RESEARCH AND INNOVATION IN TECHNICAL AND VOCATIONAL EDUCATION AND TRAINING
e-ISSN: 2785-8138

RITVET

Vol. 4 No. 1 (2024) 54-65
https://publisher.uthm.edu.my/periodicals/index.php/ritvet

Automatic Tire Pressure Sensor at Petrol Pump

Nur Sabrina Mohd Isa[1]*, Alias Masek[1]

[1] *Faculty of Technical and Vocational Education*
Universiti Tun Hussein Onn Malaysia, 86400 Batu Pahat, Johor, MALAYSIA

*Corresponding Author: riena.isa@gmail.com
DOI: https://doi.org/10.30880/ritvet.2024.04.01.006

Article Info

Received: 14 February 2024
Accepted: 12 June 2024
Available online: 30 June 2024

Keywords

Sensor, inductive, infrared, height, air pressure, tire

Abstract

The average air pressure within each automobile tire is determined according to the specified range as stated for the Axia 1.0 AV model, which is 230 kPa per tire. Insufficient air pressure poses a high risk. Failure to maintain the recommended tire pressure level led to significant consequences for the user. This is due in part to time constraints, which are one of the difficulties in determining tire pressure right at the initial stage. Therefore, this introduced project aims to design, develop, and implement testing for the functionality and usability of an Automatic Tire Pressure Detection System at Petrol Pump to address the aforementioned issue. The Design Thinking model, encompassing five phases of empathy, definition, ideation, prototyping, and testing, was chosen to support a human-centered process as well as emphasizing three main aspects which are human, technology, and entrepreneurship. The installation of infrared sensors as car position detectors, as well as inductive sensors calibrated at specified height levels, is capable of detecting low tire pressure when the sensor senses the car rim. The project results show that the product runs smoothly and meets the established objectives. Expert validation tests yield positive results, with experts suggesting continued product development by expanding the scope to include the development of an IoT system for the prototype that can recognize various vehicles with varying tire sizes. As a result, the developed product has been approved for commercialization in the industrial sector.

1. Introduction

Petrol stations are very important for vehicle users to fill their fuel needs. Additionally, petrol pumps also provide air and water services to aid users in inflating vehicle tires, thereby enhancing the efficiency of their travels. It helps prevent accidents resulting from overlooked underinflated tires. Insufficient air pressure can lead to damage to the car rims, causing imbalance and resulting in difficulties controlling the vehicle on the road. According to Yusop (2022), decreased tire load capacity raises rolling resistance, ultimately causing mechanical damage due to elevated heat levels. Therefore, maintaining proper tire pressure is crucial for safety, as highlighted by Mekanika (2016).

In general, the standard tire pressure specifications for cars vary depending on the vehicle category. Referring to Hamzah (2019), there are five car categories: sedan, city, MPV, commercial, and SUV. Examples of sedan cars include the Honda Civic, Toyota Corolla, and Vios, which require an air pressure of 28 – 30 psi. City cars like Jazz, Yaris, and Axia, on the other hand, need tire pressure between 29 – 32 psi. Moving on, MPV cars such as Avanza, Alza, Exora, and commercial vehicles each require a pressure range between 30 – 33 psi and 30 – 35 psi, respectively. Finally, SUVs like Fortuner and Pajero require higher tire pressure, ranging from 35 – 40 psi. It is important to note that the mentioned pressure ranges refer to the safe tire pressure differences in Malaysia.

In line with this, the developed project can detect the quantity of air pressure based on the specified range for the tire diameter size used. Subsequently, the system project displays the air pressure conditions (kPa/psi) for each car tire on the LCD screen, indirectly providing a warning if any tire is underinflated. LED lights representing each vehicle tire serve as indicators, notifying which part of the car tire needs inflation. Therefore, micro-processing, LCD, and various sensors, along with other components, are required and programmed together to ensure that the developed project has the potential for marketability.

2. Methodology

In this context, the Design Thinking model is used for the product development implementation process to address the challenges faced by the target group. This is because the model employs a design-based approach to solving human problems (Muna, 2020). The selection of this model by the researcher was made due to a human-centered approach as several stages in the model highly prioritize three main aspects humans, technology, and entrepreneurship (Rao & Kalyani, 2022). The design thinking model consists of five phases, starting with the empathy phase, followed by the define, ideate, prototype, and concluding with the testing phase (Ayu & Wijaya, 2023). This methodology aids the researcher in gaining a deeper understanding by following the order of the model to be used (Dijksterhuis & Silvius, 2017).

