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Bluetooth-*Connected Vehicle: A Case Study of Android-Based Speed Monitoring System Using CAN Bus*

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Abstract

The speedometer plays an important role in displaying and measuring the vehicle's speed. A vehicle driver will always monitor and maintain the vehicle's speed according to the conditions of the road or terrain being traversed, thus enhancing the safety of the rider. The odometer is also important in measuring and recording the distance travelled. This research proposes a Bluetooth-based speedometer and odometer system integrated with a smartphone for electric motorcycles using the Controller Area Network (CAN) Bus communication system, allowing real-time speed and distance monitoring through an Android application. This system is evaluated based on the accuracy of the measured speed and distance. The results show that the proposed device can transmit data collected from the CAN bus via Bluetooth to the high-resolution Liquid Cristal Display (LCD) and SPEETER (the proposed name of the Android-based application) with 99.31% accuracy. The system had the data history to provide a statistical analysis for users and stakeholders. The advantages of this system include a user-friendly interface and good integration with mobile devices, making it an ideal solution for environmentally friendly transportation of electric vehicles.

Keywords: Android application, bluetooth, CAN Bus, odometer, speedometer.

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I. INTRODUCTION

Electric motorcycles represent a significant innovation in modern transportation, utilizing stored electrical energy in batteries to replace fossil fuels. This technology is not only environmentally friendly by reducing greenhouse gas emissions and air pollution but also offers operational cost efficiency, up to 75% lower compared to fuel-powered motorcycles [1]. The interest in electric motorcycles continues to rise, with research showing their use in Indonesia increasing 13-fold from 1,947 units in 2020 to 25,782 units in 2022 [2]. Research in the field of electric transportation is a topic receiving much attention. This field encompasses a wide range of aspects, including policy, simulation, hardware and software development, economic analysis, and future planning. Research on electric transportation, particularly electric motorcycles, involves various components, one of which is innovation in monitoring and acquisition systems [3],[4]. Although measurements of speed, distance, voltage, power and other parameters of an electric motor can be carried out, the proposed method does not yet consider statistical measurements. Driving history data in the form of speed is very important as a consideration in decision-making for users and stakeholders.

The current era witnesses rapid and extraordinary technological growth. Various technological innovations continue to develop to facilitate human activities effectively. Technological advancements are fundamentally driven by human needs, so technological innovation must be directed and aligned with those needs. One of the technologies experiencing significant development is CAN Bus communication technology. The CAN Bus network is widely used in vehicle technology development, agricultural equipment, and the industrial world. The CAN Bus network is used for control and data acquisition, consisting of two CAN High and CAN Low cables, designed to withstand interference from external noise using twisted pair cables [5].

Speedometers and odometers play crucial roles in vehicles. The odometer records the distance traveled, enabling the driver to evaluate when to recharge the battery and plan regular maintenance. The relationship between effective battery consumption and trip planning in electric vehicles (EVs) is critical for maximizing efficiency and minimizing range anxiety. Proper trip planning, including selecting optimal routes, considering terrain, and anticipating traffic conditions, allows for more efficient energy use. Factors such as average speed, regenerative braking, and load also influence consumption. By aligning trip planning with battery capacity and charging infrastructure, EV drivers can ensure they use their battery's energy effectively, avoid unnecessary detours, and optimize charging stops, leading to a smoother and more reliable journey. A mathematical formula to model the relationship between effective battery consumption C_{eff} and trip planning factors can be expressed as [6][7][8]

$$C_{eff} = \frac{E_{bat}}{D} + f(R, T, S, L) \quad (1)$$

where:
C_{eff}: Effective battery consumption (kWh/km)
E_{bat}: Total battery energy consumed during the trip (kWh)
D: Total distance traveled (km)
$f(R, T, S, L)$: Adjustment factor accounting for trip-specific variables

The adjustment factor $f(R, T, S, L)$ depends on:
R: Route characteristics (e.g., terrain, elevation).
T: Traffic conditions (e.g., stop-and-go scenarios).
S: Speed profile during the trip.
l: Load and weight carried in the vehicle.

This formula can be further refined with empirical data to model specific scenarios and optimize planning for efficient energy consumption. Monitoring the distance traveled (*D*) also helps calculate battery power consumption efficiency and plan trips to avoid running out of power midway. The speedometer helps the driver monitor and maintain speed according to road conditions to enhance safety. This issue was solved by Sumendra et. al. who proposed speed restrictions through an Android-based application [9]. Another study using the Android application is also proposed to obtain information about speed and distance [10],[11], [12]. Even though it has used an Android application, the proposed research has not used the CAN bus so it is difficult to implement because of the large wiring [10] [11].

