DetGas: A Carbon Monoxide Gas Leakage Detector Mobile Application

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Summary
Many incidents of Carbon Monoxide (CO) poisoning have occurred because of people being unaware of its presence. There are currently available systems on the market, but they are limited to measuring CO in a certain area and lack vital functions. Additionally, little to no evidence-based information on their quality was available. Thus, a mobile application for detecting CO gas leakage in a vehicle and critical features to assist victims was developed. A usability and functionality test were conducted to determine the product's quality utilizing nine usability and six functionality task scenarios (n=5). Then, a System Usability Scale test was performed to obtain system satisfaction, usability, and learnability (n=50). The usability and functionality test shows that all the tasks given for both tests were 100% successful. The overall score obtained for SUS was 71.4, which indicates good acceptance and usability. Around 20% of respondents claimed that they would need the support of a technical person to be able to use the application and that they needed to learn a lot of things before they could use the application, which indicates the overall high learnability of the application. The result provides empirical evidence that the CO gas leakage detection mobile application is successful and receives good usability, functionality, acceptability, learnability, and satisfaction assessments. DetGas could benefit automobile owners and other stakeholders by mitigating the risk and harm associated with gas leaking that exceeds the safe limit.

Key words:
CO Gas Leakage Detector, System Usability Scale SUS, Task Scenario

1. Introduction

Carbon monoxide (CO) is a colourless, odourless, and tasteless gas that may be harmful because it is not always detectable despite its high concentration in the atmosphere. Because it is detectable only via CO gas detectors, it frequently goes undetected, or the driver or passenger is unaware of the presence of gas leakage. There have been reports of drivers being unaware that their vehicle should be equipped with a CO detector. For example, a study by [1] found that the majority of Saudis do not have CO detectors in their cars (89%). Cases of sudden death while sleeping in a car have sparked increasing concern among all over the world. Particularly for drivers and passengers who frequently stop for a break but become suffocated and contaminated by CO while resting or sleeping.

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On the market, there were several gas detector mobile applications. However, the majority of applications only monitor gas levels in a specific area and do not include push notifications, a call to authorities, or a feature that displays nearby hospitals. Although they were claimed to be convenient and easy to use, little to no evidence-based information about their quality was available. This necessitates the development of an application that enables CO detection in a vehicle while also meeting the immediate and necessary needs of the car driver and passengers, as well as providing quality evidence about the application.

Thus, this study's objective is to develop a CO gas leakage detector mobile application, named DetGas, that will detect the presence of CO and notify car drivers or passengers if the reading is unsafe. Additionally, it will assist drivers and passengers who are unaware of CO poisoning in taking precautions during emergencies. They can obtain comprehensive information about CO poisoning (e.g., the symptoms they experienced after inhaling CO gas and how to prevent CO poisoning) on DetGas. Additionally, user will be able to locate the nearest hospital by utilizing the application's nearby hospital features and ambulance call button. Usability, functionality, learnability, and satisfaction tests were then conducted via task scenarios and the System Usability Scale (SUS), to assess the perceived quality of the application by the users.

2. Literature Review

2.1 CO and Safety

CO is a by-product of internal combustion engines, both diesel and gasoline. CO is tasteless, odourless, colourless, and transparent to humans [2-5]. CO concentrations in the atmosphere are typically less than 0.001%, but can be higher in urban areas or enclosed spaces. CO toxicity is frequently an unintended consequence of gas engine exhaust [2, 6]. The CO gas emitted by the engine, as well as the CO accumulated in the car's cabin compartment due to exhaust system leakage, depletes the oxygen levels.

CO poisoning has been increasing in recent years. Few poisonings are self-inflicted, but the majority are unintentional. It is the most frequent cause of accidental poisoning in the world. CO poisoning is the leading cause of poisoning-related injuries and deaths worldwide [3, 5]. In 2019, approximately 50 people died and 200 were seriously injured in the United Kingdom as a result of CO poisoning [7]. By comparison, the majority of fatalities in the United States are caused by inhalation of exhaust gases. In the United States, it is estimated that over 40,000 people seek medical attention each year for CO poisoning [8].