2.1 Research Design

Project design is a method or technique used throughout the development process of a project (Chiva & Alegre, 2022). The decision-making procedure of project design is very important in ensuring that the project development can run smoothly as well as tackling the obstacles encountered by the vehicle user at the petrol pump. Thus, the consequence of the five stages is listed in Fig. 1.

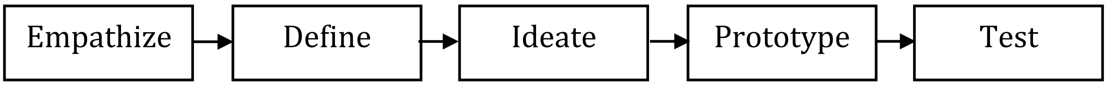


Fig. 1 *Flow Chart Model Design Thinking*

2.2 Research Procedure

2.2.1 Empathize Phase

Recognize the contextual factors contributing to challenges encountered by users at petrol stations through the execution of observational methods, engage in a thorough exploration and active involvement in the issues experienced by the target group, as suggested by Muna (2020). Researchers use the "walk in their shoes" approach to ask the reason individuals have a lack of concern for the air pressure of car tires to position themselves as consumers within the target group. This practice allows the researcher to gain a deep understanding, facilitating effective interviews with the target group to uncover authentic problems and establish connections among various aspects related to the emerging issue (Prabhu et al., 2021).

Consequently, the sampling involved the random selection of five individuals from Axia users in the campus area. The concept of 5W1H has rules in questioning, such as 'you do not know if you do not ask' and none of the questions presented allow for a simple YES or NO response (Knop & Mielczarek, 2018). Therefore, the researcher employs the 5W1H concept in interview questions to obtain comprehensive answers from respondents. The findings indicate that the majority are aware that responsible drivers pay attention to the condition of their car tires. However, detecting the air pressure in physical car tires can be challenging in the early stages, leading to monitoring only when necessary.

Flat tires do not occur simultaneously, making it difficult for drivers to sense changes due to insufficient air pressure while driving. The inconvenience of service congestion and time constraints discourages car users from stopping by to assess their tire air pressure in a brief timeframe. Additionally, the air pumps at existing petrol pumps lack automatic pressure control. Respondents expressed difficulty in visiting the water and air section at the petrol pump solely to check tire pressure. Here, the results of interviews to obtain data from respondents can be summarized in Table 1.

Table 1 *Interview questions and answers*

5W1H	Questionnaire	Problem
How?	How do you park the car in the yellow space when filling up the car? How do you know the air pressure in a car tire that does not follow the specified specifications?	...just a little bit... ...if it can refuel... ... just a guess... ... notice when people criticize...
Who?	Who consistently pays attention to the tire pressure of the vehicle they operate? Who encounters difficulties when inspecting the air pressure in the tires of the vehicle they drive?	... who drives the car… ... the individual who drives the car as well …
What?	Is it challenging to physically detect the air pressure in car tires during the initial stages? What condition were you aware that not adhering to specified tire pressure conditions can be hazardous? What challenges do you face when inspecting your car tire pressure after refueling? What type of information regarding tire inflation conditions, consistent with the standard, does the current petrol pump provide?	...did not feel any change, in case too deflated... ...it is dangerous but lazy to always check… ... yes, it is hard because it must turn the car around... ...chasing time, crowded car... ... not at all, just information about the pressure conversion table...
When?	When do you assess the state of your car tires? What are your thoughts on how often you should inspect the air-pressure car tires?	...when there is less air... ...when the steering wheel feels too heavy to turn... ... just when necessary...
Where?	Do you usually inflate your car tires at petrol pumps or tire shops?	...Petrol pump...
Why?	In your opinion, why does non-compliance with the specified air pressure have an impact on car users? In your opinion, why is tire air pressure closely related to user safety?	...feels unsteady when driving the car... ...the tires are a crucial part of the car's movement...

2.2.2 Define Phase

The next step in a standard Design Thinking procedure is known as the Define phase which includes gathering information from the initial observation stage (the first stage is referred to as Empathize) to clearly articulate the design problems and obstacles (Rikke Friis Dam, 2019). Researchers collect and categorize existing issues that are faced by users and find some solutions so that these problems can be better dealt with. Table 2 shows the researcher translating the feedback from user interviews into technical terms where it is easier to understand for implementing the next phase.