II. Research Method

The system is designed by proposing the Android-based driving parameter application, electronic circuit and its electronic box, In designing a main system, several steps are required including collecting the data from the CAN bus system. The detailed steps can be shown in Figure 1.

A. *Electronic Circuit*

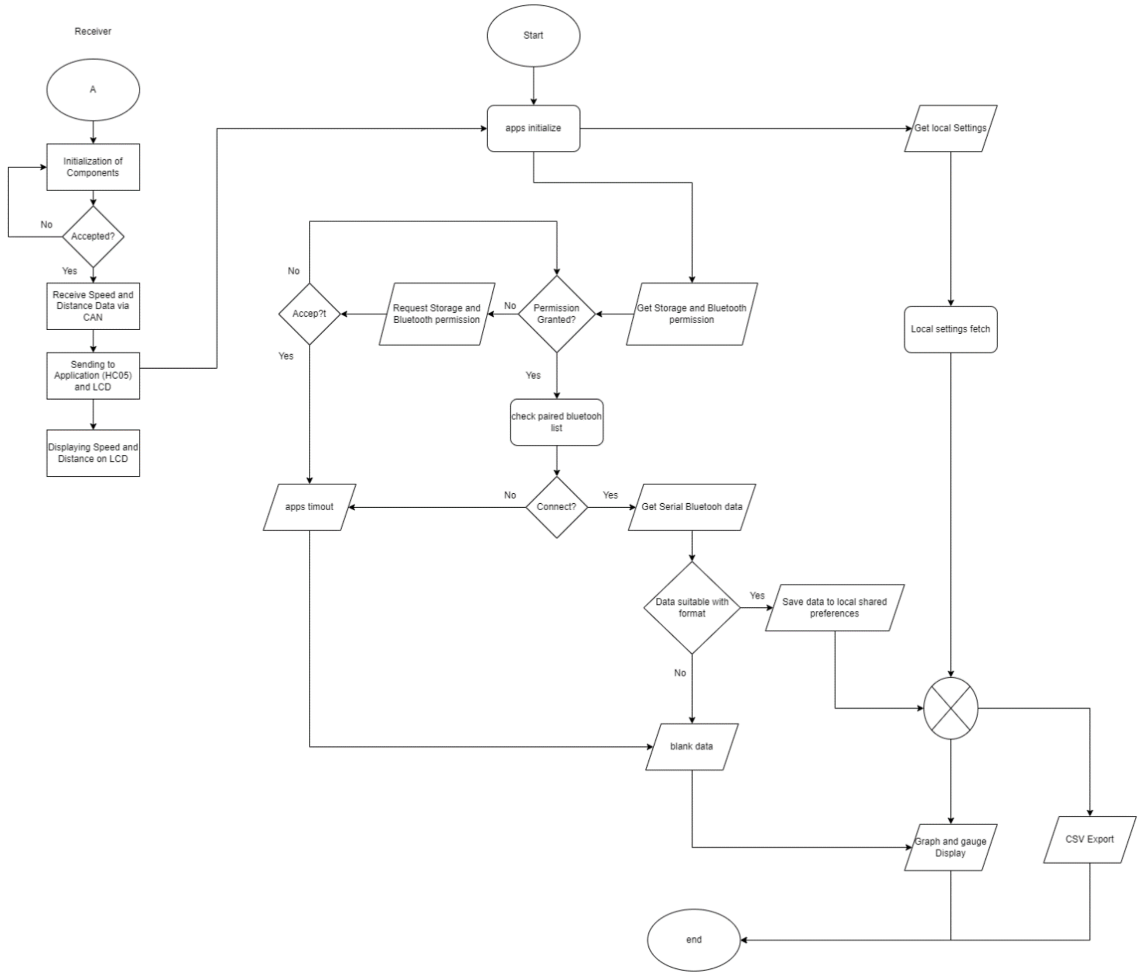

Fig. 1. Flowchart of the proposed system

The first stage involves designing the device with components such as LCD Nextion, MCP2515, Arduino Uno, Bluetooth HC-05, and RTC DS3231, where each component's functionality is processed. The electronic circuit design can be seen in Figure 2. Figure 2 illustrates a receiver circuit responsible for reading data from the electric motor controller, including speed and distance readings for the electric motor's speedometer. This system's implementation integrates various components to create a comprehensive control system. The system is controlled by a microcontroller, specifically the Arduino Uno, which runs the program and manages the operation of all connected devices. The Arduino Uno receives power from the main source, a lithium-ion battery (commonly referred to as Li-ion or LIB) with a capacity of 12V-84V-48Ah, and its voltage is stepped down to 5V using the MP1584 buck converter module [13]. This voltage reduction is done to provide appropriate power for the Arduino Uno and other components.