In Malaysia, there have been several incidences of CO poisoning caused by motor vehicles, resulting in major health problems and death. A young woman was discovered unconscious in a car with the engine running and spent three months in a coma following CO poisoning. Besides, two teens were discovered dead, suspected of CO poisoning, after sleeping in a car with the engine running and the air conditioning on. Additionally, there have been instances where drivers left their children unattended in automobiles with the engines running, putting them at risk of CO poisoning if stranded for several hours. Most automobiles, particularly those with an older model year and manufacture date, are not equipped with CO detection system. CO continues to be released from the car and accumulates. Individuals who are unaware that CO is leaking into their vehicle through holes can develop carbon monoxide poisoning if they inhale the gas for an extended period of time [9].

2.2 Mobile Applications and Safety

There has been research done on mobile applications and vehicle related safety in recent years. Although mobile phones have been associated with road accidents, researchers have in turn taken steps to research the use of mobile phones itself as a means to enhance the safety of drivers on the road. In promoting a healthy and safe environment for driving, [10] analysed data obtained from the GPS sensor of a Smartphone to detect driving behaviour and road anomalies on the road. [11] researched an algorithm for road accident detection through a mobile application to enable notification for prompt medical assistance.

Similarly, work on the use of mobile applications to reach medical assistance promptly during injury is also seen in the work of [12] on ski accidents and augmenting awareness via real-time information sharing between all traffic participants, to improve the safety of pedestrians and cyclists at intersections. Interestingly, research has extended to the use of mobile phones as a safety alert system by detecting drivers' emotional states [14], and detecting sleepiness [15], in an effort to avert road accidents. Similarly, [16] used mobile applications as a means of sending voice notifications when a vehicle approaches any past accident blackspot and using a microcontroller to reduce the vehicle's speed. On another aspect, a few studies have been done on the use of mobile applications to detect transport and location schedules [17], and detect vehicle locations in crowded areas [18].

A study implementing IoT and mobile applications to measure CO concentration and produce alerts was done by [19] in an area. Although it could possibly be useful for use in vehicles, it only sends alerts to the users. Additionally, the application quality was tested on its ability to detect the presence of CO concentration per se and did not include the features to aid the victim in an urgent and necessary need. This has left a research gap on the more meaningful functions and use of the system, and quality assessment via functionality, usability, learnability, and satisfaction tests.

2.2 Usability and Functionality Evaluation

Usability and functionality test is done to ensure quality of computerized systems. Past research has been using a number of observable and quantifiable metrics mostly according to usability attributes based on ISO 9241-11 to test efficiency, effectiveness, and satisfaction. Among all, there were the use of metrics based on the standard to assess usability of web system [20-21] and mobile application [21]. There were also the use of System Usability Scale (SUS) to assess web usability [22], and learning management system [23], as well as Nielsen heuristics to assess user interface design [24]. The evaluation is crucial for all systems as it will provide evidence for their quality, and or provide sound foundation for enhancement to its usability, usefulness, efficiency, effectiveness and satisfaction, in the effort to ensure the designed and developed applications will be useful to the intended users.

3. Methods

A gas detector mobile application was developed based on functional (Table 1) and non-functional requirements (Table 2) gathered from relevant past literature and a review of five similar applications was done to determine the suitable features based on their strength and limitations.

Table 1: The functional requirement

Item	*Description*
Authentication	The user needs to create an account and login to use DetGas.
Real-time monitoring gas	The user can view the level of CO gas in ppm in real-time.

Push notification	The user will be notified when the gas level exceeds 35 ppm.
View CO poisoning precaution and symptoms	The user can read the precautions and symptoms.
Call medical authority	The user can take action by calling an ambulance to reduce risk/damage.
Find nearby hospital	The user can find a nearby hospital from their location.
Profile	The user can view and edit their profile.

