.

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The invention of a carbon monoxide gas detector has been well documented in the literature. Hence, a study reported the death cases investigated showed that carbon monoxide poisoning has occurred due to several factors, including sleeping in a car, couples parking, driving, stuck in snow, working on car, and others factor including drunk [11]. Most of the reasons were the result of poor maintenance [12]. For that reason, the sensors for car cabin was less popular and deemed isolated cases. The most interesting focus has been on the remote sensing of motor vehicle exhaust emission to protect environment [13].

The background history of the invention of the carbon monoxide sensors were varying from traditional to a more sophisticated one. For example, late in 1971, some automobiles have a fan operated ventilation system to circulate fresh air to keep out exhaust gas poisoning for passengers [11]. In the recent advance technology, sensor has been one of the solution to the problems. The most recent publication has revealed amongst the most advanced microscale sensor using Micro-electro mechanical system (MEMS). Installing the sensor control multiple variables including emission [12].

However, the challenge for the car manufacturer is to keep the price in affordable range for common users. Although, some authors have stressed that inexpensive and reliable sensor has prevent the car to be fixed with this type of security system [11], but a secure and cost–effective real-time sensor will always be the priority for the new vehicles control system requirement [14].

III. PROBLEM STATEMENT

Sudden death cases while sleeping in car has raised alarming among Malaysian and authority. Especially for a car driver and passengers who typically stop by somewhere else (e.g. by the road side) taking a rest, but unfortunately suffocated and poisoned by carbon monoxide while sleeping. The exhaust gas leakage has contaminated the car passenger compartment, especially for car that has been not well maintained. Previous report suggests a sudden death was caused by a gas poisoning while sleeping because inhaled carbon monoxide gas in a density range of more than 800ppm. The carbon monoxide gas leakages are hardly traced by drivers, absence of an addition tool to detect the presence of carbon monoxide gas is a big issue and its application is seen as unimportant. Therefore, this paper proposes a prototype of an automatic carbon monoxide gas detection system using Arduino that could benefit the driver and the passengers of the car. The specific objectives of the study are:

i. To design a prototype of the carbon monoxide gas leakage detection system (COLDES) for a car cabin.
ii. To develop a prototype of the carbon monoxide gas leakage detection system (COLDES) for a car cabin.
iii. To test the functionality of the carbon monoxide gas leakage detection system (COLDES) for a car cabin.

IV. METHODOLOGY

Design Thinking is a design methodology that provides a solution-based approach to solving problems, were used to develop carbon monoxide gas leakage detection system (COLDES) with five main phases to be followed: Empathies, Define, Ideate, Prototype and Testing. Hence, this model is suitable for this project because Design Thinking methods will empower anyone to solve complex problems that occur around us.

A. Phase 1: Empathy

In these empathy phase, studies on problems rose in relation to the death case in car caused by the toxic gas of carbon monoxide during sleep were conducted by researchers. The initial studies have been done by the researcher through collecting information related to the problems using questionnaire. Based on the questionnaire distributed, it helps the researcher to understand the problems faced by the car user. Hence, it facilitates researchers to develop software according to consumers' need. In addition, researchers also collected information on problems that occur through reading and observation. Through these method, researchers have identified that, users who often sleep in the car due to fatigue while driving especially in a long-distance travel. They were amongst the car users who in high-risk to inhale toxic gases such as carbon monoxide as a result of the exhaust gas leakage into the car cabin space. The effects of inhaling gas toxicity will increase the risk of obscuring since carbon monoxide accumulation affects the reduction in oxygen levels. User's also complaint on the absence of the built-in indicator for car cabin space (low and medium-end car type), as well as the absence of notification system.