To maintain an accurate setting of time, the system uses an RTC DS3231 module connected to the Arduino Uno. Long-distance serial communication is implemented through the RS485 module. Meanwhile, the Controller Area Network (CAN) is managed with the help of the MCP2515, which is used to receive data from the CAN Bus-based controller. The CAN bus is a robust communication protocol widely used in electric vehicles (EVs) to enable efficient data exchange between various electronic control units (ECUs). It allows real-time monitoring and control of critical functions such as battery management, motor control, braking systems, and infotainment. The MCP2515 is a standalone CAN controller that integrates seamlessly with the CAN bus in EVs [14]. It interfaces with a microcontroller via the Serial Peripheral Interface (SPI) protocol and acts as a bridge between the microcontroller and the CAN bus. The technical relationship can be summarized as follows:

1. Data Handling: The MCP2515 processes CAN data frames by managing message prioritization, arbitration, and error detection. It ensures that messages from high-priority systems, like braking or battery management, are transmitted promptly.
2. Signal Translation: When the microcontroller sends data, the MCP2515 converts this data into CAN-compliant frames, including the identifier, data length code (DLC), and data payload, and transmits them over the CAN bus.
3. Interrupt Management: The MCP2515 generates interrupts to alert the microcontroller about events such as successful data transmission, receipt of new messages, or detected errors. This enhances system responsiveness.
4. Error Control: With its built-in error management capabilities, the MCP2515 helps maintain CAN bus reliability by handling error frames and maintaining the CAN bus protocol rules.
5. Flexibility: By offloading CAN protocol handling from the microcontroller, the MCP2515 simplifies microcontroller design, allowing it to focus on other EV functions.

Long-distance serial communication using the HC-05 Bluetooth module and its connection to the CAN bus involves bridging wireless communication with a wired protocol. The HC-05 enables Bluetooth-based wireless transmission of data, allowing remote devices to send or receive commands and monitor vehicle systems [15]. When connected to a CAN bus via an interface like the MCP2515, the HC-05 acts as a wireless gateway. It receives CAN messages from the vehicle, transmits them wirelessly to a paired Bluetooth device (like a smartphone or PC), or relays wireless commands from the Bluetooth device back to the CAN bus for execution.

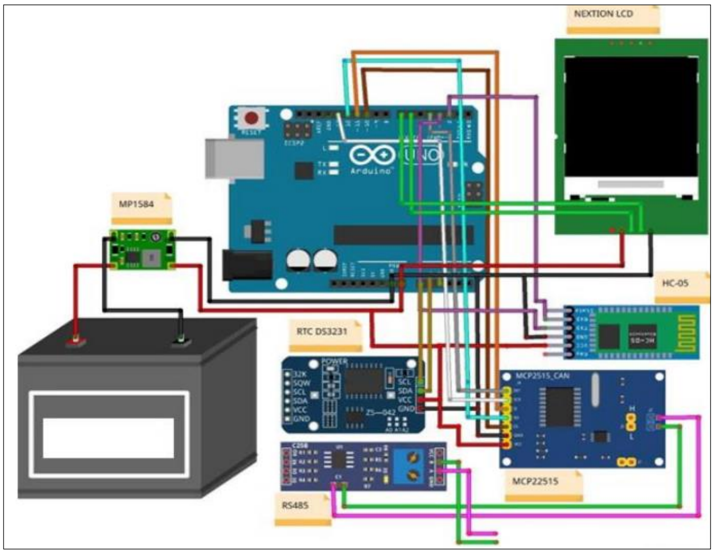

Fig. 2. Electronic circuit design for receiver

The user interface is built using a touchscreen display, specifically the Nextion LCD, and software in the form of a custom smartphone application that not only clearly displays system information but also facilitates direct interaction with the user. Each component in this system is connected to designated pins on the Arduino Uno, ensuring efficient communication and control according to the system's design. With good integration between hardware and software, this system can deliver optimal performance tailored to the needs of the intended application, whether in automotive, industrial environments, or other applications that require careful monitoring and control

B. 3D Design of Component Box

The 3D design of the electric motorcycle instrument display using Tinkercad starts with a basic sketch, adding screw holes for the LCD Nextion, and creating a cover enclosure, as shown in Figure 2. Tinkercad allows the creation of a more realistic and interactive speedometer design.

