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Product Development for Preventing Drunk Driver Driving Using Alcohol Sensor in ESP32 Microcontroller

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ABSTRACT – Drunk driver driving is a part worldwide main cause of deathly accident. With current technology in IoT, preventing this accident can be an automatic solution to alert the driver to be cautious. Thus, the aim of this paper is to tackle the issue using accessible IoT and applied in actual-scale. The use of ESP32 microcontroller and coded on Arduino IDE platform, alcohol sensor, GSM module, and motor driver tested and finally come out with the best design. The design, complete with marketable packing and ready to install on an actual car. Intensive analysis of TRIZ approach is used to solve the network speed issue for transaction of GPS location data. Through this project, solution for the issue is proposed. Hence, this resulted practical design as it is tested with full scale implementation.

KEYWORDS : esp32 microcontroller, arduino ide, alcohol sensor, gsm module, motor driver

1.0 INTRODUCTION

Violating the law by driving a car under the influence of alcohol can cause serious injury or death to others. Statistically, alcohol use is related to about 40% of total deaths in traffic accidents. Additionally, a significant number of accidents involve pedestrians. In Malaysia, police officers stopped approximately 2,692 people for drunk driving in 2021, and 1,249 separate enforcement actions were taken to tackle drink driving that year. Therefore, addressing the danger caused by drunk driving is a significant issue.

Scientific research has successfully contributed to the development and accessibility of hardware and software for driver monitoring. The focus of this paper is on the use of hardware for monitoring drunk driving. While significant technological advancements have been made to improve the safety of personal vehicles, developing robust and efficient solutions to reduce accidents caused by drunk driving remains a crucial priority. With the current advancements in software and hardware in the Internet of Things (IoT), a smart system integrating software, sensors, and microcontrollers can prevent drunk driving. This paper proposes a detailed description of an IoT system that can prevent drunk driving.

Based on a literature review, it was found that five papers designed systems similar to the one proposed in this paper. The first paper [9] designed a system using an ESP32 microcontroller with a distance sensor, vibration sensor, Global Positioning System (GPS), Global System for Mobile (GSM), and alcohol sensors. Similarly, [8] used a similar microcontroller with GPS, GSM, ultrasonic sensor, IR sensor, gas sensor for tracing alcohol, and an accelerometer. Furthermore, [10] also used an ESP32 microcontroller with an alcohol sensor, speed control, GSM, and engine control. The fourth paper [11] circuited an ESP32 microcontroller with GPS, GSM, ultrasonic sensor, IR sensor, alcohol sensor, and an accelerometer. The fifth paper [12] used a microcontroller with an alcohol sensor. Another factor that similarly applies in papers by [9] and [10] is applying an engine auto-stop mechanism in preventing drunk drivers from operating the vehicle.

The significant finding based on this review is that the listed systems were only applied on a simulation and miniature scale. For instance, [9] and [11] tested their proposed systems on a software model. Although [12] applied the system on software simulation, their system advanced through artificial intelligence in monitoring the potential driver alcohol level.

However, [10] and [8] applied the proposed system on a miniature scale - a toy model or prototype. None of these researches applied the proposed systems to actual cars, hence this paper justifies the application of these proposed systems to actual cars.

Table 1. The Previous Study Design Comparison uses ESP32 Microcontroller

Author	Scale	Function										Advantage	Disadvantage
		A	B	C	D	E	F	G	H	I	J		
[8]	MS	/	/	/			/	/	/			Detect accident occurrence and trace the location.	No actual scale study tested.
[9]	MoS				/	/	/	/	/		/	Remote engine switching off/on (RESO).	No actual scale study tested.
[10]	MS							/	/	/	/	RESO	No actual scale study tested.
[11]	MoS	/	/	/			/	/	/			Detect accident occurrence and trace the location.	No actual scale study tested.
[12]	MoS								/			Wristband sensor detects alcohol present through sweat in real-time manner.	Driver wears the wristband the whole time – impractical. It connected to simulation car model software.
This Paper	AS							/	/		/	RESO with actual scale or car is used for the study and trace the location.	High cost to conduct for a full-scale experimental study.