B. Phase 2: Define

The define phase requires researchers to determine the users' need in overcoming the problem of carbon monoxide gas leakage in a car cabin compartment. Most of the car users highlighted the needs on a system that capable of detecting the gas leakage and providing an early warning system. In addition, they need a monitoring system to display the current gas readings, so that they would be aware of the level of carbon monoxide gas that might be fatal to human respiratory system. A clear problem definition has led the researcher to come up with an idea to design and develop a system flow (block diagram as in figure 2) for the prototype of carbon monoxide gas leak detection system (COLDES) that meet and fulfil the users' need.

C. Phase 3: Ideate

Sketching rough ideas has become the main activity to find out the solution of the problem that has been defined in the previous phase. The activity also includes to match between the mechanism of the system and the materials needed. In this phase, researchers focuses on detailing the flow of the system. COLDES prototype that consists of three main sections which were circuitry hardware, software to be used and project overview. Figure 2 shows the flowchart of the Carbon Monoxide Gas Leakage Detection System Prototype. There were several aspects that need to be taken into consideration during designing phase in terms of safety, project functionality and reality checked.

Figure 3 shows the Carbon

Monoxide Detector Circuit and Figure 4 shows the Circuit of operational control that been used in this research.

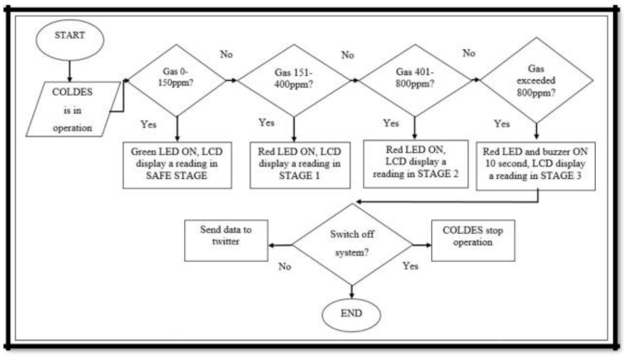

Fig. 2. Carbon Monoxide Gas Leakage Detection System Prototype Flowchart

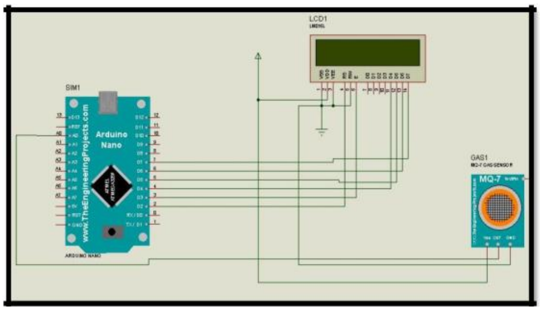

Fig. 3. Carbon Monoxide Detector Circuit

D. Phase 4: Prototype

The development of COLDES prototype was divided into three parts that is circuit development, programming system development and panel box development. In circuit development phase, electronic components were connected on the NodeMCU ESP8266 board. Next, the programming systems development phase focuses on programming for the input parts of the gas sensors in detecting gas leakage. The programming systems development on output parts connected LCD, LED and buzzer which also include programming on cloud pushing box to send information directly to twitter. For panel box development, it describes the work processes performed to place the output components on the prototype.

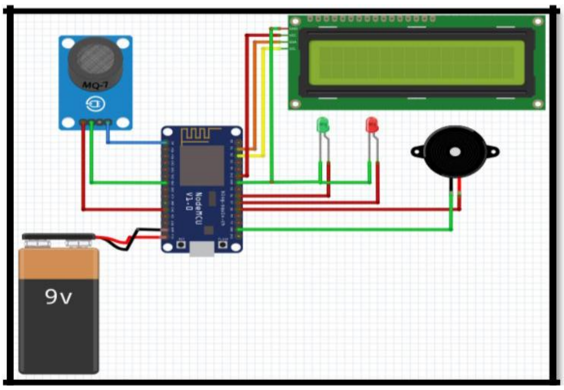

Fig. 4. Circuit of operational control

The prototype is installed with LCD to display current carbon monoxide readings and also warning indicators using LED and buzzer. In this phase, the designed circuit was done in a breadboard to connect NodeMCU ESP8266 microcontroller and jumper wire to connect the other electronic components. This prototype has also developed with internet of things (IOT) features, enabling information being sent to the Fire and Rescue Department for a prompt action.