C. User Interface

a) Smartphone Application

This paper highlights the first contribution in terms of application is developing a smartphone application to monitor the performance of electric vehicles. This application is created using MIT App Inventor software, which allows visual application development with programming blocks. The application displays important information such as speed, distance traveled, performance graphs, top speed, and average speed in a user-friendly interface, as shown in Figure 3.

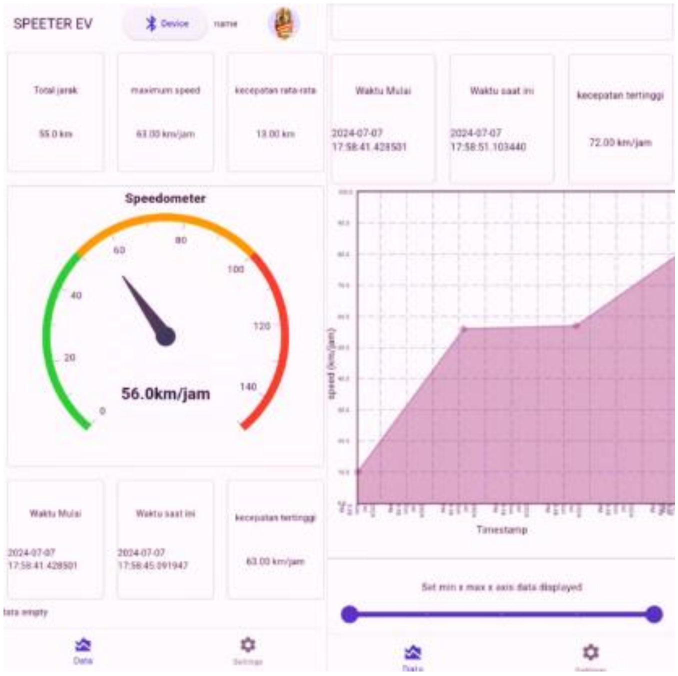

Fig. 3. Android-Based Application (SPEETER)

b) Display Instrument

The second contribution in terms of monitoring applications is designing the LCD Nextion using Nextion Editor. The Nextion Editor is software for designing user interfaces (UI) on the LCD Nextion. Nextion is a series of HMI (Human Machine Interface) touch screens widely used in various electronic projects due to their ease of use and ability to display interactive user interfaces. In the LCD Nextion design, there are two layers: the first for the opening display, as shown in Figure 4. The second is the main design for displaying speed, distance traveled, clock, motor temperature, battery voltage, battery status, turn signal indicators, and light and Bluetooth indicators, as shown in Figure 4.

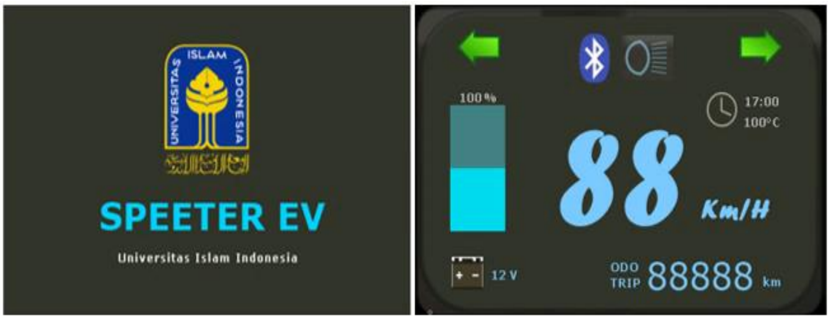

Fig. 4. LCD Display installed in electric motor

D. System Implementation

In this design, the system can monitor speed and distance on electric motorcycles through a Bluetooth integration system capable of sending speed and distance data to an Android application. This system can be implemented on electric motorcycles with a CAN Bus communication system. Figure 5 shows the final design of the electric motorcycle.

