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DEVELOPMENT OF A BUS TRACKING AND MONITORING DEVICE USING ARDUINO NODE MICROCONTROLLER

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Graphical abstract

Abstract

Since the opening of Universiti Teknologi MARA Shah Alam Campus (UiTM-SAC), the university has accommodated its students by providing free bus transportation around the campus. The buses are operated based on a specific time schedule. However, students often have to wait a long time for buses because the buses do not usually arrive on schedule. In addition, the bus schedule is manually controlled by an officer, which takes time, and the data can easily be lost. Hence, the goal of this research is to develop a bus tracking and monitoring system for the UiTM-SAC. Arduino node microcontroller unit and global positioning system (GPS) sensors were used to send and receive GPS location information. The data retrieved from these sensors were displayed on an organic light-emitting diode and stored in a web-based software spreadsheet. For the experimental test, only one bus was used for collecting and analysing data. Data were immediately presented on the user interface. The results indicate that the system was able to track and monitor the bus by providing the bus's latitude, longitude and speed. The results also revealed some key factors that affect the time required for a bus to complete a route based on users' demands at that time. The difference in demand was 76.2%, as most students use the UiTM bus service in the morning than in the evening. In conclusion, by using the proposed bus campus tracking and monitoring system, users can easily find the exact location of buses running at the UiTM-SAC.

Keywords: Arduino node microcontroller, automatic location update, bus tracking, global positioning system, monitoring system

1.0 INTRODUCTION

Vehicle tracking systems consist of electronic devices that are mounted on vehicles to allow their owners to locate them [1, 2, 3, 4, 5]. In consumer vehicles, vehicle tracking systems are a popular option for preventing theft and for recovering stolen vehicles [6, 7]. Most modern vehicle tracking systems use a global positioning system (GPS), which can precisely determine the vehicle's location [8, 9, 10, 11, 12]. The position of a vehicle can be determined from a combination of a mobile phone cellular network, wireless fidelity (Wi-Fi) network, and the cloud system, among other components [12, 13]. A GPS can provide a vehicle's location under any atmospheric condition through both offline and online methods [14, 15, 16]. When a GPS is turned on, the satellite broadcasts signals that the GPS receiver uses to provide its current latitude, longitude, and altitude, along with the time of day [17, 18, 19, 20]. Additionally, middleware services can retrieve device location data and upload it onto a cloud database; it then continues to update the location automatically for a specified time period.

In previous research [4, 21, 22], traffic conditions and different transport management processes were reviewed in several universities. Empirical evidence was provided regarding the effectiveness of campus bus services and green gestures in ensuring a sustainable environment. Specifically, it was found that although 51.5% of students travelled on campus buses, students' satisfaction with the services was rated as 3.24 out of

5. The mean ratings for waiting time and accuracy were especially low, at 2.77 and 2.84, respectively. Meanwhile, in [5, 23, 24], research involving a real-time web-based bus tracking system found that most public buses are delayed by heavy traffic and roadwork, among other causes. As a result, people often spend a long time waiting at the bus stop without knowing when the bus will arrive.

The Universiti Teknologi MARA (UiTM) Shah Alam Campus Bus Service provides free transportation to students throughout the campus. Every day, 18 buses are provided, and all buses are scheduled by the UiTM Unit of Vehicles. Although there is a bus schedule, students still have to wait a long time for buses because the schedule is inaccurate. Moreover, the bus schedule is done manually using Excel, which is time-consuming. It also means that the scheduling data can be lost easily. This also affects the schedule manager's ability to know which drivers are on duty. Hence to solve the problem, the current research proposes a bus tracking system that can monitor and track buses operated at the UiTM Shah Alam Campus.

The rest of this paper is organised as follows. Section 2 reviews on vehicle monitoring systems. Section 3 describes the hardware design, software design, and the experimental test. Section 4 discusses the results. Conclusions drawn from the results and recommendations for improving the bus system are the topics of Section 5.

2.0 REVIEW ON VEHICLE MONITORING SYSTEMS

A literature review has been conducted on vehicle monitoring systems. This section describes some of the existing research related to the electronic technology used in producing vehicle monitoring systems, as well as the results of previous studies.