Table 2: The non-functional requirement

Item	***Description***
Platform compatibility	The application can be useful and run on an Android phone.
Performance and responsiveness	The application response is prompt and displays immediate output.
Usability	The applications provide an easy and simple user interface to interact with.
Security	The users need to log in before using DetGas.

Communication between the car system and the mobile application is the key to the success of the gas detection. Accordingly, the development includes the following hardware: Android smartphone, a microcontroller, a gas sensor, a green and red LED, and a buzzer. On the other hand, the Arduino integrated development environment (IDE) was used to configure the Internet of Things (IoT) for the CO gas leakage detector to detect the presence of CO and warn the driver and passenger in a car (Refer Fig. 1). The Arduino IDE was used in the application to programme the microcontroller, sensor, and Wi-Fi module to transmit data to Google Firebase via internet connection.

The system starts with the microcontroller, NodeMCU, establishing an internet connection with a Wi-Fi network. The process will be repeated until NodeMCU gets an internet connection. After the internet is successfully connected, the gas sensor starts operating to read the sensor data and a green LED will be turned on when it detects the CO value is below 35 ppm. The threshold is based on the safe level at which no symptoms appear after six to eight hours of exposure [5, 25]. The sensor data will continue to be updated in the Firebase Realtime Database. If the sensor value exceeds 35 ppm, the user will get a push notification about a CO gas leakage alert.

The DetGas sensor will emit a sound from the buzzer and a red LED will be turned on until the gas value returns to a normal value.

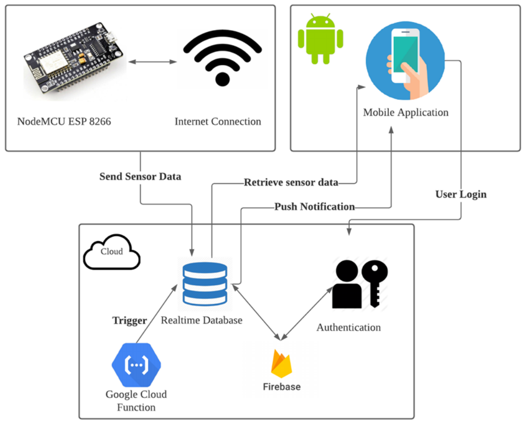
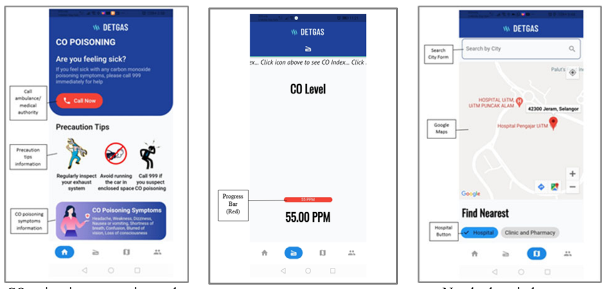


Fig. 1 DetGas system structure.



CO poisoning precaution and symptoms | Realtime monitoring page (red alert) | Nearby hospital page notification

Fig. 1 Instances of the application.

The DetGas will retrieve sensor data from a real-time database to display the CO gas level over time. User login is verified through Firebase Authentication during the sign-in session to allow user access to the system. Finally, when the sensor detects a high CO gas value, the user will receive push notifications. A Google Cloud Function will be triggered by a real-time database to send push notifications to DetGas. Fig. 2 shows instances of the application.

The developed application was then tested to obtain user feedback in terms of its usability and functionality. Usability metrics based on task scenarios were used to assess the application's effectiveness, efficiency, and satisfaction. Effectiveness is a term that relates to the accuracy and completeness with which users accomplish defined goals. While efficiency refers to the resources used in relation to the accuracy and completeness with which users accomplish goals. Satisfaction, on the other hand, relates to the ease and acceptability of use. This study gathers user feedback and evaluates the efficiency, effectiveness, satisfaction using 9-session usability test and 6-session functionality test with car drivers (n = 5). The usability tasks and their scenarios are described in Table 3, while the functionality tasks and their scenarios can be found in Table 4.