Fig. 5. Implementation of SPEETER on Electric Vehicle

E. System Performance Indicators

The parameters used to test the performance of this system consist of two main parameters as follows:

a) Success Rate of Speedometer and Odometer Data Reading

The success rate of speedometer and odometer data reading is assessed based on data transmission to users and the accuracy of the displayed information. A total of 32 trials will be conducted to evaluate the effectiveness of data transmission and display accuracy on the LCD. The success rate is calculated as a percentage of successful trials out of the total trials. The parameters tested include speed accuracy, aiming to ensure accurate distance readings on the SPEETER application. The speed-accuracy calculation formula is used to measure errors in speed readings.

$$\text{Speed Accuracy} = 100\% - \text{Speed Error} \tag{2}$$

The distance accuracy calculation is based on previously calculated errors. The goal of this calculation is to ensure that the distance readings displayed on the SPEETER application are accurate. The distance accuracy calculation formula is as follows:

$$\text{Distance Accuracy}\ \% = 100\% - \text{Distance Error} \tag{3}$$

b) Testing Using Tachometer

The testing method involves installing a tachometer to measure the vehicle's RPM and recording it at various speeds. The vehicle's speed is calculated from RPM data using the conversion formula and then compared with the speed data from the system on the instrument display or application. The purpose of the test is to ensure the measured speed matches the speed calculated from the RPM. The test method with the tachometer and speed calculation is

$$\text{Speed} = \text{RPM x Wheel circumference (km)} \times 60 \tag{4}$$

After obtaining the speed value, the next step is to calculate the distance traveled using equation 5 if the distance is in meters, then equation 6 can be followed.

$$\text{Distance (m)} = \text{speed x } \frac{\text{seconds}}{3600\ \text{second/hour}} \tag{5}$$

$$\text{Distance (km)} = \text{speed x } \frac{\text{seconds}}{3600\ \text{second/hour}} \text{ x}1000 \tag{6}$$

$$\text{Wheel circumference} = \pi \text{ x d} \tag{7}$$

Before calculating the speed, it is better to know the wheel diameter to calculate the wheel circumference as in equation 2.

c) Error Value of Speed and Distance

Speed error will be calculated based on experimental results. In each experiment, the speed value read by the system will be compared with the tachometer speed. The tachometer speed is obtained from speed and distance calculations. If the distance or speed error approaches 0%, the accuracy approaches 100%. Error calculations for both speed and distance can be calculated using equation 8.

$$Error = \left|\frac{Messured\ Value - True\ Value}{True\ Value}\right| x\ 100\ \% \quad (8)$$

III. Results and Discussion

A. LCD Readings and Application

This measurement was conducted using readings from the LCD over 32 trials. Figure 6 illustrates the testing process and data collection on the simulation tool.

Fig. 6. The results of LCD Readings

Figure 6 present the LCD readings. The distance values generated at each speed (2 km/h, 4 km/h, 6 km/h, and 8 km/h) show an increase because the travel time at each speed ranges from 15 seconds to 120 seconds. The longer the travel time, the greater the distance traveled. This is a direct relationship between time, speed, and distance traveled in the linear motion law.

The results indicate that at low speeds, such as 2 Km/h, the readings from the LCD and the application are relatively consistent, although there are small fluctuations at certain distance points. The application occasionally shows speeds slightly higher or lower than the LCD, but these differences are not significant and do not greatly affect the overall pattern displayed by both measurement methods.

As the speed increases to 4 Km/h and 6 Km/h, the differences between the readings from the LCD and the application become more noticeable. The application often provides higher readings, especially at certain points during the journey. This may suggest that the application is more responsive to small changes in speed or more sensitive to speed variability occurring during the tests. These fluctuations become more apparent at medium speeds, where the application shows higher results compared to the LCD after a certain distance.

At the highest speed tested, which is 8 Km/h, the application consistently tends to show higher readings than the LCD, especially at longer distances. This difference suggests that the application might be quicker in capturing speed changes but could also indicate higher sensitivity to speed variability, which may not be entirely accurate. Nonetheless, both methods still show similar patterns and can be relied upon for speed monitoring, despite some differences in responsiveness and accuracy at higher speeds.