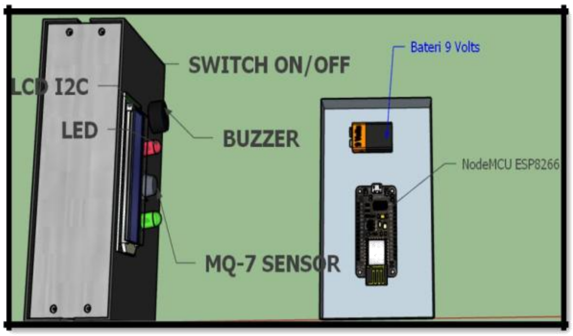

Fig. 5. Three-dimension sketch view

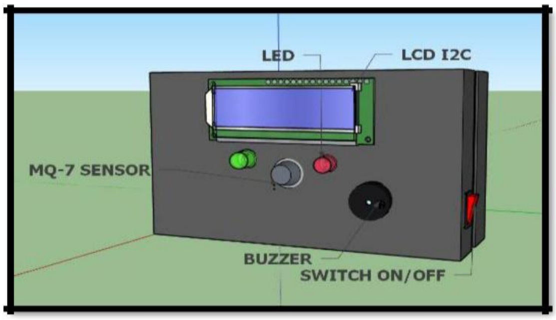

Fig. 6. Top sketch view

E. Phase 5: Testing

In this phase, the main purpose was to test the functionality and usability of this prototype on built-in components and user acceptance. Functionality test intended to check on input sensors (MQ-7) and output function for LED, buzzer and internet notification (IOT) while usability test intended to catch experts' perception on the design and purpose, as well as the potential for commercialization. Functionality testing procedure has been carried out to ensure that the systems were functioning as planned; the result as indicated in the next section. Usability testing procedure was conducted to involve three experts who were instructor engineer to verify the functionality of the built-in components. The result indicated a positive feedback.

V. RESULT AND DISCUSSION

The first testing process that had been carried out in the post development phase was to test the outcome, which was in this case, the inputs for the gas sensor MQ-7. The testing needs to use suitable equipment such as oscilloscope and multi-meter, as well as the test was conducted in an actual environment (car cabin space). Table I show the data recorded from the simulation to determine the existence of carbon monoxide gas leaks in the car cabin compartment. After 30 minutes of test, it is proven that the MQ-7 gas detector is capable and very sensitive to detect carbon monoxide.

Table I. Result of MQ-7

carbon monoxide gas sensor

Time (Minute)	Gas Value (PPM)	Level
00.02	93	Safe
00.04	92	Safe
00.06	143	Safe
00.08	187	Stage 1
00.10	346	Stage 1
00.12	503	Stage 2
00.14	532	Stage 2
00.16	766	Stage 2
00.18	807	Stage 3
00.20	770	Stage 2
00.22	602	Stage 2
00.24	413	Stage 2
00.26	205	Stage 1
00.28	132	Safe
00.30	97	Safe

Fig. 7. Output from the test

Figure 7 shows the output from test that had been conducted on the MQ-7 carbon monoxide gas sensor. The results of the test were shown in table II. The functionality for this carbon monoxide gas sensor was at a good performance. The sensor capable of detecting the four stages of gas leakage at (0 – 150ppm) safe stage, (151-400ppm) first stage, (401-800ppm) second stage and above 801ppm for third stage. This prototype seems better compared to several existing products that only have warning indicator, such as LED and buzzer without indicating and displaying current reading of detected carbon monoxide value [11-12].

