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Developing a water driving cycle tracking device based on GPS and GSM for advancing water vehicle performance

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ABSTRACT

Driving cycles are speed-time profiles used to evaluate vehicle performance, fuel consumption, and exhaust emissions. However, real-world driving-cycle data for water vehicles are still limited, restricting accurate assessment of their energy efficiency and environmental impact. This study developed a low-cost water driving cycle (WDC) tracking device using an Arduino UNO integrated with global positioning system (GPS), global system for mobile communications (GSM), secure digital (SD) card storage, and an liquid crystal display (LCD) display. The device records speed, time, longitude, and latitude during water-vehicle operation. Prototype validation was performed by comparing the recorded speed with a standard GPS speedometer, while field testing was conducted along the Payang Water Taxi (PWT) route in Kuala Terengganu. The collected data were processed to construct a WDC and analysed using the advanced vehicle simulator (ADVISOR). Validation results showed percentage errors of 0.30% and 0.16%, indicating device accuracy within 5%. The ADVISOR analysis estimated fuel consumption of 24.1 L/100 km and emissions of 4.154 g/km HC, 2.851 g/km CO, and 0.08 g/km NOx. The proposed device provides a practical data-acquisition tool for water-vehicle performance evaluation.

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1. INTRODUCTION

Evaluating vehicle performance with respect to efficiency, fuel consumption, and exhaust emissions remains a central focus in transportation research. Driving cycles, which represent vehicle speed-time profiles, are widely used to assess fuel economy, emissions, and overall vehicle performance under real-world operating conditions [1]-[4]. Standardized, regional, and real-world driving cycles have been developed to represent actual vehicle operation, including the world-wide harmonised light-duty test cycle (WLTC), the China light-duty vehicle test cycle, and driving cycles developed from large-scale vehicle trajectory data [5]-[7]. While extensive studies and standardized driving cycles have been developed for land vehicles [8]-[10], research related to water vehicles remains limited. One of the main challenges in developing a water-driving-cycle tracking device is the difficulty of collecting accurate, real-time data in a water environment, where vessel motion, water resistance, and signal variability can compromise data reliability. In addition, the lack of standardized water-driving cycles and limited studies on the fuel efficiency and emissions of water vehicles hinder comprehensive environmental performance evaluation [11], [12]. Designing effective powertrains and energy management strategies requires reliable driving-cycle data that accurately represents real operating conditions. Although several global positioning system (GPS) and global system for mobile communications (GSM)-based tracking systems have been developed for vehicle monitoring, real-time location tracking, and data acquisition [13]-[15], these systems are generally designed for land vehicles and primarily focus on location tracking rather than on detailed construction of driving cycles. Studies on water-vehicle driving cycles are relatively few, and existing approaches often rely on predefined or simulated cycles rather than real-world operational data [16].

To address these challenges, this research focuses on developing a water driving cycle (WDC) tracking device specifically designed for water-vehicle applications. The objectives of this study are to design and develop a WDC tracking device using an Arduino UNO integrated with GPS and GSM modules to collect speed, time, longitude, and latitude data during water vehicle operation; to validate the prototype under real operating conditions by comparing its measurements with a standard GPS speedometer; and to utilise the collected data to construct a WDC for fuel consumption and emission analysis using advanced vehicle simulator (ADVISOR) software [17], [18]. Compared with existing tracking devices, the proposed system is designed to support the development of water driving-cycle models based on real-world data, providing a practical and low-cost solution for evaluating water-vehicle performance and supporting environmentally focused research [19].

2. RESEARCH METHOD

This research comprises four phases: designing the WDC tracking device using Proteus, developing the WDC tracking device using an Arduino UNO, validating the prototype with an existing device, and analyzing the data collected using WDC in ADVISOR. Figure 1 illustrates the overall flow of the research activities, beginning with the design of the WDC tracking device using simulation software, followed by prototype development, validation, and data analysis. This structured workflow ensures that the device is properly designed and verified before being deployed for real-world data collection and performance evaluation.