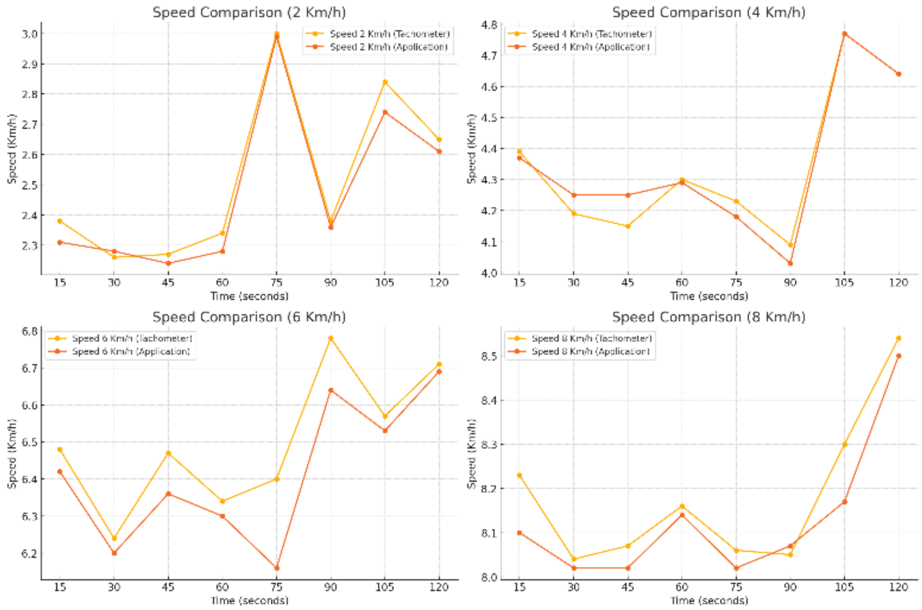

Fig. 7. Speed Comparison of Tachometer and Application

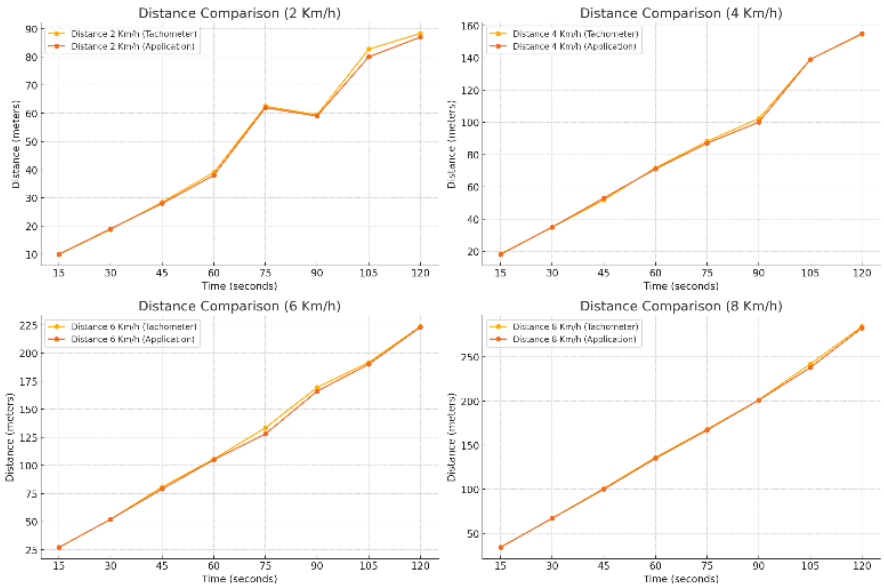

Fig. 8. Distance Comparison of Tachometer and Application

This means that the distance traveled (s) is the product of speed (v) and time (t). If the speed remains constant, the longer the time spent traveling, the greater the distance traveled.

C. Theoretical RPM Readings and Application

This measurement was conducted using readings from the Tachometer and an Application over 32 trials. Figure 8 and 9 show the speed and distance calculations from the tachometer. The RPM readings from the tachometer are used to calculate speed and distance traveled. This calculation uses the speed and distance formulas in Equations 3 and 4. It was found that the higher the RPM, the higher the resulting speed. The obtained speed values are then used to calculate the distance traveled. Additionally, the distance measurement results are directly proportional to the applied time, meaning the longer the time traveled, the farther the distance covered. In this test, the team collected data from two sources: tachometer readings and application results. These results were then compared to evaluate the error rate and accuracy of both sources.

By comparing them, the team could determine the accuracy and reliability of both systems in measuring speed and distance traveled.