With the growth and accessibility of new technology, wireless communications and the internet of things (IoT) have become involved in all aspects of human lives. The prevalence of decision automation systems demonstrates the rapid rise in the number of internet users over the previous decade. The development of the IoT also guarantees that surveillance system techniques will become more advanced since a user's information can be accessed anytime and anywhere, even from a distant place [7].

Communication based on the global system for mobile (GSM) communications was used to monitor the location of an automobile at a remote monitoring station and allow the car to stop when necessary. An alert signal was generated at the surveillance station using a secret switch when at risk [9]. This research offered a solution for continuous or intermittent localization updates as required by the condition and status of the car being tracked and, of course, for commercial trackers and local guidance systems.

Table 1 provides a summary of previous studies completed by researchers on vehicle monitoring systems. C. L. Hsieh *et al.* [8] proposed a vehicle monitoring system based on the long-range (LoRa) communication protocol. They developed a vehicle monitoring system to monitor GPS signals and gas information and transmit the data through the LoRa protocol to a cloud server. In order to show the storage of sensing data on the cloud server, a user interface was designed. In addition, an Android-based vehicle tracking system was proposed by S. Safdar *et al.* [12]. The SIM808 module incorporated with GPS and GSM modules was used in this system. The results were provided from GPS coordinates on a Google map as the graphical user interface (GUI).

A. Rajeevan and K. Payagala [13] proposed a vehicle monitoring and tracking system using an Android application. They made use of vehicle tracking, vehicle functions (such as door locks, parking lights) monitoring, controlling and vehicle status notifications anywhere by using mobile phone applications. The research designed a complete solution for monitoring and controlling vehicle functions using the sensor-actuator module, communication module, and an Android application.

A real-time anti-theft vehicle tracking system was proposed by K. Maurya *et al.* [14]. GPS and GSM technology were used in this project. The results showed that all the data could be sent to the server, and the project could determine whether the car was traveling locally or in a foreign land.

K. P. Kamble [15] proposed a smart vehicle tracking system. The author determined the geographic location of a vehicle and transmitted the information to a remotely located server. The location was determined using GPS and transmission mechanisms. The work determined the coordinates with latitude and longitude using the GPS device and sent a message to the user through mobile phones or websites using short message service (SMS) and email.

From the literature review, the lessons can be drawn. First, a microcontroller should be used because it serves as the main controller to allow a system to operate thoroughly. The previous studies used a relatively large size of microcontroller for operations. In addition, the use of GPS sensors is crucial to determine the location of a device. Hence, this study proposes a bus tracking and monitoring device using an Arduino node microcontroller. With this device, the user or driver of a bus can see the device's actual location via a light-emitting diode (LED) screen.

3.0 BUS TRACKING AND MONITORING DEVICE DEVELOPMENT

This section describes the methodology implemented for this research in detail. Figure 1 shows the NEO-6M GPS sensor module pin connection to NodeMCU ESP8266. The function of the GPS sensor is to detect the latitude and longitude coordinates of the bus, as well as its speed. The I2C OLED display module pin was connected to the 3.3V pin NodeMCU to activate the module. The program was uploaded to the Arduino microcontroller and successfully executed.