Note: Miniature Scale (MS); Model on Software (MoS); Actual Scale (AS); IR Sensor (A); Ultrasonic Sensor (B); Accelerometer (C); Distance Sensor (D); Vibration sensor (E); GPS (F); GSM (G); Alcohol sensor (H); Speed control (I); Motor Driver\Engine Control (J);

This fact rationalizes the need to conduct a full-scale experiment on an actual car, which is the ideal approach to obtain realistic outcomes. Table 1 shows a comparative literature study that specifies the advantages and disadvantages of previous studies. Although a full-scale experiment may be expensive, it represents the actual issues raised through the developed prototype, which may not be gathered through simulation or miniature scale studies. This study aims to tackle the problem by using easily accessible IoT technologies and testing them on an actual car. In addition, the study makes use of input devices to detect the driver's alcohol level and automatically controls the engine to start at a safe condition for both the driver and the car. The output device, through a GSM module, is designed to inform the next of kin of the drunk driver, while the ESP32 microcontroller creates connectivity between the car and an application that provides the car's location.

2.0 ONGOING PROJECT

Throughout this ongoing project, the lecturers' skills have been enhanced with the primary goal of participating in national and international innovation competitions. This initiative began in 2017 with a number of sub-modules that were integrated into a single, multifunctional module. By mid-2017 and early 2018, the project had successfully developed two full-scale prototypes focusing on an anti-theft mechanism using a starter-by-pass switch. These modules were designed to be installed in a hidden location to start the engine switch. The first module used a basic switching technique, while the second module used a much more efficient technique and was developed in early 2018. Both modules were integrated with a Global Positioning System (GPS) for stolen car traceability. By the end of 2018, a sub-module for motion sensor functioning was developed using an ATmega 328 microcontroller. This model was designed for dual applications, i.e., anti-theft and child alert, and was integrated with the Global System for Mobile communication (GSM) to send Short Messaging System (SMS) alerts to the car owner's mobile phone. The motion sensor was replaced by a Passive Infrared (PIR) sensor using an ATmega 328 microcontroller for the later module in 2019. This module is a much more effective mechanism, also for dual applications - anti-theft and child alert. The PIR sensor is applied inside a car based on heat detection for both theft and unintentionally left child detection. This module is integrated with a GSM for SMS usage and a GPS module for car tracing so that the user can communicate with their car through their mobile phone. In 2020, a new module was developed primarily to prevent drunk drivers from driving a car. This paper focuses on this 2020 module. All of these designs have been successfully registered with the Intellectual Property Corporation of Malaysia (MyIPO).

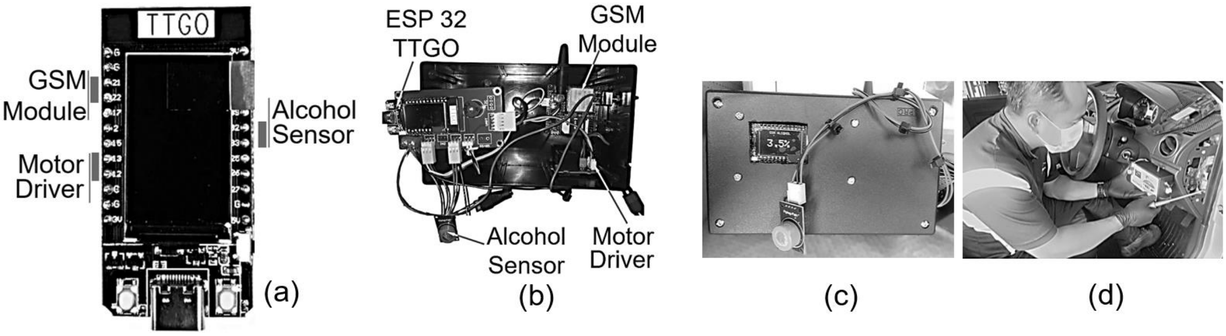

Figure 1. (a) TTGO ESP32 Microcontroller with pins usage by the sensors; (b) Actual Components Circuit Connection; (c) Packaging of the System; (d) Installation into Actual Car