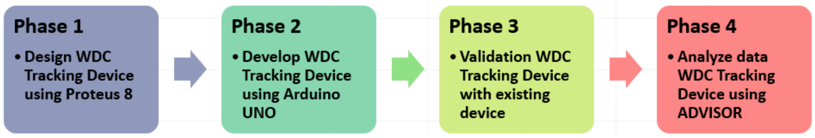

Figure 1. Flow of research activities

2.1. Phase 1: design water driving cycle tracking device using proteus software

Figure 2 presents the system architecture of the WDC tracking device, showing the interaction between the Arduino UNO, GPS module, GSM module, and liquid crystal display (LCD). The diagram highlights the direction of data flow and communication among the components, providing a clear overview of how positional and speed data are collected, processed, and displayed. The bidirectional arrows between the Arduino UNO and the GPS and GSM modules suggest that there is a two-way communication. The Arduino not only receives data from these modules but can also send commands to them. The unidirectional arrow to the LCD indicates that it receives data for display but does not send any data back to the microcontroller. The WDC tracking device uses an Arduino UNO combined with a GPS module and a GSM module. The function of the GPS module is to obtain the longitude and latitude on the selected route [20] and transfer the data to the GSM module [21] via Arduino UNO. The GSM module will display the data collected on an LCD.

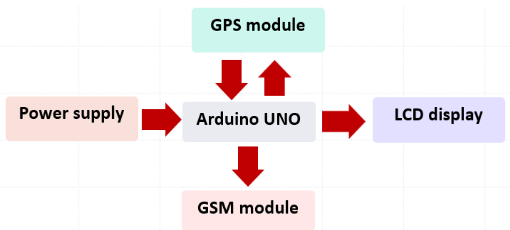

Figure 2. System architecture of WDC tracking device

Proteus 8 is a software application that allows the design, test, and simulation of electronic circuits and microcontrollers [19] is shown in Figure 3. Proteus is widely used for the creation, testing, and layout of printed circuit boards (PCBs). With this tool, it can create schematic captures, simulate microprocessors, and develop PCB layouts. Each component, like the GPS module, GSM module, Arduino UNO, and others from the tracking device's architecture, can be selected from a vast library and placed on the workspace to create a connected schematic diagram. Once the schematic is drawn, Proteus allows for the simulation of the circuit. After the schematic is finalized and simulated, Proteus can convert the diagram into a PCB layout and design the physical board that connects all the components. It provides tools for manual routing, as well as auto-routing, which automatically finds optimal paths for electrical traces. Proteus includes a range of microprocessor models to simulate the operation of embedded systems. For the Arduino UNO in your tracking device, Proteus could simulate its firmware to check how it reads GPS data, sends GSM signals, and displays information on the LCD.

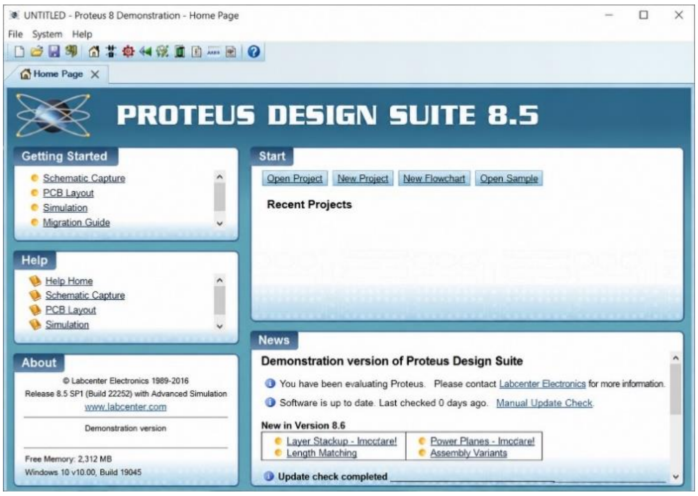

Figure 3. Proteus screen display

2.2. Phase 2: develop water driving cycle tracking device prototype

The development of the WDC tracking device prototype will be carried out in this stage. The five main components are the Arduino UNO, GPS module, GSM module, secure digital (SD) card, and LCD, as listed in Table 1. This project uses SIM808 GSM/GPRS/GPS as the main component to collect the driving cycle data. The SIM808 is a quad-band GSM/GPRS/GPS module that supports the 850/900/1800/1900 MHz frequency bands. It is a powerful and versatile module that can be used for a variety of applications, including tracking and navigation. The SIM808's GPS capability allows it to track the device's location and provide real-time positioning data.