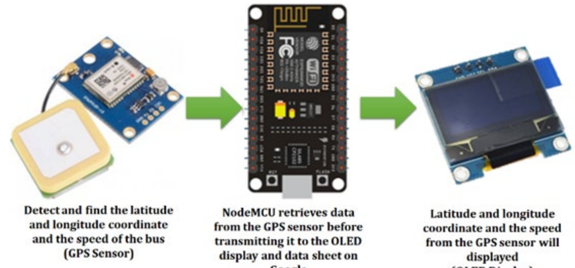


Figure 1 Connection hardware

Table 1 Research on vehicle tracking monitoring

Author	Hardware Layer and Software Interface	Application and Research Result
C. L. Hsieh et al (2017) [8]	Hardware: Arduino Mega 2560, sensor-shield board, transmission module (GIoT Module_GL6509), weather information module (SHT11), vehicle information module (OBD-II I2C adapter), air quality sensors, GPS module (NEO-7M chip), LoRa gateway. Software: IBM Bluemix platform through the MQTT protocol.	Receives traffic information instantly and monitors air conditions on the road. Obtains vehicle information via OBD-II and collects gas information through different gas sensor modules. The GPS module locates the driver's car on the street. The data was gathered and presented in a GUI.
S. Safdar et al (2018) [12]	Hardware: ATmega328p microcontroller, GPS and GSM module (SIM808 GPS). Software: Database (SQLiteOpenHelper), Android Studio.	Plots the location of a vehicle on a Google map and has the capability to keep the previous route history of the vehicle. It provides GPS coordinates to a mobile phone and users can easily track their vehicles.
A. Rajeevan and K. Payagala (2016) [13]	Hardware: Sensor actuator module (PIC 16F876 interface), GPS, and GSM. Software: Android application	Able to monitor and control the door, parking lights and side mirror of a user's car by using their mobile phone along with vehicle tracking and status notifications for the vehicle engine, temperature, and car door.
K. Maurya et al (2012) [14]	Hardware: NAVSTAR-GPS, microcontroller device (AT89C51), base station system mobile communication.	An anti-theft vehicle tracking system using GPS and GSM technology. It can be used for wildlife tracking, asset tracking and stolen vehicle recovery.
K. P. Kamble (2012) [15]	Hardware: Microcontroller, GSM modem, GPS receiver, RF transmitter sent to a computer. Software: Plotting a point of software program.	Monitors and reports vehicle status on demand. Able to access information on a vehicle's position, speed, distance travelled and duration of each stoppage through mobile phones or websites.

Figure 2 shows the flowchart of the development of a bus tracking and monitoring device. The development began by connecting the Arduino node microcontroller to all the sensors and modules that transmitted the data. The program started with the interaction component and was introduced by configuring the service set identifier (SSID) and the device's password to connect to the internet. This communication element was put in place to ensure the Google services employed would connect the hardware device to the spreadsheet. NodeMCU retrieved the data from the GPS sensor and transmitted it to the OLED display and the Google data sheet. Then, the data packet that had been retrieved from the device was sent to the Google sheet through a Wi-Fi mobile hotspot (Figure 3).

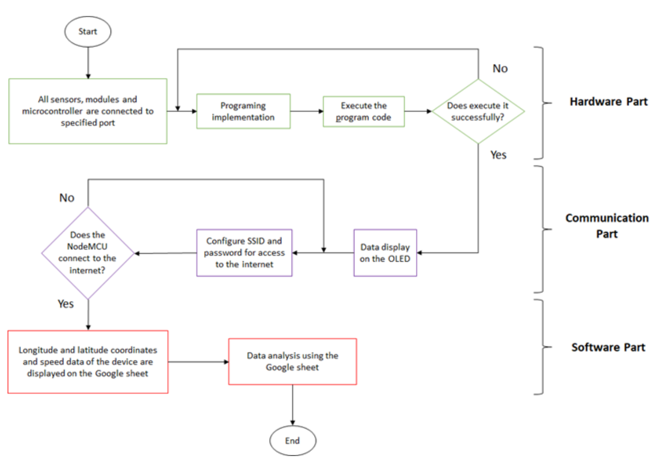


Figure 2 Flowchart of the development of a bus tracking and monitoring device

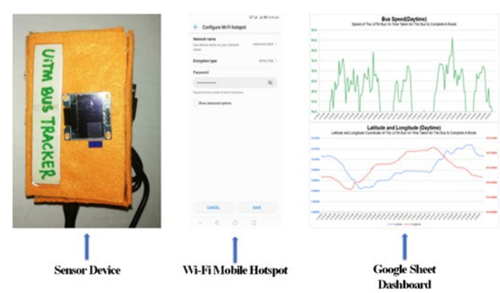


Figure 3 Devices used for the coordinate and speed monitoring system

Figure 4 and Table 2 show where the bus tracking and monitoring system was tested. The image provided below is of the UiTM map and bus stop sites within the UiTM area. Meanwhile, the bus stops are listed in Table 2. Throughout the experimental test, only one bus was used for collecting and analysing data. The test was conducted along the bus route and at the bus stations of UiTM. Data were compared considering the latitude and longitude coordinates and the speed of the bus.