Table 2 *The technical term for the problems*

Problems	Technical Terms
...just a little bit... ...as long as it can refuel... ... just a guess... ... notice when people criticism...	Did not have real-time detection indicators when parking the car in the yellow space at the petrol pump
... who drives the car… … the individual who drives the car as well …	The driver is responsible for the car's tire pressure.
...did not feel any change, in case too deflated... ...it is dangerous but lazy to always check… ... yes, it is hard because it must turn the car	Drivers find it challenging to detect differences in car tire pressure because it is not noticeable in the early stages.

around... ... chasing time, crowded car... ... not at all, just information about the pressure conversion table...	Struggling to find time for the air and water station. Air pumps at petrol pumps are not user-friendly hence there is no tire pressure detection information indicator.
...when there is less air... ...when the steering wheel feels too heavy to turn... ... just when necessary...	There is no device available to measure pressure according to the correct specifications. Additionally, there is no indicator guiding the implementation of inflating or deflating car tire pressure.
...Petrol pump...	Petrol pumps are the places where most people go to increase or decrease tire pressure.
...feels unsteady when driving the car... ...the tires are a crucial part of the car's movement...	Maintaining the equilibrium of a car's drive involves considering the role of the tires as a crucial factor.

2.2.3 Ideate Phase

The concept for creating this tire pressure sensor product arose when a researcher observed a device used to inflate air into bicycle tires. This equipment is user-friendly and highly portable, allowing for flexibility in transportation. However, the method of introducing air is currently carried out manually by pressing the addition button (+) to inflate the tire and the subtraction button (-) to reduce air pressure. This operation requires human effort to consistently monitor the tire's condition. Therefore, the researcher has taken this idea and applied its concept to automatic usage, eliminating the need for human intervention.

Car users encounter challenges in identifying tire pressure deviations from specifications at an early stage, prompting the development of an automatic tire pressure detection product. This situation can save users time, as it is integrated into the vicinity of the fuel dispenser. Thus, it is more effective in quickly detecting tire pressure while users are refueling their cars. The researcher states that developing a set of guidelines as an indicator for proper parking can also assist in addressing the issue, in addition to using cameras positioned on the top of the car to track its position.

Otherwise, the researcher proposes to develop a portable tire pressure detection device with automatic sensing to instill confidence without relying on user intervention, thus minimizing the risk of errors. Hence, various proposed solutions articulated by the researcher can be formulated through the technical terms in Table 3 below.

Table 3 *The solution in technical terms*

Technical Terms	Proposed Solutions
• Did not have real-time detection indicators when parking the car in the yellow space at the petrol pump	i) Utilizing sensors to detect the proximity of a car in the yellow box. ii) Developing guidelines as indicators for cars to stop in the correct location. iii) Tracking the position of the car through a camera placed on the top of the car.
• The driver is responsible for the car's tire pressure.	i) Designing a portable device to easily detect tire pressure by manually inserting it into the tire valve. ii) Creating an automatic tire pressure detection device.
• Drivers find it challenging to detect differences in car tire pressure because it is not noticeable in the early stages. • Struggling to find time for the air and water station.	1. Using processing by comparing images of wind pressure. • Before • Following standards • Latest i) Using a sensor to detect the

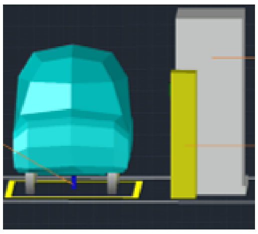
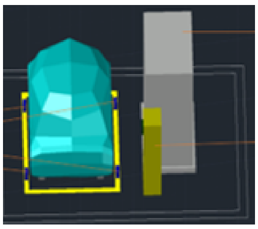
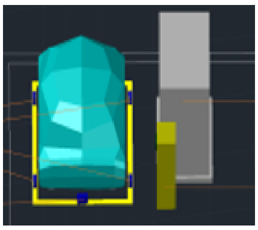
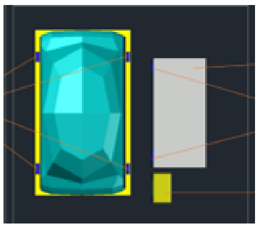
• Air pumps at petrol pump are not user-friendly hence there is no tire pressure detection information indicator.	pressure at the specified specification.
• There is no device available to measure pressure according to the correct specifications. • There is no indicator guiding the implementation of inflating or deflating car tire pressure.	i) Using ultrasonic to detect the height of car tires. ii) Provide a platform to display information related to car tire pressure. iii) Using a sensor to detect the rim of the car to find out the tire pressure

The researcher goes through a process to find the main problem as well as some preliminary designs for prototype development so that the problems that arise can be better dealt with. So, researchers take various initiatives to generate various solutions from different points of view. Different drafts of tire pressure sensor products are executed, drawing upon suggestions and insights from researchers aimed at addressing challenges encountered by car users. In this regard, initial sketches were crafted to inspire concepts for the advancement of products integrating cutting-edge technological features while prioritizing user safety. Consequently, the resulting product sketch encompasses functionality focused on detecting air pressure specifically for the target group, Axia 1.0 AV users.