Table 3: Usability task scenario

Tasks	***Scenario***
Install and launch DetGas on the user's smartphone	The user obtains the DetGas APK, installs, and runs the application on their Android smartphone.
Register an account	The user clicks on the create account button, fill in name, email, and password, and finally clicks on the sign-up button.
Login to the system	The user types in their email and password and clicks the sign in button.
View information	The user goes to the home page and views precaution information and CO poisoning symptoms on the home page.
Call an ambulance	The user clicks on the call now button to call an ambulance.
View the CO level	The user clicks on the CO Realtime Monitoring icon at the bottom navigation bar to view the CO level, and clicks on the CO index button to view the level of CO.
Find a nearby hospital	The user clicks on the map icon and finds a nearby hospital, clicks on the hospital button to locate the nearest hospital, and clicks on the direction button to show navigation to the hospital location.
Edit profile	The user clicks on the profile icon, settings button, and update profile button to edit name and email address, and then clicks on the update profile button.
Log out from the system	The user clicks on the sign out button to log out from the system.

Table 4: functionality task scenario

Tasks	***Scenario***
Detect the presence of CO gas in the car.	Click the CO level button to view the presence of CO gas in the car.
Buzzer produces sound when CO gas is at a high level.	Expose the DetGas sensor to a high CO level to experience the buzzer emitting a sound to indicate the gas sensor detects a CO level exceeding 35 ppm.
Buzzer silent when CO is at a normal level.	Expose the DetGas sensor to a normal environment and the buzzer stops to indicate the gas sensor detects a CO level below 35 ppm.
Red LED turns on when CO is at a high level.	Expose the DetGas sensor to a high CO level and the red LED turns on to indicate the gas sensor detects a CO level exceeding 35 ppm.
Green LED turns on when CO is at a normal level.	Expose the DetGas sensor to the normal environment and the green LED turns on since the gas sensor detects a CO level below 35 ppm.
Receive a push notification when the CO level exceeds 35 ppm.	Expose the DetGas sensor to a high CO level and the user receives a CO leakage alert since the gas sensor detects the CO level exceeds 35 ppm.

The users were selected among experienced car drivers, and they were asked to experience the application by performing the specified tasks on their smart phone. Each scenario was to be completed within two minutes. The success of task completion and time taken were recorded. The respondents were then asked to give overall feedback on their experience using an open-ended form.

A SUS test was conducted with car users (n=50) of an equal proportion of males and females to assess the DetGas. SUS has been shown to be as effective as or better than proprietary questionnaires at discriminating between unusable and usable systems [26]. It includes a global indicator of system satisfaction as well as subscales for usability and learnability [27]. The learnability dimension is represented by items 4 and 10, while the usability dimension is represented by the remaining eight items [27-28].

The respondents were asked to experience the DetGas, and record their ratings based on the SUS items. They were asked to record their immediate response to each item, rather than thinking about items for a long time. Descriptive analysis was then conducted to analyse the gathered data from the SUS, to determine satisfaction, usability, and learnability, as well as to provide relevant recommendations.

The SUS was given to participants to rank based on the following 10 items, with one of five responses that ranged from "Strongly Agree" to "Strongly Disagree":

1. I think that I would like to use the DetGas frequently.
2. I found the DetGas unnecessarily complex.
3. I thought the DetGas was easy to use.
4. I think that I would need the support of a technical person to be able to use this DetGas.
5. I found the various functions in this DetGas were well integrated.
6. I thought there was too much inconsistency in the DetGas.
7. I would imagine that most people would learn to use this DetGas very quickly.
8. I found the DetGas very cumbersome to use.
9. I felt very confident using the DetGas.
10. I needed to learn a lot of things before I could get going with this DetGas.

The statement in each item covers a variety of system usability aspects, such as the need for support, training, and complexity, and thus has a high level of face validity for measuring the usability of a system [28].