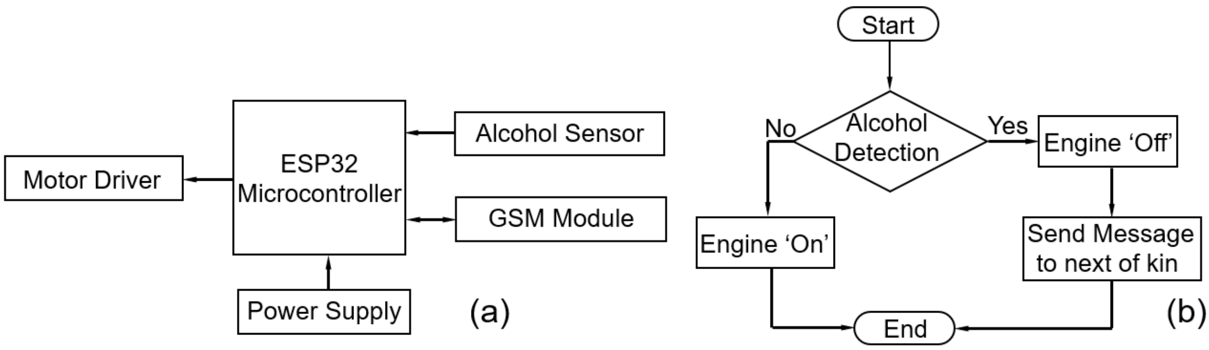

Figure 2. (a) System's Block Diagram and (b) The Operation Flow Chart

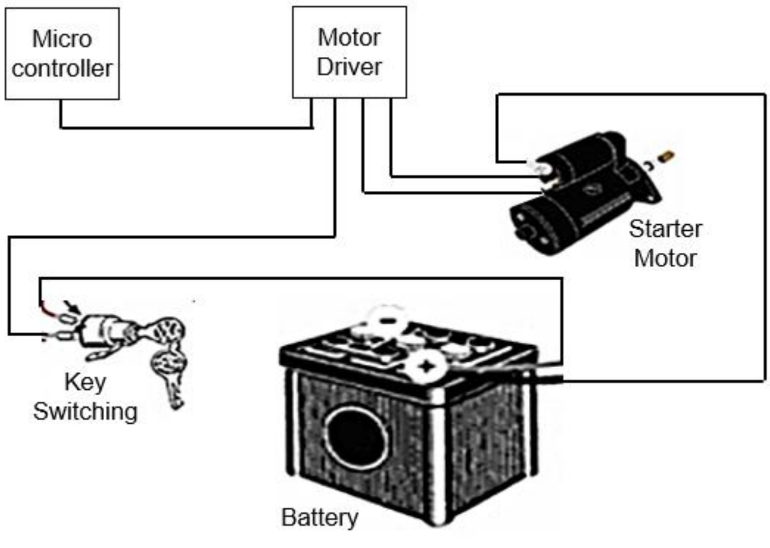

Figure 3. The Module-to-Car Wiring

For this project, the pin locations of the three main components installed on the TTGO ESP32 microcontroller are shown in Figure 1(a). The soldered components are shown in Figure 1(b), while the commercially packaged integrated component is shown in Figure 1(c). Figure 1(d) shows the module installed on an actual car dashboard. The direction of the component mechanism, i.e., one-way (→) or two-way (↔), is shown in the system block diagram in Figure 2(a), while the flow of component operation is shown in Figure 2(b).

This project was completed in 2020 with the prime intention of preventing drunk driving. Although there are multiple ways of tracing the presence of alcohol in a body, the easiest way is through tracing the user's breath, which can be effectively done by an MQ3 Alcohol Sensor. The sensor is also well-known for tracing the presence of multiple gases, but for this paper, it is set for alcohol detection. Tentatively, as shown in the operational flowchart in Figure 2(b), the user must exhale their breath into the sensor to start the engine. In the case of the breath sensor reading above 0.35 g/L, the microcontroller will direct the motor drive to prevent any mechanism from starting the engine. The brief wiring between the module and the user's car wiring is shown in Figure 3. Simultaneously, the microcontroller will direct the GSM module to send a miscall, SMS, and location to the user's next of kin. These three mechanisms are shown in Figure 4. However, if the breath reading is below 0.35 g/L, the microcontroller will direct the motor drive to allow the engine to start.