The first design incorporated only an ultrasonic sensor. Despite the cost-saving advantage of using a small number of sensors, this design was rejected due to inaccuracies in height detection. Placing the sensor at the bottom corner resulted in a significant distance between them, leading to considerable errors in height readings. The second prototype sketch is rejected referring to the views and opinions voiced by users where the development of ultrasonic sensors alone is not sufficient because some people do not care about the position of the car when refueling. The third sketch for the prototype involves adding another sensor to detect the position of the car at the front and rear. However, this design is unacceptable due to the distance between the car placed from dispenser, it still detects the presence of the car even if it is not in the right position.

The fourth design involves replacing the ultrasonic sensor with an inductive sensor. While the ultrasonic sensor relies on the concept of reflection to detect distance, the inductive sensor can identify metal on the tire rim. The functional difference between these sensors affects the accuracy of the results for both. In addition, the presence of several amounts of an infrared sensor to indirectly determine the car's position, combined with the inductive sensor on each side of the tire, enables accurate height detection. Therefore, this design is acceptable. Hence, it will implement improvements to better detect car tire pressure. Table 4 shows the four designs of ideas in using the right sensor with the suitable position.

Table 4 *Design of prototype*

			
First Design	Second Design	Third Design	Fourth Design
The ultrasonic sensor is placed on the yellow box that has in front of the dispenser (under the car that enters there)	The ultrasonic sensor is placed on the yellow box that has in front of the dispenser (on every side of the tire)	Use two types of sensors: Ultrasonic and Infrared (every side of the tire within the front of the car position)	Use two types of sensors: Infrared (on every side of the tire) and Inductive (in front of the petrol dispenser)
Rejected	Rejected	Rejected	Accepted

The position of the sensor to detect wind pressure does not provide accurate data output. The data obtained is too much according to the angle of the detector causing the LCD to constantly change	Several elements can meet the needs and features required by users. Some things need to be improved to ensure that the facilities given emphasize safety aspects in the operation product	The position of the sensor on the front is not very effective. If the car is placed far from the dispenser, it still detects the presence of the car even if it is not in the right position	Infrared detects the right position of the car. Inductive sensors detect the presence of metal such as rims on car tires. If the sensor detects metal, the condition indicates that the car's tires do not meet the specification range

2.2.4 Prototype Phase

In this phase, the development of the prototype is carried out by selecting the best prototype based on the design that meets user requirements. The fourth design has a high possibility of generating accurate output in detecting car tire pressure through height by using an inductive sensor. Figure 2 shows the block diagram that consists of two types of sensors that connect to the microcontroller for input processing, ultimately generating results displayed on an LCD, indicated by LEDs, and signaled by a buzzer.

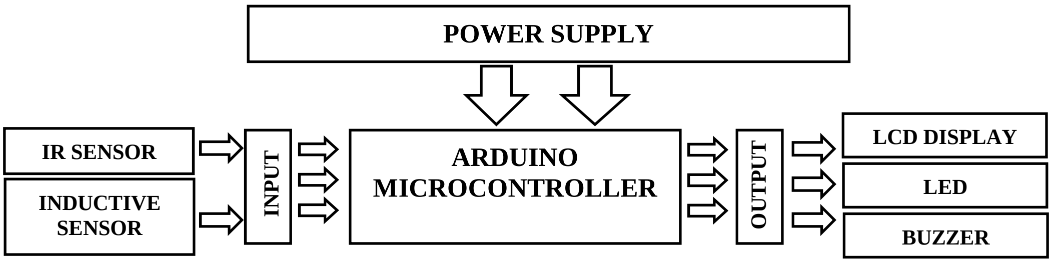


Fig. 2 *Block diagram project*

Figure 3 illustrates the product operational flowchart. When a car enters the petrol pump premises, it normally moves to the specified yellow box in front of the fuel dispenser to facilitate the fueling process. The developed project begins operating and the sensor for detecting car tire positions will automatically activate. When the position is incorrect, the buzzer rings out and the LCD panel displays the corresponding data. To activate the height sensor, the car's position must be properly aligned. The height that does not meet specifications illuminates the red LED and the pressure conditions in each tire are displayed on the LCD screen.