Table II. Functionality testing result

Gas capacity (ppm)		Output		
		Green LED	Red LED	Buzzer
1	65	ON	OFF	OFF
2	251	OFF	ON	OFF
3	592	OFF	ON	OFF
4	803		ON	ON

Meanwhile, prototype validation analysis was based on the feedback given by three experts. Experts were selected based on expertise and experiences in the field of electric and electronics engineering. Feedback data were analysed based on the responses given by the expert using a simple checklist form. The checklist was developed in three parts; which were design, functionality and commercial potential. As a result, this prototype seems succeeded with good level review in all parts. However, some of the expert commented about the sized that can be reduced, as well as organizing distinctive design for particular place in car cabin, so it will meet current requirement [12] [14], as well as align to green technology needs [15][16].

Result in table III shows that out of these 7 items, only one expert disagrees on the design of COLDES prototype. The expert suggested not to fit the prototype in the car dashboard panel but placed in somewhere else more suitable in the middle of the car compartment and to be diminished in size, so that the sensor would be able to detect gas leakage occur in the car cabin space.

Table III. Expert response on the design of COLDES prototype

No	Item	Agreement Yes	Agreement No
1.	The casing of the product was appropriately designed for the car dashboard panel	2	1
2.	The product has a neat array of components	3	0
3.	The product has appropriate size for car cabin compartment	3	0
4.	The product has an appropriate safety features	3	0
5.	The product is safe for common car users	3	0
6.	The product design was suitable for the current car voltage supply value	3	0
7.	The material used is durable	3	0

Based on table IV, the data shows positive feedback on the functionality of COLDES prototype but there was one item that expert disagree about the functionality of this prototype because it is not being tested in real situation as it is quite difficult for the researcher (third expert, testing was performed in the laboratory). Besides, there were also reviews from the experts that request to improve the function of its tracking system so that this prototype can detect user exact location using GPS.

Table IV. Expert response on the functionality of COLDES prototype

No	Item	Agreement Yes	Agreement No
1.	The gas detector works well	3	0
2.	MQ-7 detects an actual carbon monoxide gas dispersion (real time)	3	0
3.	MQ-7 detect the capacity of carbon monoxide in the car cabin compartment	2	1
4	LCD displays current readings of carbon monoxide dispersion	3	0
5.	Green LED lights up when the sensor was triggered at safe level (0-150ppm)	3	0
6.	Red LED lit when the sensor was triggered at stage 1 (151ppm - 400ppm) and stage 2(401ppm - 800ppm)	3	0

7	Red LED lit and the buzzer sounds for 10 seconds when the sensor was triggered by gas exceeds 801ppm level 3 (danger).	3	0
8	The prototype can be connected to wifi internet	3	0
9	The prototype sends alerts to the Fire and Rescue Department's twitter for more than 801ppm (mock-up)	3	0

Lastly, based on table V, expert has commented on the commercial potential of COLDES prototype. Through analysis of the first item, the researcher found that experts agreed to use this prototype in his/her car. For the second item pertaining to the prototype market price, 67% of the experts agreed with the reasonable price indicated. Next, the third question, experts have agreed that the prototype capable of protecting and preventing mishap for their car. Finally, the fourth question result shows that experts agree to recommend COLDES prototype to his/her colleagues as it is useful for car users, especially for medium class.

Table V. Expert response on the commercial potential of COLDES prototype

No	Item	1 Disagree	2 Not sure	3 Agree
1.	I am willing to use this detector system for my personal car.			3 100%
2.	I am willing to buy this detector system regardless of the price.		1 (33.33%)	2 (66.67%)
3.	I find that the detector system can protect me and my car.			3 (100%)
4.	I will recommend this detector system to my friends.			3 (100%)

VI. CONCLUSION

This paper discussed the design, development and testing the functionality of the prototype of the carbon monoxide gas detection system for car cabin compartment. The prototype has been successfully tested and capable to detect the presence of the carbon monoxide gas in the car cabin compartment and notify passengers using LED and buzzer. However, the notification to fire rescue department needs improvement with an additional tracking system to push the car location information to the respective parties for rescue action.

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