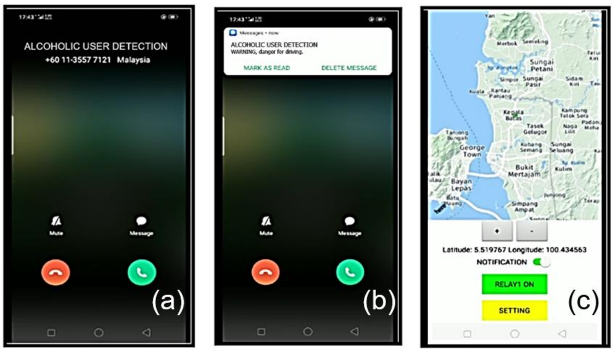

Figure 4. The GSM Module mechanisms: (a) Miscall; (b) SMS Sending; (c) Location Tracing

Table 2. The Component Specification

Component	Model	Applicable Unit
Microcontroller	ESP32 TTGO	2.7 - 4.2V
Alcohol Sensor	MQ3	mg/L
GSM Module	SIM900	4.8 - 9VDC (2A max.)
Motor Drive	L298N	5 - 12V

Table 2 shows the components used for the project, including the model and applicable unit. The ESP32 microcontroller, developed by Espresif System Company, is a widely used microcontroller in various areas, with hardware and software compatible with the microcontroller [10]. The programming language used for this project is Arduino IDE, which utilizes the C programming language [13]. The MQ3 Alcohol Sensor is used to detect the alcohol level and decide whether the driver is allowed to drive a car. The microcontroller controls the motor driver to prevent or allow the engine to start based on the sensor reading, and also sends notifications to the driver's family. The GSM module allows communication between the microcontroller and the next of kin, using digital pins 2, 3, and 7 for communication. The motor drive component controls the engine to start or switch off, based on the program in the microcontroller. The handoff process is used in the technology to transfer an active call or data session from one cell to another in a cellular network, which affects network performance [17]. Soft handoff is used in 3G technology, which does not cause any breaks during the transaction, while hard handoff is used in 4G technology, causing a break before setting up a link to the next cell [18]. The motor drive component allows for excellent system performance in efficiency, controllability, and overall performance [19]. It is controlled by the program in the microcontroller and the voltage change between the microcontroller and the motor control, resulting in the engine starting or switching off based on the coded program.

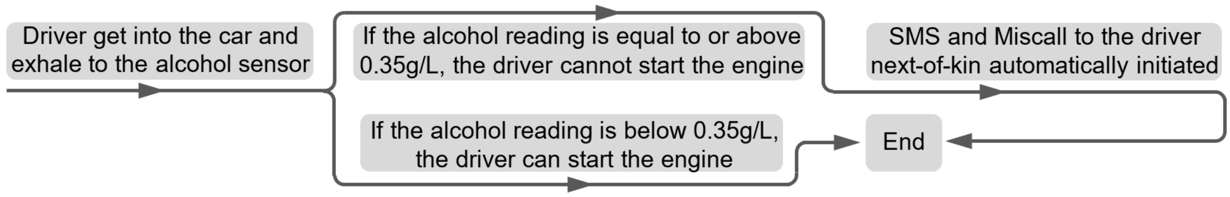

Figure 5. Product Operating Procedure

The product operation procedure is shown through the flowchart in Figure 5. The driver exhales into the alcohol sensor, which reads the alcohol level present in the breath. If the reading is below 0.35g/L, the driver can start the engine and end the procedure. If the reading is equal to or above 0.35g/L, the engine is prevented from starting and an SMS and Miscall are automatically initiated to the pre-set next-of-kin. The next-of-kin can assist the driver by calling a taxi or coming to pick them up, with the assumption that they know the driver's location. Alternatively, the next-of-kin can start the car by exhaling into the alcohol sensor with a reading lower than 0.35g/L. This helps prevent the drunk driver from driving and ensures the safety of everyone on the road.