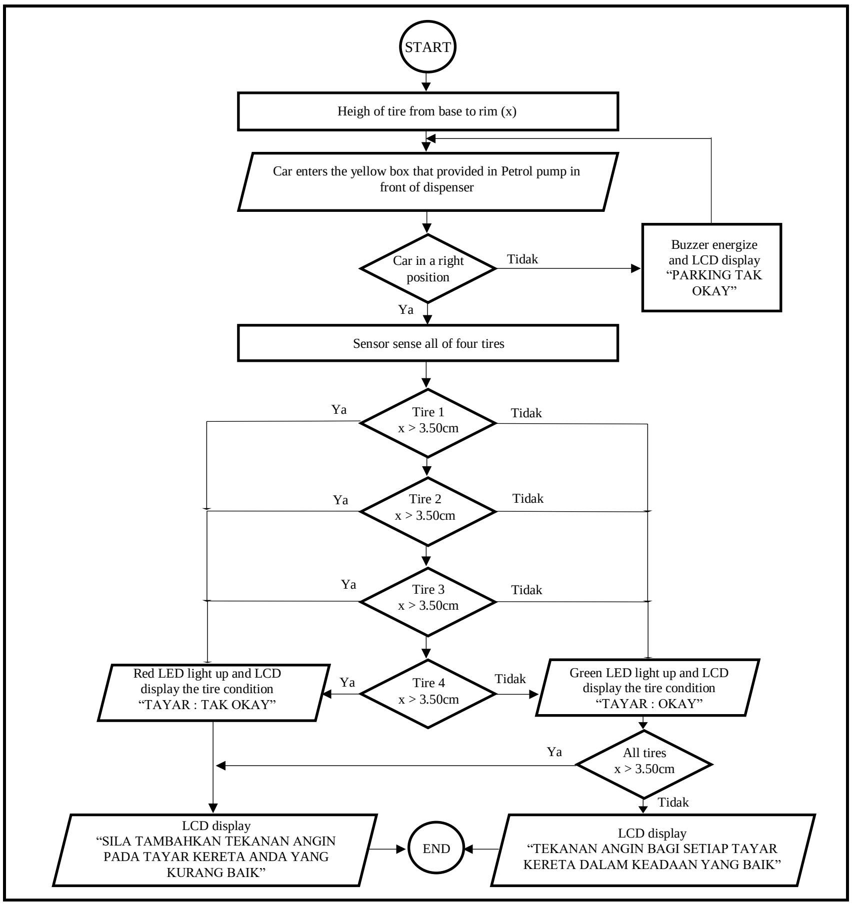


Fig. 3 *Operation flow chart*

The final product development is depicted in Figure 4 which includes a controlling box with an electronic circuit inside it and four smaller boxes containing two types of sensors each for detecting the position of the model and the tire air pressure through height setting. Additionally, there is a model situated on the yellow box, which indicates the situation at the petrol pump.

Fig. 4 *Final product*

2.2.5 Test Phase

In this stage, several tests were performed on the developed product including data analysis for design, circuit analysis, and efficient operation. In addition, expert analysis was carried out to assess the functionality of this prototype to improve its value as well as commercial viability. However, the outcome stage is depicted in the result section.

2.3 Expert and User demography

The experts selected for the evaluation process of the developed product consist of three individuals, one of them is an assistant engineer and the remaining two are lecturers specializing in the field of electronics. Table 5 shows the demography of the expert who tests the product functionality. This project also received feedback from five user parties to enable product evaluation based on public perspectives. Table 6 shows the demography of the user who tests the product usability.

Table 5 *Demography of expert*

Details	Working period	Field of specialization	Sector	Position
Expert 1	2 Years	Electronic	Government	Assistant Engineer
Expert 2	25 Years	Electronic	Government	Lecturer
Expert 3	16 Years	Electrical and Electronic, Education and Multimedia Technology	Government	Lecturer

Table 6 *Demography of user*

Details	Working period	Field of specialization	Sector	Position
User 1	No	Electrical and Electronic	No	Student
User 2	6 Month	Electrical and Electronic	Government	Civil Servant
User 3	13 Years	Electronic	Government	Assistant Engineer
User 4	2 Years	Electrical and Electronic	Government	Civil Servant
User 5	2 Month	Electronic	Government	Student

2.4 Expert and User Assessment Analysis

Table 7 shows the evaluation percentages assigned to each aspect of the prototype design by three electronics experts and five Axia AV1.0 car users. Nearly all aspects outlined in the prototype design garnered approval from each party. However, one aspect received a dissenting opinion, specifically regarding the utilization of durable and high-quality materials since the project will be situated in an exposed environment and subjected to frequent use.