Table 1: Usability test

No.	*Task completion*	*Errors*	*Average Time taken (second)*
1	5	0	63
2	5	0	34
3	5	0	48
4	5	0	23
5	5	0	14
6	5	0	17
7	5	0	42
8	5	0	48
9	5	0	8

Table 2: Functionality test

No.	*Task completion*	*Errors*	*Average Time taken (second)*
1	5	0	60
2	5	0	125
3	5	0	110
4	5	0	124
5	5	0	116
6	5	0	30

4. Results

4.1 Test of Usability and Functionality

Tables 5 and 6 show the test results for task completion, errors, and average time to complete each user task scenario (refer to Tables 1 and 2) given to the five respondents.

Five car users were chosen to conduct user testing for the DetGas system throughout the testing phase. The testing was conducted via Google Meet due to the Movement Control Order (MCO) enforced by the Malaysian Government, which posed a significant barrier to conducting face-to-face testing. The first testing was conducted to measure the functionality of the DetGas. The DetGas APK file was distributed to users, and they were asked to install the APK file on their smartphone before starting the test. Next, these users were assigned with 9 usability and 6 functionality task scenarios to test the DetGas.

These results were used to determine the application's efficiency via task completion and time taken, and effectiveness via success rate. Based on the test results, all respondents were able to perform all the tasks given for both tests without having any problems and they are 100% successful. Finally, the users were asked to fill in their thoughts on the DetGas system via Google Form. They were asked to provide comments on the DetGas and give suggestions or ideas to improve the application.

Table 3: User Feedback

Comments/Errors	*Suggestions/recommendation*
Usability: • I liked the feature that allows to contact medical authorities in an emergency. • The user interface looks modern and amazing, • I liked the find a nearby hospital feature. Functionality (CO gas detection): • The application helps to detect CO.	• Add family dependence for safety reasons. • Enable the user's family to monitor the CO level and the location of users who are using the car. • Enable the user's family to also receive notification if the CO level exceeds 35 ppm. • Develop DetGas for the iOS platform.

The synthesized respondents' feedback and recommendation is shown in Table 7. This result will be useful to enhance the usability and functionality of the application.

4.2 Satisfaction, Usability, and Learnability Based on SUS

A 10-item SUS was used to assess the DetGas in terms of its satisfaction, usability, and learnability with 50 respondents. The respondents comprised the majority of those having more than 1 year of driving experience, with an equal proportion of each gender group. Items 4 and 10 provide the learnability dimension and the other 8 items provide the usability dimension.

Table 8 shows summary statistics for the SUS dataset. The result shows that the average score is 71.4, which is higher than the 68 benchmark in [29]. This indicates overall good satisfaction across users. However, the result shows a wide variation from a minimum score of 40 to a maximum score of 100, in a 60-point range. Nevertheless, it is slightly more restricted as compared to 64 in [29], which falls under the acceptable range.

Table 4: SUS Summary Statistics

Statistic	*Overall*	*Female*	*Male*
N	50	25	25
Mean	71.4	76	66.8
SD	12.729	12.930	10.933
Range	60	47.5	45
Minimum	40	52.5	40
Maximum	100	100	85

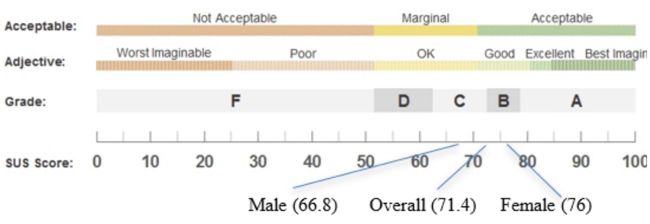


Fig. 3 SUS result.

Figure 3 shows the result of how participants evaluated the DetGas usability with an overall score of 71.4 (SD 12.729) which is categorised as good acceptance and usability. From different gender perspectives, there was a difference in SUS scores. Male participants evaluated the usability of the system with a score of 66.8 (SD 10.933), while female participants evaluated the usability with a score of 76 (SD 12.930). In terms of learnability, the result shows that a low number of respondents agree that they would need the support of a technical person to be able to use the DetGas (20%), and need to learn a lot of things before they could use the application (24%). This indicates the overall high learnability of the application.