3.0 EXPERIMENTAL THE INTEGRATED MODULE

The entire module components were tested to ensure that they meet the expected design quality. Testing was conducted to certify that the module works as expected, following the code programmed in the microcontroller. This included verifying that all connected components function properly. Additionally, the location tracing application's communication between the microcontroller and the next-of-kin's mobile phone was installed and coordinates were provided correctly. Furthermore, testing monitored the communication through miscalls and SMS messages between the microcontroller and the next-of-kin's mobile phone to ensure that the program's full specifications were met. Finally, the communication speed between the microcontroller and the user's next-of-kin mobile phone was tested and found to be at an acceptable speed. During the experimental test, some errors were discovered, and these were corrected in both the circuit and code. The most significant issue found was that the microcontroller's 4G performance was not meeting expectations during the experimental testing process. Although the ESP32 microcontroller with 48 pins is compatible with 4G technology, the 4G performance was very slow, taking over five minutes to get a response from the microcontroller on the user's mobile phone. Through trial and error, the SIM card registered with 4G was replaced with a SIM card registered with 3G. The results showed that in this project, 3G technology is much faster than 4G, with the response rate being less than 30 seconds. Therefore, further investigation into this matter is required.

4.0 THE INTEGRATED MODUL PERFORMANCE STUDY

Generally, 4G technology is known to offer ten times the speed of 3G technology [20]. For example, the download and upload speeds for 3G technology are about 7Mbps and 2Mbps respectively, while for 4G technology, the speeds are approximately 40Mbps and 20Mbps [21]. Due to its faster speed, 4G is more suitable for handling data-intensive applications that 3G cannot handle well. However, the performance of these wireless systems is affected by the radio sources that cover the service and the quality of the service provided [22]. Although there are available channels, a transmission handoff may fail if the network response time for the link is too long [23]. Handoff failures can be caused by a transmission drop or a time-out mechanism for the signalling path, leading to the drop [24]. These failure characteristics are similar to the problems encountered when using 4G technology. Therefore, we decided to investigate the comparison between 3G and 4G by subscribing to two different SIM cards to see the network configuration and pattern of both networks. To monitor the network configuration, we used the LogicMonitor software, which is a network monitoring tool that determines the speed performance of both networks based on the Reference Signal Received Power (RSRP). The standard handoff mechanism is based on the RSRP measurement on user equipment [23]. This enables a comparative study of both networks up to an acceptable standard, determined by the download and upload speed performance, and the results obtained.

Table 3. Transaction Speed Between the Modul and A Hand Phone by LogicMonitor Software

Transaction Between the Module and A Hand Phone		
Network Technology	3G (Mbps)	4G (Mbps)
Download	6.75	3.56
Upload	2.38	1.17

Based on the performance results, the retracted performance of 4G is believed to be due to the issue of network handoff. Since 4G uses hard handoff, it is possible that the linkage between one break to another in the data transaction is inefficient at the time between the module and the user's mobile phone. However, even though 3G is a slower network, the use of soft handoff makes the transaction less difficult as the link is always available without any break. The results of the speed performance between the two technologies are shown in Table 3. Additionally, there are performance metrics mentioned in previous research papers, and a comparative study was conducted to compare the previous papers and this paper through a literature review, which is listed in Table 4.