Table 7 *Expert and user analysis (design aspect)*

No.	Items	Approval			
		Yes		No	
		Quantity	Percentage (%)	Quantity	Percentage (%)
1.	The prototype has a creative design to illustrate the desired operation	8	100%	0	0%
2.	Appropriate prototype size	8	100%	0	0%
3.	The use of durable and quality materials	7	88%	1	12%
4.	The developed prototype model clearly illustrates the purpose of the product development concept	8	100%	0	0%
5.	The position of the detector sensor is at the optimal position	8	100%	0	0%
6.	The connection between the control box and the detection sensor is done neatly	8	100%	0	0%
7.	Prototype circuit well protected and sealed	8	100%	0	0%

Subsequently, the assessment findings show that it strongly indicates agreement among users for every element outlined in the usability of the prototype under development. This signifies that the prototype fulfills the requisite standards, ensuring seamless automatic detection of car tire air pressure, thus facilitating convenience. On top of that, the findings from the functional testing indicate unanimous agreement among all experts regarding items such as sensor functionality, automatic control, and power supply. Nonetheless, there are recommendations concerning the automatic control features, suggesting improvements to the buzzer signal responsiveness to ensure the buzzer only activates when the sensor detects car tires entering the designated yellow box compound. Thus, preventing unnecessary buzzing when there's no car present. Therefore, the expert agreement data in confirming the item for the functionality aspect is as below. Additionally, there are comments and suggestions for enhancement provided by both experts and users following the evaluation of the Automatic Car Tire Pressure Sensor product at the Petrol Pump. Consequently, these remarks and recommendations can be condensed and summarized as shown in Table 8 below.

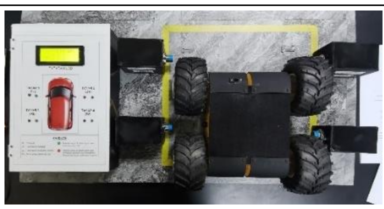
Table 8 *Evaluator recommendation*

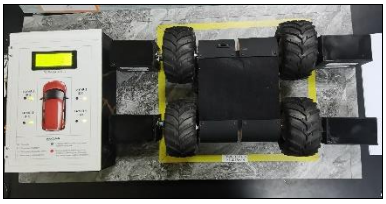
Evaluator	Reviews and Improvement Suggestions
Expert	i) Utilize high-quality materials to prevent potential issues during implementation in the petrol pump. ii) Integrate solar systems to conserve electricity. iii) Implement a programming feature to display 'SILA ISI ANGIN TAYAR KERETA ANDA' after the air pressure indicator turns red, as a reminder to the driver to fill up the tire. iv) Configure the buzzer to sound only when the tire enters the yellow compartment if the tire is positioned incorrectly.
User	i) Specify the battery life duration. ii) Installing LEDs to indicate the correct position of the car tires. iii) Develop an Internet of Things (IoT) system prototype incorporating an air pressure datasheet, number of vehicles per day, and vehicle type.

3. Result and Discussion

The outcomes section reflects the findings derived from testing the functionality of the product and the evaluation information of the process are presented in tabular form. The testing is running well as the output indicates LED and LCD with an operated buzzer. Table 9 shows the outcome for the indicator LED with LCD of the product operation.

Table 9 *The outcome of the product operation*

Input	Hardware Position With Indication Led	LCD Display
Power supply provided	 All LED are deenergize	
Some of the infra-red sensors do not detect the presence of car tires	 All LED are OFF while the buzzer energized	

An infra-red sensor detects all four tires of the car	 All LED are OFF while the buzzer deenergized	
Some inductive sensors detect car tire rims Condition after some inductive sensors detect car tire rim	 Red LED in position P2 light-up and the rest light-up green LED	 
Inductive sensors do not detect any rim of the car tire Condition after the inductive sensor completes detecting every position	 The green LED lights up in every position	 

3.1 Discussions

The development of automatic car tire air pressure detectors at petrol pumps was initiated to address the challenge of identifying insufficient air pressure in tires at an early stage. The researcher concluded that the project development was successful and met the study objectives. Previous product development varies in terms of design, with the usage of several distinct electronic components resulting in variations in the methodology employed for detecting air pressure in car tires. Consequently, the discussion elaborates on the three study objectives which involve designing, developing, and testing the usability and functionality of a prototype Automatic Car Tire Pressure Sensor at Petrol Pump.