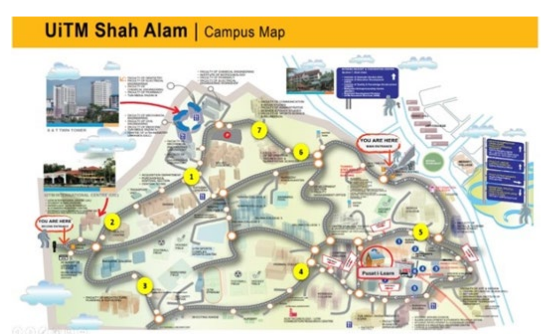


Figure 4 UiTM Shah Alam campus map and point location. Reprinted from Map UiTM, In www.scribd.com., Retrieved July 1, 2021, from https://www.scribd.com/doc/268223343/Map-Uitm. Copyright 2021 by Universiti Teknologi MARA. Reprinted with permission.

Table 2 Bus stop locations at UiTM Shah Alam

Point	Bus Stop Location
1	Hentian Mawar (DC)
2	Hentian Pusat Kesihatan
3	Hentian Anggerik
4	Hentian Anggerik
5	Hentian Seroja
6	Hentian FSKM
7	Hentian FKPM (Mascom)

4.0 RESULTS AND DISCUSSION

The results obtained after applying the methods are described presently. The results are related to the latitude and longitude coordinates of the experimental bus, as well as its speed.

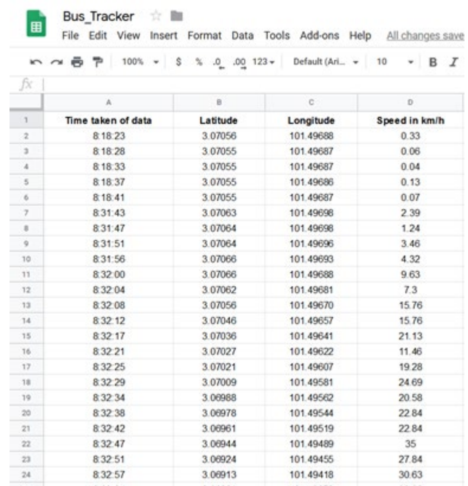
4.1 Real-Time Monitoring of the Vehicle Tracking System Using Time Arduino NodeMCU

Figure 5 shows the data that were retrieved from the GPS sensor and displayed on the I2C OLED. The I2C OLED provided the latitude, longitude and the bus speed as the bus approached a bus stop. The bus station name was also displayed on the OLED. Figure 6 provides the real-time timestamps, as well as data for latitude, longitude, and the bus speed, that were recorded on the Google Sheet. The data analysis was based on the data presented in the methodology.

Figure 5 I2C OLED data

4.2 Analysis of Latitude and Longitude Coordinates

The data for latitude and longitude coordinates were collected on for two days from 8.00 am to 8.30 am and from 8.00 pm to 8.30 pm. Figures 7 and 8 show the location coordinates of the UiTM bus and the time taken for the bus to complete its route in the morning. Meanwhile, Figures 9 and 10 depict the same data for the same route at night. The bus took significantly longer to complete its route in the morning than at night. For example, the bus spent 1 minute and 54 seconds at the 'Hentian Seroja' stop on the morning of Day 1; it spent 2 minutes and 5 seconds at the same stop on the morning of Day 2 (a difference of 11 seconds). Meanwhile, on the night of Day 1, the bus spent 30 seconds at this stop; on the night of Day 2, it spent only 15 seconds at the stop. On average, the bus spent 2 minutes at each location in the morning and only 22 seconds at night, reflecting a difference of 138%. Thus, it can be concluded that the demand for buses is much higher in the morning than at night.