Table 4. The Performance Comparison

Author	**Performance Highlight**	**Performance Through This Paper**
[8]	The gas sensor based on MQ3 model is tested senses alcohol level threshold value greater than 3000ppm, which in another unit, the tested value is 3g/L.	Generally, the MQ3 alcohol sensor detects 25 to 500 ppm of alcohol or 0.025 – 0.5 g/L [15]. Though our setting for the alcohol detection is 0.35 g/L, the MQ3 sensor applied in this paper successfully alarms the traceability of alcohol is positively traceable at the specified rate. Thus, the performance of the sensor in this study is tested sense better that the sensor tested in [8].
[9]	Paper [9] uses GPS for accident detection, location detection and used GSM in sending notification through SMS is tested in a hardware model. A few minutes is taken to detect the location of the system when switched ON by GPS. The coordinates were sent to the provided phone number within fraction of seconds.	The image location of the car is approximately at 35kb of memory. Besides, the 3G rated which recorded 6.75 Mbps for download and 2.38 Mbps for upload. By rough calculation, the speed rate for the transaction of the image is that goes through upload for 0.00519s and download for 0.0147s for the image is less than one second, approximately 0.01989s. For the whole operation that includes the GPS data transfer time according to the LogicMonitor software, on average the operation takes 23 seconds to complete. The length of time also much influence of distance between a hand phone and a model used GPS, hence compare directly this value is not the proper approach in finding which model performance is better.
[10]	Similarly, paper [10] also using trial and error test approach in finding the best performance of the communication technology. [10] uses 4G or 3G or 2G connection for this test.	By comparison, this paper also makes similar action to compare each technology application i.e. 3G and 4G to obtain the best possible solution for the speed of transaction. Through this paper, the conclusion is for the network usage, 3G is better than 4G. But there is no conclusive suggestion through [10] paper. Technical-wise this performance is influenced by the quality of network provided by the network provider.
[12]	Paper [12] proved that the wristband device gave more than 97.5% accuracy at the concentration of 0.50 mg/mL or 0.5 g/L and above. Nevertheless, [12] uses Non-invasive Sweat Alcohol Metal Oxide (MOX) gas sensor for the sensor detection.	By this study, the used MQ3 sensor is more sensitive that the sensor used through [12] study. By comparison, this paper sensitive detection 0.35g/L and through [12] the sensitive is 0.5 g/L and above. However, this direct comparison is unjust due to the different type of sensor is used for alcohol detection, i.e. MQ3 by this paper and MOX by [12].

Note: No specific information on performance provided by author [11].

4.1 The Use of TRIZ to Find a Solution for the Problem

The TRIZ approach was applied to solve the issue of slow data transmission rates for GPS information using 4G, with results varying from those using 3G network. The TRIZ approach has the advantage of achieving exceptional engineering and scientific ideas to find alternative solutions [25]. Although it may sound like a high technical approach, its flexibility allows it to blend problem and solution uncertainties, linking general issues with specific problems. Thus, this approach helps to identify any flaws in the product design and deal with issues through various brainstorming techniques, which may lead to a coincidental solution [26]. The TRIZ approach has four tools for finding solutions to the problem, including the contradiction matrix, law of technical evolution, substance-field analysis, and the algorithm of inventive problem, all subject to selective usage [27]. Furthermore, there are 39 engineering features and 40 inventive principles that are also subject to selective usage [28].

Table 5. The Summarized Contradiction of TRIZ

Improving Features (39 Engineering Features)	**Worsening Features** (39 Engineering Features)	**TRIZ solution principle** (40 Inventive Principles)
#09 velocity – transaction speed	#38 automization degree of system	#06 Universality
	#37 degree of complexity in the subsystem driving	#10 Preliminary action
	#33 facility in subsystem operating	#20 Continuity Action of Useful Action
	#27 reliability	#15 Dynamics
#25 time spans of idle work	#25 time spans of idle work	#23 Feedback Principle
	#24 loss of information	#27 Inexpensive Short-Lived Objects

Table 6. Design Strategy Based on Identified TRIZ solution principles

TRIZ Solution Principles	**Solution Description**	**Design Strategy**
#10 Preliminary action	The full-scale model i.e. the module, must run as good as time spans of idle work.	The use of SIM card registered for 3G and 4G can be alternately used for preliminary action.
#20 Continuity Action of Useful Action	Due to other location might show difference good network coverage, hence for continuity the useful action, interchangeable use of 3G and 4G is proposed for useful action.	While the testing locating is assumed receiving bad network for 4G, for actual application suppose 4G network is in good condition. Thus, replacing 3G to 4G registered SIM card is proposed – use cards interchangeable. This is due to the ESP32 Microcontroller comes with a single SIM card slot.
#23 Feedback Principle	Since, the network is inconsistence on a certain location, thus user feedback refers to alternate use of 3G and 4G SIM card installed.	The use of SIM card is economically not a burdensome, thus using two SIM cards are proposed in order to get the best network coverage.