The design for the smart tire air pressure monitoring system uses electronic elements embedded within the tire encompassing pressure sensors, signal processing units, and temperature sensors attuned to ambient temperature variations (Silalahi et al., 2019). In contrast, the implementation of the Tire Pressure Monitoring System with Wireless Communication involves the incorporation of high-cost components such as the OMRON E8CC 10 Pressure Sensor, Microcontroller, RF Transmitter and receiver, lithium batteries, and a power supply. These components facilitate wireless communication, enabling the system to detect air pressure in each car tire. However, the product that was developed, which is the Automatic Tire Pressure Sensor at Petrol Pump, only uses two types of sensors together with a microcontroller to execute automated air pressure detection operations. Users have not concerned themselves with scenarios wherein vehicular shocks or vibrations during transit might jeopardize the integrity of sensor functionality (Massimo Canale et al., 2007).

Product development is individual aiming to distinguish existing products from innovative or recently introduced ones. This distinction becomes evident through the various perspectives that lead to both advantages and disadvantages for the introduced products. Consequently, it also happened to the development of Automatic Tire Pressure Sensor at Petrol Pump where detection through height cannot display wind pressure readings (kPA) to show the pressure range within the specified specifications (Radarpena, 2023). This is different from previous products that are implemented directly into the car tire tube where wind pressure detection can be displayed through the reading value. However, this product was designed for vehicles who do not have an autonomous air pressure detection system. The concept of metal detection is only through height through height allows users to quickly assess the condition of car tire air pressure, specifically during refueling without incurring any costs to acquire the product.

Analyzing functionality and usability involves inspecting system operations that are relevant to product development objectives (Hans, 2020). An RF transmitter used in the Smart Tire Pressure Monitoring System to help balance pressure fluctuations with changes in external temperature (Silalahi et al., 2019). However, this method may not identify air pressure changes if all tires experience a consistent pressure reduction (Caban et al., 2014). Next, the Design of Tire Pressure Monitoring System Using a Pressure Sensor Base, requires affixing an electronic device unit directly onto the valve of the car tire to integrate the tire pressure monitoring system (TPMS) through Bluetooth, automatically initiates the compressor (Silalahi et al., 2019). Implementation of Tire Pressure Monitoring System with Wireless Communication adopts the concept of measuring air pressure within the car's pneumatic tires. Each TPMS unit is equipped with a unique ID code to prevent the reception of false data from nearby vehicles (Hamzah, 2019).

On the other hand, the development of Automatic Tire Pressure Sensor at Petrol Pump utilizes two sensors to ensure smooth operations. Infrared sensors are employed to verify the car's position within the yellow box, while inductive sensors detect the air pressure of the car tires based on the height between the ground and the bottom of the car rim. This underscores that tire pressure detection in this context does not necessitate an additional electronic medium for data acquisition (Hamzah, 2019). Experts inspire future product development by broadening the scope to include the development of an IoT system for the prototype that can detect various automobiles with varying tire sizes. As a result, the developed product has been approved for commercialization in the industrial sector.

4. Discussions

The outcomes of the project indicate that the product operates smoothly and meets the established objectives. Expert validation tests yield positive results, whereas verification tests conducted by experts have confirmed the effectiveness of the infrared sensor in accurately identifying the tire position. Additionally, the activation of the buzzer occurs when the vehicle is not positioned correctly within the designated yellow box. Proper alignment of the vehicle indirectly facilitates the operation of the inductive sensor, enabling it to accurately detect tire air pressure based on the high distance between the floor and the bottom of the car rim. Detection of car rims at a specific height through inductive means serves as an indicator of inadequate tire pressure. The LCD screen displays the current tire pressure status, and corresponding LEDs illuminate to indicate the tire pressure status of each tire. Experts suggest continued product development by expanding the scope to include the development of an IoT system for the prototype that can recognize various vehicles with varying tire sizes. As a result, the developed product has been approved for commercialization in the industrial sector.

Acknowledgment

The authors would also like to express appreciation to the Faculty of Technical and Vocational Education, Universiti Tun Hussein Onn Malaysia for its support and assistance throughout project implementation.