Bus_Tracker
File Edit View Insert Format Data Tools Add-ons Help All changes save

	A	B	C	D
1	Time taken of data	Latitude	Longitude	Speed in km/h
2	8:18:23	3.07056	101.49688	0.33
3	8:18:28	3.07055	101.49687	0.06
4	8:18:33	3.07055	101.49687	0.04
5	8:18:37	3.07055	101.49686	0.13
6	8:18:41	3.07055	101.49687	0.07
7	8:31:43	3.07063	101.49698	2.39
8	8:31:47	3.07064	101.49698	1.24
9	8:31:51	3.07064	101.49696	3.46
10	8:31:56	3.07066	101.49693	4.32
11	8:32:00	3.07066	101.49688	9.63
12	8:32:04	3.07062	101.49681	7.3
13	8:32:08	3.07056	101.49670	15.76
14	8:32:12	3.07046	101.49657	15.76
15	8:32:17	3.07036	101.49641	21.13
16	8:32:21	3.07027	101.49622	11.46
17	8:32:25	3.07021	101.49607	19.28
18	8:32:29	3.07009	101.49581	24.69
19	8:32:34	3.06988	101.49562	20.58
20	8:32:38	3.06978	101.49544	22.84
21	8:32:42	3.06961	101.49519	22.84
22	8:32:47	3.06944	101.49489	35
23	8:32:51	3.06924	101.49455	27.84
24	8:32:57	3.06913	101.49418	30.63
25	8:33:01	3.06894	101.49379	33.69

Figure 6 Google sheet data

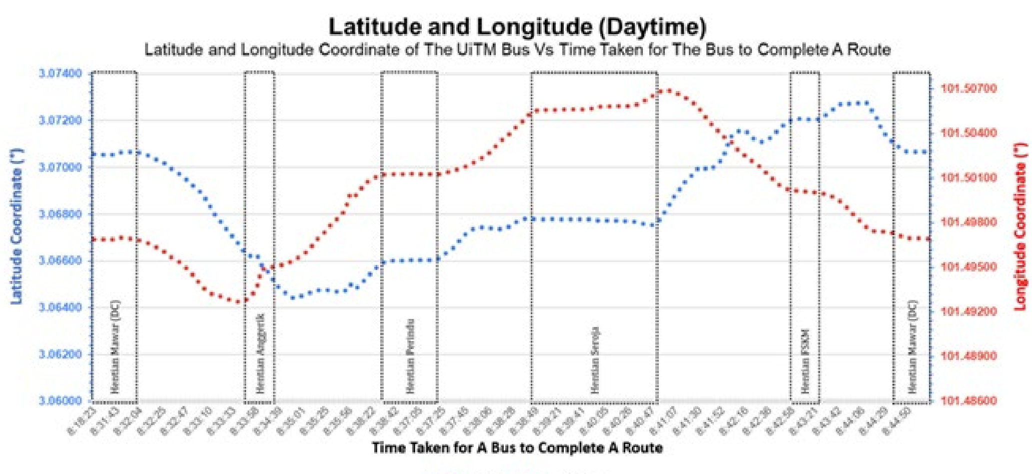


Figure 7 Location coordinates vs time taken to complete a route on the morning of Day 1

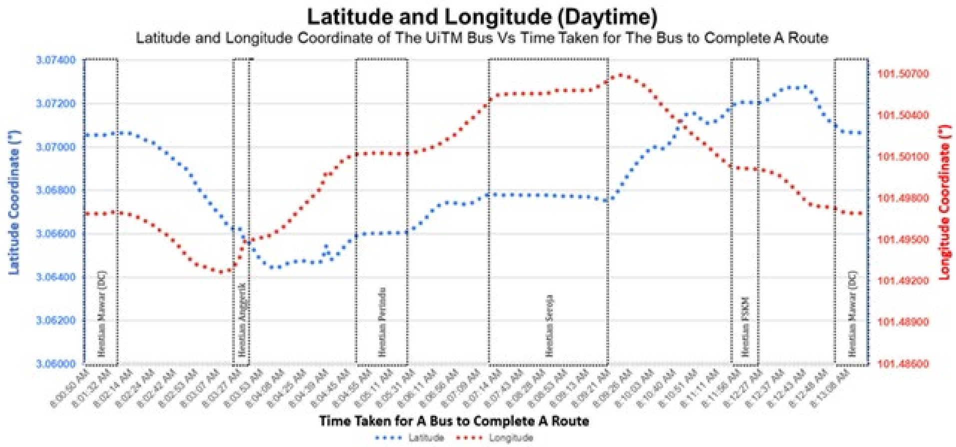


Figure 8 Location coordinates vs time taken to complete a route on the morning of Day 2