The respondents were also asked whether they had the intention to use this application shortly, whether they would recommend this application to others, and how much they were satisfied with the DetGas. The majority of respondents (78%) agree that they have the intention to use the application soon, 92% agree that they will recommend the application to others, and 94% of the respondents stated that they are overall satisfied with the DetGas.

4.3 Mean SUS scores rating

With regards to grade scale and adjective rating, 18% of respondents scored DetGas as best imaginable (grade A), with SUS scores above 80.3, 36% rated it as excellent (grade B), with SUS scores between 68 and 80.3, and 38% graded it as reasonably good (grade D). With an overall mean SUS score of 71.4, the majority of respondents (92%) rated the DetGas as having a reasonably good, excellent and best imaginable subjective rating and acceptability range. An analysis of the extreme low and high SUS scores showed that only 8% of users considered the application to be worst imaginable (grade F), with less than 51 SUS score. This indicates there is room for improvement in the application.

5. Discussion

As can be seen from Tables 5 and 6, 100% of users were able to complete all tasks, both in terms of usability and functionality. No errors were encountered while they conducted the task scenario for both cases. All usability tasks were completed within 1 minute, except Task 1, which took a few seconds longer. Similarly, all functionality tasks were completed within 2 minutes. This reflects the good efficiency of the DetGas in both aspects of usability and functionality.

The success rate of task completion is used as a measure of the effectiveness of the application. As described earlier, all tasks have achieved a 100% completion rate, and the data shows that all users were able to complete the tasks. This indicates that DetGas is regarded as effective, based on a benchmark of 78% as the threshold for an average successful completion rate.

The SUS score for DetGas was located on a scale ranging from 0 to 100. Based on the overall SUS score of 71.4, the adjective rating for the application is interpreted as good. This also means that the interface and interaction of the application are evaluated as acceptable by the users and classified under the B grade. Based on the quartile ranges, the result illustrates that the DetGas application falls under the percentile rank of 70%, which indicates that it has higher perceived usability than 70% of other applications.

The results also showed that a majority of users (80~84%) agree that the application has high learnability, and they indicate that they have intension to use the application soon. Almost all users stated that they would recommend the application to car users, and were overall satisfied with it. A minimal number of users (8%) indicated a low grade for the applications with low SUS scores, which suggests there is room for improvement for the application. Additional features for family dependent users, monitoring of CO level by other family members, and user location are among the improvements that are suggested.

6. Conclusion

This study has identified functional and non-functional requirements for a car CO gas leakage detection mobile application. Arduino was used to configure the Internet of Things (IoT) for a CO gas leakage detector to detect the presence of CO and warn the driver and passengers in a car when it reaches an unsafe level. The DetGas helps users to monitor the presence of CO gas in the car and alert users through their mobile application. Besides, it helps users get rapid treatment by using call-in medical authorities and finding nearby hospital features. Lastly, to help users take precautions when having CO poisoning symptoms. DetGas will detect the presence of CO gas in two stages: normal (1 ppm-35 ppm), the green LED will turn on to indicate the gas at a normal level. Finally, if the gas concentration exceeds 35 ppm, which is a high level, the red LED will light up, the buzzer will sound, and the mobile application will notify the user that the gas level is high.

The application was then tested in terms of its usability and functionality using task scenarios (n=5), and a SUS test was conducted to assess user satisfaction, usability, and learnability (n=50).

The results of the analysis revealed that DetGas is highly effective and efficient, with a high level of user satisfaction. The result provides empirical evidence that the CO gas leakage detection mobile application is successful and receives good usability, functionality, acceptability, learnability, and satisfaction assessments. DetGas could benefit car users and other stakeholders by reducing the risk and harm that could occur when the gas leakage goes beyond the safety level.