In speed measurement, both at low speed (2 Km/h) and high speed (8 Km/h), the speed variation patterns captured by the tachometer and the application tend to be similar. However, the application sometimes shows a response that is slightly faster or slower compared to the tachometer, especially when there are sudden changes in speed. For instance, at 2 Km/h, there is a significant deviation between the two measurements around 60-75 seconds, where the spike appears sharper in the application compared to the tachometer. On the other hand, at speeds of 4 Km/h and 6 Km/h, the difference between the readings from both sources becomes smaller, indicating that at moderate speeds, the application is better able to follow the tachometer's readings.

In distance measurement, the difference between the readings of the tachometer and the application is minimal at all tested speeds. The graphs show that both methods provide almost identical results, indicating that the application is quite accurate in calculating the distance travelled. From 2 Km/h to 8 Km/h, the distance readings from the tachometer and the application move in tandem, with negligible deviation. This indicates that the application performs very well in terms of distance measurement and can be relied upon as an alternative to the tachometer.

D. Speed and Distance Error and Accuracy

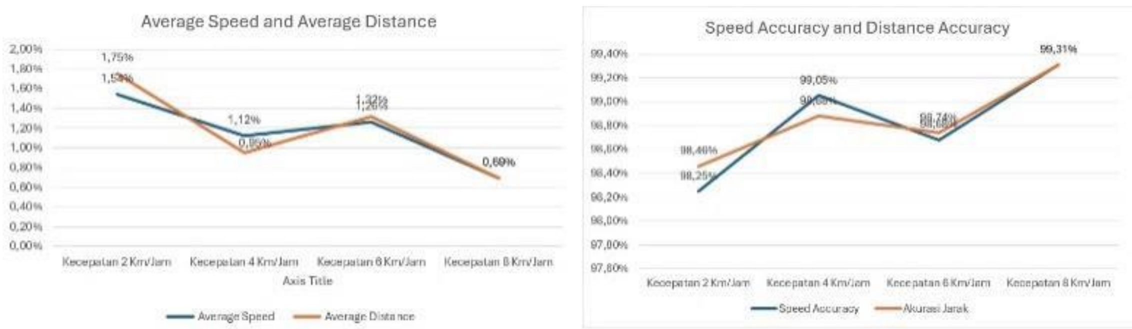

Fig. 9. Average Speed and Distance Error and Accuracy

Based on the testing and calculations, the error and accuracy values of speed and distance measurements at various speeds (2 km/h, 4 km/h, 6 km/h, and 8 km/h) show satisfactory performance. Figure 9 shows the error and accuracy results obtained by calculating the average error from eight trials at each speed. It can be known from the figure that the lowest error value is recorded at a speed of 8 km/h, with speed and distance errors of 0.69%. The highest error occurs at a speed of 2 km/h but is still within safe limits, i.e., less than 5%. Measurement accuracy was also considered to support these results. Table 4 shows that the lowest accuracy occurs at a speed of 2 km/h, at 98.25% for speed and 98.46% for distance travelled. On the other hand, at a speed of 4 km/h, there is a significant increase with speed and distance travelled accuracies of 99.06% and 99.05%, respectively, indicating better performance compared to other speeds.

At a speed of 6 km/h, although there is a slight decrease in accuracy from 4 km/h, accuracy remains high with values of 98.74% for speed and 98.64% for distance travelled. The 8 km/h speed shows the best results with speed and distance accuracies above 99%, i.e., 99.31%, indicating that the system functions with excellent consistency and precision at that speed. Overall, the measurement results show that speed and distance accuracy are within safe limits, with good performance at speeds of 4 km/h and 8 km/h. Although accuracy at 2 km/h is lower, it still shows a small error rate, indicating that the system performs reliably.

IV. CONCLUSION

The speed and distance measurement system based on the Android application on the electric motor has been implemented with accurate measurement results. The Bluetooth communication system provides easy access to data sent by the proposed hardware. The high-resolution LCD installed on the vehicle dashboard provides real-time information on speed and distance parameters taken from the CAN bus. The Android-based monitoring system, namely SPEETER, helps users to control their driving behavior. The simulation results show that the system created can provide accurate speed and distance measurement results. This is indicated by the accuracy value of both parameters reaching 99.31%. The history of speed and distance data on the application can facilitate users and stakeholders in driving management and system development. The limitation of the proposed device is the communication range between Bluetooth and Android-based applications. It can be improved using cellular communication for future research.

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