ABSTRACT

As the number of vehicles increases in dense environments like the Telkom University campus, the availability of efficient parking space becomes a major challenge. The prevalent issues are not only limited to the difficulty of finding vacant parking slots but also the high risk of vehicle damage due to overly close parking. This risk is validated through a dimensional analysis of parking spaces, which indicates that the existing slot configuration has zero margin for placement error, thus making the urgency for a distance monitoring solution highly significant. To address these problems, a prototype of a smart parking system based on the *Internet of Things* (IoT) was designed and implemented.

This solution utilizes an HC-SR04 ultrasonic sensor to detect the presence of and measure the distance between vehicles in *real-time*, controlled by an ESP32 microcontroller connected to Firebase as a *cloud database*. The system is also equipped with local warnings via a *buzzer* and LEDs, and is designed to be energy self-sufficient through a power supply subsystem based on a solar panel and Lithium-ion batteries. Comprehensive testing results show a highly satisfactory system performance, successfully exceeding the targeted specifications. Sensor testing demonstrated an average accuracy rate of 97.2%. The local actuator response time was recorded to be very fast, with an average of only 0.412 seconds. From the user's perspective, the system was very well-received, evidenced by an overall satisfaction score of 92.8% from the User Acceptance Test (UAT). Furthermore, power supply testing confirmed that the system has an operational autonomy of approximately four days from a full battery, although a daily energy deficit was identified.

Overall, this prototype has successfully proven its conceptual viability as a functional solution for enhancing parking efficiency and safety. Nevertheless, limitations are acknowledged, such as the absence of a specific vehicle identification feature and the energy deficit in the power supply, which have been addressed with a clear strategic plan for future development. This project has resulted in a solid engineering foundation for the future development of a more extensive and mature smart parking system.

Keywords: *Smart Parking, Internet of Things (IoT), Ultrasonic Sensor, ESP32, Firebase, Solar Power Supply*