References

Ayu, T. B., & Wijaya, N. (2023). Penerapan Metode Design Thinking pada Perancangan Prototype Aplikasi Payoprint Berbasis Android. [Application of design thinking method in the design of payoprint android-based application prototype] *The 2nd MDP Student Conference*, *2*(1), 68–75. https://doi.org/10.35957/MDP-SC.V2I1.4065

Caban, J., Drozdziel, P., Barta, D., & Liscak, S. (2014). Vehicle Tire Pressure Monitoring Systems. *Diagnostyka*, *15*(3), 11–14. Retrieve 27 June 2023 from https://www.researchgate.net/publication/289754141_Vehicle_tire_pressure_monitoring_system

Chiva, R., & Alegre, J. (2022). Project design management as a methodology. *Journal of Product Innovation Management*, *26*(4), 424–440. https://doi.org/10.1111/J.1540-5885.2009.00669.X

Dijksterhuis, E., & Silvius, G. (2017). The Design Thinking Approach To Projects 1. *PM World Journal The Design Thinking Approach To Projects*, *5*(6), 1–15. www.pmworldlibrary.net

Hamzah, A. (2019, December 11). *Berapakah tekanan angin tayar kereta yang optimum?* [What is the optimum pressure for a car?]. Motoqar. https://www.motoqar.com/2019/25737/berapakah-tekanan-angin-tayar-kereta-yang-optimum.html

Hans. (2020). *Tekanan angin tayar, jangan ambil mudah*. [Tire pressure, do not take it lightly]. Engear. https://engear.tv/tips/keselamatan/2020/12/09/jaga-tekanan-angin-tayar-kalau-tidak/1463/

Knop, K., & Mielczarek, K. (2018). *Using 5W-1H and 4M Methods to Analyse and Solve the Problem with the Visual Inspection Process-case study*. *183*(MATEC Web Conf., 12th International Conference Quality Production Improvement – QPI 2018), 42–200. https://doi.org/10.1051/matecconf/201818303006

Massimo Canale, Lorenzo Fagiano, & Mario Milanese. (2007, December). *Tire Pressure Monitoring (Application of Control)*. IEEE Control Systems Magazine. https://doi.org/10.1109/mcs.2007.909477

Mekanika. (2016, December 24). *PELAJARI TEKNIK PENJAGAAN TAYAR YANG BETUL*. Mekanika (Pemotoran Gaya Baru). https://www.mekanika.com.my/pelajari-teknik-penjagaan-tayar-yang-betul/

Muna. (2020, May 28). *Design Thinking - Suatu Pengenalan* [*Design Thinking - Introduction*]. Ulung Creative. http://muhaimisuhaili.com/index.php/ms/portfolio/23-design-thinking#empati

Prabhu, R., Alzayed, M. A., & Starkey, E. (2021). Not Good Enough? Exploring Relationships Between Students' Empathy, Their Attitudes Towards Sustainability, and the Self-Perceived Sustainability of Their Solutions. *Proceedings of the ASME Design Engineering Technical Conference*, *4*. https://doi.org/10.1115/DETC2021-71960

Radarpena. (2023). *Senarai Tekanan Angin Tayar Kereta Mengikuti Rim. [List of car tire pressure according to rim]. | 2023*. Radarpena. https://radarpena.com/tekanan-angin-tayar-kereta/

Rao, D. T., & Kalyani, C. R. (2022). *Design Thinking: A Human-Centered Approach Towards Innovation -A Conceptual Framework*. https://doi.org/10.34218/IJMHRM.12.2.2021.006

Rikke Friis Dam. (2019). *Stage 2 in the Design Thinking Process: Define the Problem and Interpret the Results*. Interaction Design Foundation. https://www.interaction-design.org/literature/article/stage-2-in-the-design-thinking-process-define-the-problem-and-interpret-the-results

Silalahi, L. M., Alaydrus, M., Rochendi, A. D., & Muhtar, M. (2019). Design of Tire Pressure Monitoring System using a Pressure Sensor Base. *Sinergi*, *23*(1), 70–78. https://doi.org/10.22441/sinergi.2019.1.010

Yusop, M. S. (2022, September 8). Jaga tayar demi keselamatan nyawa - Kosmo Digital. [Take care of the tires for the safety of life] *Kosmo*. https://www.kosmo.com.my/2022/09/08/jaga-tayar-demi-keselamatan-nyawa/