Table 1 summarizes the main hardware components used in the development of the WDC tracking device prototype. Each component plays a specific role in ensuring accurate data acquisition, processing, storage, and display. The Arduino UNO functions as the central control unit, coordinating communication between the GPS, GSM, SD card, and LCD. The GPS module is responsible for collecting positional and speed data, which form the basis of the WDC. The GSM module facilitates data communication and integration with the storage system, while the SD card is used to store the collected data for offline analysis. The LCD provides real-time visual feedback of the recorded parameters during operation. Together, these components form a complete and reliable tracking system for water vehicle driving cycle data collection.

Table 1. List of components used in prototype development

Equipment components	Quantity	Remarks
Arduino UNO R3	1	Main control unit
LCD display	1	Output display
GSM module 808	1	To communicate with the SD card
GPS shield module	1	Collect data
SD card	1	To store data collected
Programming cable	1	To communicate with the controller
Jumper wire	As needed	Connection

2.3. Phase 3: validation of water driving cycle tracking device prototype

At this stage, validation of the WDC tracking device prototype will be compared with a standard GPS speedometer. This inspection is to ensure that the WDC tracking device prototype meets the standards and performance to record and collect speed, time, longitude, and latitude data. The relative percentage error [22] between WDC and speedometer will be calculated and analysed to ensure the accuracy of the WDC tracking device prototype to collect data.

$$Error, E_t = \frac{|true\ value - measured\ value|}{true\ value} \times 100\ true\ value \tag{1}$$

The data collection phase was conducted under controlled experimental parameters to ensure the reliability of the WDC. The GPS-GSM tracking device was configured with a data sampling frequency of 1 Hz, recording speed, and coordinate points at one-second intervals to capture high-resolution transitions in the boat's velocity. Environmental settings during the field tests were characterized by clear weather conditions and calm water surfaces to minimize the impact of external drag and wind resistance on the vehicle's performance. To ensure data consistency, the Payang Water Taxi (PWT) followed its standard commercial route at a consistent payload capacity, reflecting typical operating conditions. The recorded data were subsequently filtered to remove noise before being imported into the ADVISOR software for fuel-consumption and emission modeling.

2.4. Phase 4: analyze data water driving cycle tracking device using advanced vehicle simulator

In Phase 4, PWT route was selected for this research. This route, a water-vehicle course used for recreational activities in Kuala Terengganu, begins at Hentian Pulau Warisan, proceeds to Hentian Pulau Duyong, Hentian Seberang Takir, and Hentian Pasar Payang, and then returns to the starting point. Figure 4 shows the selected PWT route used for field testing and data collection. The route represents a typical operational water transport path in Kuala Terengganu and serves as the basis for constructing the WDC used in this study.

Figure 4. PWT route

When the boat starts moving, the WDC tracking device also needs to be started. The movement of the water vehicle and the prototype must start simultaneously. The collected data will be displayed on the LCD screen. The data is recorded from the GPS and sent to the GSM. After the water vehicle route has been completed, the data will be transferred to the SD card. Figure 5 shows the workflow of the WDC tracking device.

The data stored in the SD card of the WDC was analyzed in the ADVISOR software to study the fuel consumption and emissions produced from the PWT driving cycle. Computer models analyze how driving cycles impact fuel consumption and vehicle exhaust pollutants. Exhaust emissions include unburned hydrocarbons (HC), carbon monoxide (CO), nitrogen oxides (NOx), and particulate matter (PM). Previous studies have utilised simulation software such as ADVISOR to predict vehicle fuel consumption and exhaust emissions [17]. Operational cycles are also widely used in maritime transportation to support energy-efficiency benchmarking and emission assessment under representative operating conditions [23], [24]. In addition, real-world driving cycles have been applied to estimate region-specific fuel economy and evaluate vehicle performance under actual operating conditions [25]. Figure 6 shows the ADVISOR software used in this research.