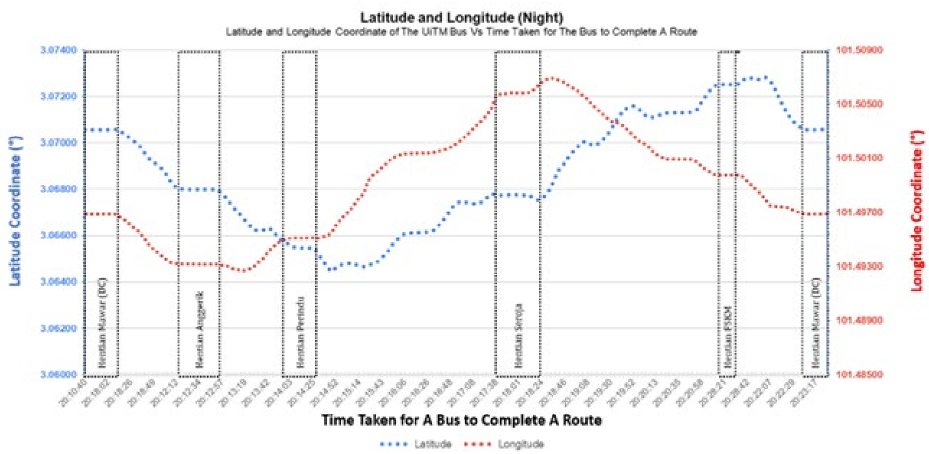


Figure 9 Location coordinates vs time taken to complete a route on the evening of Day 1

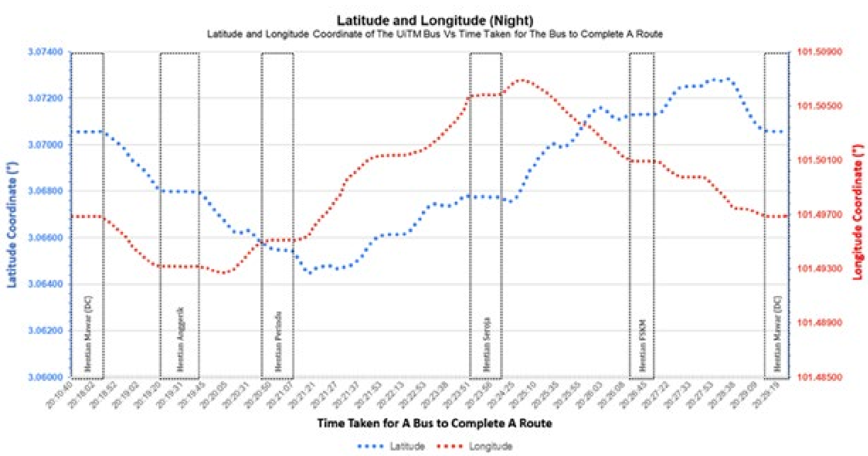


Figure 10 Location coordinates vs time taken to complete a route on the evening of Day 2

4.3 Analysis of Bus Speed

Figures 11 and 12 are graphs depicting the speed of the UiTM bus during the mornings of Days 1 and 2. Figures 13 and 14 do the same for the evenings for both days. A comparison of the data shows that the average speed for the bus in the morning is 17.42 km/h; at night, the average speed is 19.53 km/h (2.11 km/h faster). Similarly, it took the bus 29 minutes to complete the route in the morning but only 13 minutes at night, yielding a difference of 76.2%.