Nevertheless, there was indication for further improvements based on the SUS assessments, and several suggestions were obtained from the users. Although the application has good ratings and evaluations, it was developed under some limitations. For example, because it was built on the Android operating system, it cannot be used on other platforms such as iOS. Another limitation is that it was developed for individual use by the smart phone owner, and does not integrate sharing information with multiple users, such as family or friends. These limitations provide opportunities for further research using other platforms as well as enhance features such as sharing information or notification.

The study provides proof that fatalities or serious damage due to CO gas leakage can be prevented by early detection. For that matter, the DetGas mobile application offers a reasonable solution and is recommended to be used at large. However, the test of the application was limited to the usability and functionality assessment based on an experimental task scenario, and the SUS assessment tool. An extensive test is suggested via field experiments using a larger population and test conditions, which could yield a more accurate analysis of the observation. Additionally, the test was done with car users only, which limits the findings from the point of view of the car users. Studies involving the authorities, medical units, as well as family members could bring deep insights into the usability and usefulness of the application. Automobile industries and communication industries can then address the knowledge gained and adopt it into the design of the automobile and smart phone systems, thus extending the usability and usefulness of the developed application.

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References

[1] Waseem, H., Abrar, A., Abeer, A., Afnan, A., Enas, A., GhadahR, A., SaraBin, H.: *Public awareness and attitude of the hazards of carbon monoxide (CO) poisoning and the safety precautions applied to that regard, among Saudis for the year 2013-2014*. International Journal of Advanced Research 4, 2306-2314 (2016)

[2] Davis, N.: *Carbon monoxide poisoning*. British Medical Journal 2(6204), 1584 (2019)

[3] Miles. B., Salim, C., El-Bay, B.: *Carbon monoxide detection: an IoT application used as a tool for civil protection services to save lives*. In: Proc. of the 3rd International Conference on Future Networks and Distributed Systems, Paris (2019)

[4] Hiroshi, K., Hülya, T., Slavica, V., Shahab, N., Rafik, B., Ramin. R., Aristidis, T.: *Carbon monoxide poisoning*. Toxicology Reports 7, 169-173 (2020)

[5] Kamal, M., Gokul, K.: *Carbon monoxide poisoning*. Journal of Marine Medical Society 18(2), 179-186 (2016)

[6] Zaba, C., Świderski, P., Sommerfeld-Klatta, K., Zaba, Z., Pluta-Hadas, K., & Urbaniak, M.: *Suicidal carbon monoxide poisoning using motor vehicle exhaust in an open space.* Medical Principles and Practice 28(5), 490–492 (2019)

[7] Blumenthal, I.: *Carbon monoxide poisoning*. Journal of the Royal Society of Medicine 94(6), 270–272 (2001)

[8] Olson, K., Smollin, C. *Carbon monoxide poisoning (acute)*. BMJ Clinical Evidence, 2010: 2013 (2010)

[9] Yen, G. S., Moorthy, K., Machap, L.: *IoT based vehicle carbon monoxide monitoring, alerting and controlling system.* International Journal of Advanced Trends in Computer Science and Engineering 9(5), 334–339 (2020)

[10] Akhtar, N., Pandey, K., Gupta, S.: *Mobile application for safe driving.* In: The 4th International Conference on Communication Systems and Network Technologies, vol. 6821388, pp. 212-216 (2014)

[11] Hirawat, A., Bhargava, D.: *Enhanced accident detection system using safety application for emergency in mobile environment: SafeMe*. Advances in Intelligent Systems and Computing 336, 173-179 (2015)

[12] Yildirim Yayilgan, S., Du, Y., Dalipi, F., Jeppesen. J.: *A new ski injury registration system architecture using mobile applications to enhance skiing safety*. International Journal of Interactive Mobile Technologies (iJIM) 10(4), 4-10 (2016)

[13] Militaru, A.V., Caruntu, C.F., Comsa, C.R.: *Application design principles for road users' safety*. International Symposium on Signals, Circuits and Systems (2021)