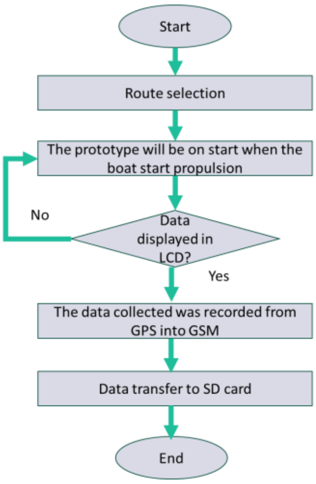

Figure 5. Workflow of WDC tracking device

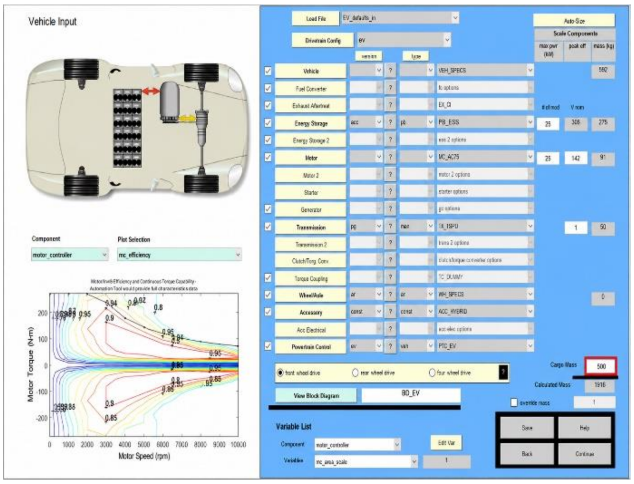

Figure 6. ADVISOR software for data analysis

3. RESULTS AND DISCUSSION

The advancement of technology has significantly contributed to the development of innovative tracking devices for monitoring and enhancing transportation systems. The WDC tracking device was designed and developed as an essential tool to capture and analyze driving cycle data. This device integrates modern technology to provide precise tracking of location, speed, and time while assessing fuel consumption and emissions. This result was discussed on design, validation and analysis on WDC Tracking Device Prototype.

3.1. Design water driving cycle tracking device using proteus software

Proteus software was a suitable platform for simulating the WDC model. As illustrated in Figure 7, the Proteus simulation environment integrates several key subcomponents to validate the system logic before hardware implementation. This simulation setup ensures that the firmware correctly parses coordinate data and manages power distribution across the modules before physical assembly.

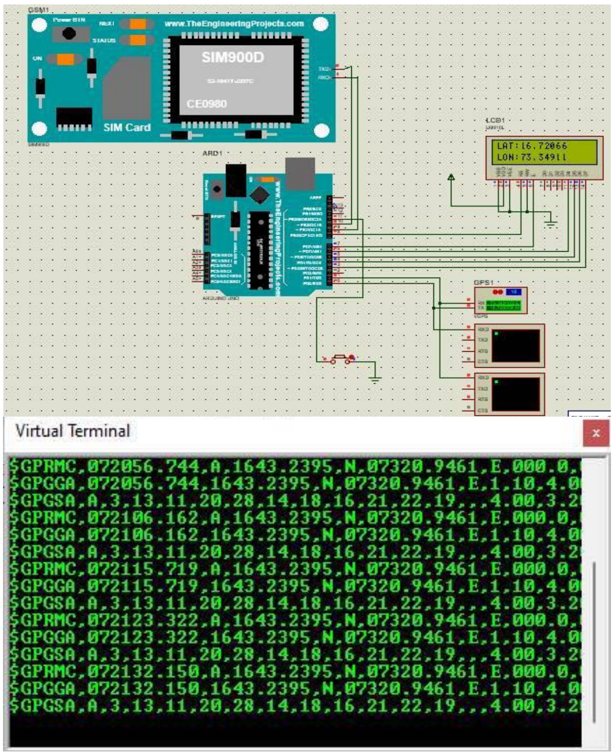

Figure 7. WDC tracking device simulation

3.2. Develop water driving cycle tracking device prototype

The WDC tracking device prototype starts with a power supply for the Arduino UNO. Arduino UNO is combined with a GPS module and a GSM module. The GPS module's function is to obtain the longitude and latitude of the selected route and transmit the data to the GSM module via the Arduino UNO. The GSM module displays the data collection on the LCD. The LCD screen, it can indicate the data of longitude, latitude, speed, and time. It also demonstrates the connection between the components, indicating that the assembly is accurate. Figure 8 shows the prototype of the WDC tracking device.