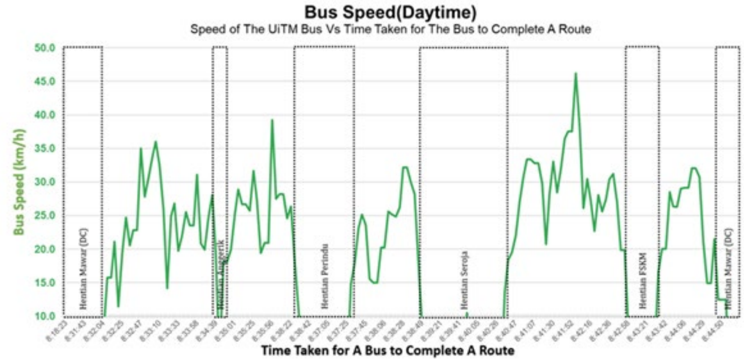


Figure 11 Speed vs time taken to complete a route on the morning of Day 1

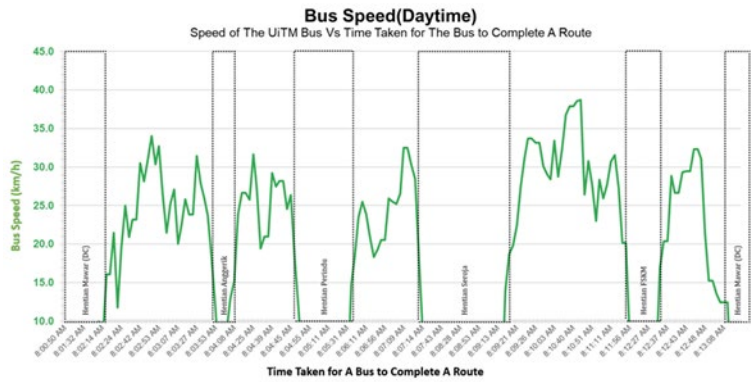


Figure 12 Speed vs time taken to complete a route on the morning of Day 2

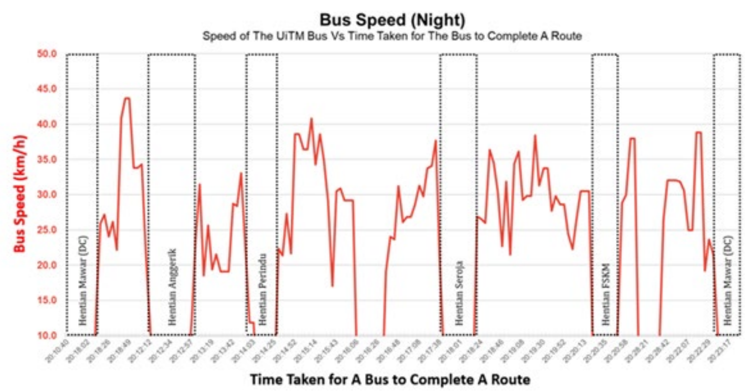


Figure 13 Speed vs time taken to complete a route on the evening of Day 1

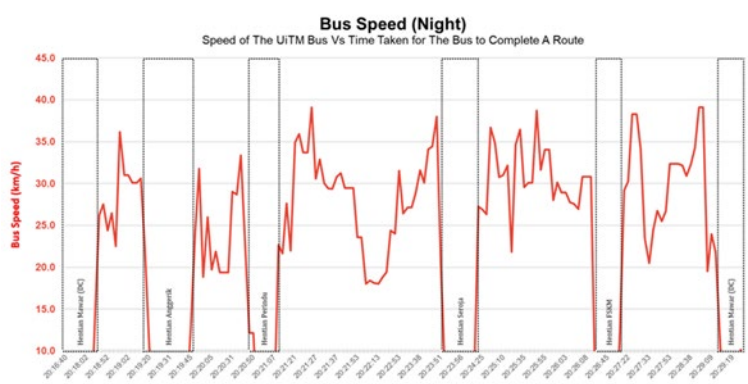


Figure 14 Speed vs time taken to complete a route on the evening of Day 2

5.0 CONCLUSION

This paper describes the development of a bus tracking and monitoring system based on a wireless system using an Arduino platform and GPS. The bus tracking and monitoring system was tested using a UiTM bus, and the functionality of the system was assessed. The system accurately tracked the bus by providing the bus's latitude, longitude, and speed. One noteworthy finding is that the time that the UiTM bus spent significantly longer at its stops in the daytime than at night due to the higher demand. Thus, the time that the UiTM bus takes to complete the full route depends on the users' demand: the higher the demand, the longer the UiTM bus will take to complete its route.

Future work is needed so existing research can be expanded to include monitoring of several buses. Researchers can also improve their analysis by adding mobile applications for users, back-end servers and connecting devices to the server. In addition, the research can look at factors such as bus demand, the frequency of bus services and time of demand from different perspectives (i.e., bus provider, bus driver, user).

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