[14] Lee, B.G., Chong, T.W., Lee, B.L., Park, H.J., Kim, Y.N., Kim, B.: *Wearable mobile-based emotional response-*

monitoring system for drivers. IEEE Transactions on Human-Machine Systems 47(5), 636-649 (2017)
[15] Huda, C. Tolle, H., Utaminingrum, F.: *Mobile-based driver sleepiness detection using facial landmarks and analysis of EAR values*. International Journal of Interactive Mobile Technologies (iJIM) 14(14), 16-30 (2020)
[16] Thangavel, R.K., Athithan, S., Sarumathi, S., Aruna, M., Nithila, B.: *Blackspot Alert and Accident Prevention System*. In: Proc. of the 10th International Conference on Computing, Communication and Networking Technologies (2019)
[17] Kassim, M., Bakar, A.S.A.A.: *The design of augmented reality using unity 3D image marker detection for smart bus transportation*. International Journal of Interactive Mobile Technologies (iJIM) 15(17), 18-32 (2021)
[18] Hussein, L.F., Aissa, A.B., Mohamed, I.A., Alruwaili, S., Alanzi, A.: *Development of a secured vehicle spot detection system using GSM*. International Journal of Interactive Mobile Technologies (iJIM) 15(4), 85-100 (2021)
[19] Rojas-Ascate, C.S., Escalaya-Angulo, A., Tasayco-Abanto, J., Huamani-Navarrete, P.F.: *Implementation of a CO concentration measurement and alert prototype applying IoT and mobile application*. In: Proc. of the 2019 IEEE 1st Sustainable Cities Latin America Conference (2019)
[20] Noor, A., Umer, A., Amin, N., Umar, A.I., Ahmad, Z., Khan, M., Jan, S.A., Iqbal, J.: *Usability Evaluation of Brain-Computer Interaction (BCI), Based Game for Normal Users*. International Journal of Computer Science and Network Security 18(6), 168-175 (2018)
[21] Ismail, N.A., Hamid, N.I.M., Lokman, A.M.: *Performing Usability Evaluation on Multi-Platform Based Application for Efficiency, Effectiveness and Satisfaction Enhancement*. International Journal of Interactive Mobile Technologies (iJIM) 15(10), 103-117 (2021)
[22] Adrees, M., Ahmad, D.N., Amelio, A., Wadeer, K.A.: *Enhancing Web Usability: Exploiting interactional properties of web interfaces with vocabulary and comprehension learning in non native English speakers*. International Journal of Computer Science and Network Security 18(10), 164-172 (2018)
[23] Alkinani, E.A., Alzahrani, A.I.A.: *Evaluating the Usability and Effectiveness of Madrasati Platforms as a Learning Management System in Saudi Arabia for Public Education*. International Journal of Computer Science and Network Security, VOL.21(6), pp. 275-285 (2021)
[24] Samrgandi, N.: *User Interface Design & Evaluation of Mobile Applications*. International Journal of Computer Science and Network Security, VOL.21(1), pp. 55-63 (2021)
[25] NIOSH (The National Institute for Occupational Safety and Health). *Carbon monoxide*. Retrieved on 30 August 2021 from https://www.cdc.gov/niosh/pel88/630-08.html. (2011)
[26] Sauro, J. (2011). *Measuring usability with the System Usability Scale (SUS).* Retrieved 30 August from https://measuringu.com/sus/. (2011)
[27] Lewis, J.R., Sauro, J.: *The factor structure of the System Usability Scale*. In: The 1st International Conference on Human Centered Design: Held as Part of HCI International, vol. 5619, pp. 94-103 (2009)
[28] Brooke, J.: *SUS: a retrospective*. Journal of Usability Studies 8(2), 29-40 (2013)
[29] Bangor, A., Kortum, P., Miller, J.: *Determining what individual SUS scores mean: Adding an adjective rating scale.* Journal of Usability Studies 4(3), 114-123 (2009)

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