The tool used in this study is TRIZ contradiction matrix to find the solution that considering the worsening features occurs by the new improving feature. For this tool, 39 engineering features were mapped together between the improving and worsening features, then solution based on 40 inventive principles are proposed [27]. The 40 inventive principles are the standard solution that is proven successfully applied in many areas such as in reducing product environmental effects [28]; new urban transportation [29], and renewal energy [30, 31]. The summary contradiction matrix shown in Table 5. Through this stage, the improving and worsening features must be spelled out, though the problem and solution to work out a specific problem is still uncertain. The preparation of Table 5 aims to visualise the contradiction matrix. Besides, Table 5 also tabled the best nominated principles as the initial guideline to improve the network speed issue. Afterward, the issue is checked thoroughly grounded by technical views. Later, based on these features, the following step is the proper 40 TRIZ Inventive Principles selection.

Throughout the TRIZ Contradiction Matrix, a proper solution is the outcome. The matrix is expressed as in Table 5, the inventive solution principles recommended by TRIZ method. In Table 5, there are eight suggested features which could be used to confront the contradiction, though this is not finalised yet. Subsequently, the finalised principle is determined align with the issue technically. The determine principles, decide the specific solution, which established the design strategy shown in Table 6. Largely, the engineering contradiction occurs due to the performance of 4G network is conflicting the performance which is very slow for 4G network compare to 3G network referring to #09. For the engineering contradiction, solution principle #10 and #20 were chosen to generate specific solution ideas.

4.2 Product Effectiveness Analysis

In this study, the TRIZ contradiction matrix was used to find a solution to the issue of slow data transmission rates for GPS information using 4G, which resulted in varying speeds compared to using 3G networks. The TRIZ approach has the advantage of achieving exceptional engineering and scientific ideas to find alternative solutions [25]. By mapping 39 engineering features together between the improving and worsening features, and proposing solutions based on 40 inventive principles [27], this approach can help solve specific problems by identifying and dealing with any flaws in the product design through various brainstorming techniques. Through the TRIZ contradiction matrix, a proper solution can be obtained. Table 5 shows the recommended inventive solution principles based on the TRIZ method. The final solution is determined based on technical views and the specific solution ideas generated by the chosen principles, as shown in Table 6. The engineering contradiction is due to the slow performance of 4G networks compared to 3G networks, which is directly related to the issue of data transmission speed (#09). The use of 3G networks speeds up the data transmission, making the work more efficient (#25), while the use of 4G technology may decrease the effectiveness of the product functions that are coded to work automatically (#27), such as SMS and miscall transactions to the driver's next-of-kin and location searches by the driver's next-of-kin. However, the use of 4G technology may also increase the complexity of subsystems (#37) and make the subsystems operate much faster (#33) under optimal conditions. The proposed solution to this issue is to use two SIM cards for network coverage, as the use of a single SIM card may not provide consistent coverage based on the location of the experiment.

5.0 CONCLUSION

In conclusion, this study successfully implemented an integrated module that could potentially prevent car accidents caused by driver drowsiness. The use of IoT technology in this design allows for the identification of actual issues that may be encountered in a real-world scenario. Although 4G technology is undoubtedly more efficient than 3G in terms of speed performance for data upload and download, the hard handoff technique used in 4G networks can result in poor performance due to inconsistency in network coverage. Further modifications to the module can be made by using a microcontroller with two SIM card slots to achieve consistent network coverage. Additionally, exploring other gas detection methods such as Carbon Monoxide, which can be dangerous to car drivers and passengers, and integrating the module with anti-theft mechanisms could expand the potential of IoT products.

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