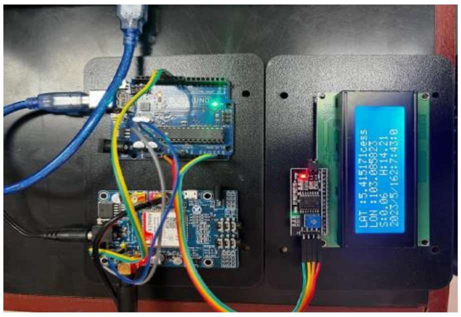

Figure 8. Prototype of WDC tracking device

3.3. Validation of water driving cycle tracking device prototype

By using in (1), Table 2 presents the validation results of the WDC tracking device prototype by comparing the measured speed values with those obtained from a standard GPS speedometer. The percentage error for each test is reported to evaluate the accuracy and reliability of the developed device. The prototype was tested twice to prove the prototype’s validation. The data that has been captured using the WDC tracking device prototype is almost the same as standard GPS. Based on the data in Table 2, the WDC tracking device prototype is considered valid because the percentage errors obtained are 0.30% and 0.16%, indicating close agreement with the standard GPS speedometer.

Table 2. Percentage error of PWT DCD prototype

No of test	Measured value	True value	Error percentage (%)
1	437.70	439.01	0.30
2	344.67	345.21	0.16

3.4. Analyze data from the water driving cycle tracking device using advanced vehicle simulator

Figure 9 illustrates the speed-time data collected by the WDC tracking device, representing the PWT driving cycle, which was subsequently analyzed using ADVISOR. Table 3 summarizes the fuel consumption results from the ADVISOR analysis, providing insight into the energy usage characteristics of the water vehicle along the selected route.

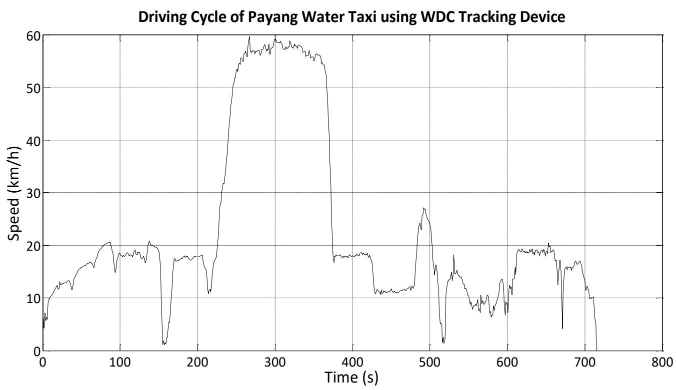

Figure 9. Driving cycle results from PWT DCTD prototype

Table 3. Results of fuel consumption

Fuel consumption	Value (L/100 km)
Fuel consumption	24.1
Gasoline equivalent	24.1
Distance	3.1

While Table 4 presents the estimated emission levels of HC, CO, and Nox derived from the simulation, which were used to evaluate the environmental impact of water vehicle operation under the developed driving cycle. The analysis stated in Tables 3 and 4 shows that the fuel consumption is 24.1 L/100 km and the emission of HC, CO, and NOx are 4.154 g/km, 2.851 g/km, and 0.08 g/km, respectively. This analysis can predict fuel consumption and emissions produced by the vehicle.

Table 4. Results of emissions

Emissions	Value (g/km)
HC	4.154
CO	2.851
NOx	0.08
PM	0

3.5. Comparison with existing tracking technologies

Compared to conventional marine data-logging systems that are often expensive and bulky, the developed WDC tracking device offers a low-cost, portable alternative that achieves a comparable error margin within 5% using open-source Arduino hardware and integrated GSM/GPS modules. Its key advantage lies in its dual-layered data recovery system, which enables both local SD card logging and real-time coordinate transmission via GSM, making it especially suitable for small-scale water taxis and fishing vessels in developing regions where affordable, high-resolution tracking is essential for effective energy management.

4. CONCLUSION

This study successfully developed and validated a WDC tracking device capable of recording speed, time, and positional data with accuracy within 5%, where analysis using ADVISOR confirmed the suitability of data collected from the PWT route in Kuala Terengganu for estimating fuel consumption and emissions. While the device offers a practical and low-cost data acquisition solution to support the development of more efficient and environmentally friendly water vehicles, the study remains limited to a single route and relies on specific GPS and GSM modules that may affect data resolution and stability. Therefore, future research is recommended to expand data collection across multiple routes and watercraft types, improve hardware components, and integrate advanced analytics or machine learning techniques to support real-time performance optimization and sustainable water vehicle development.

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AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

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Siti Norbakyah Jabar	✓	✓		✓	✓	✓	✓	✓	✓	✓		✓	✓	✓
Zulkifli Mohd Yusop	✓	✓			✓	✓	✓			✓		✓		
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Salisa Abdul Rahman	✓	✓		✓	✓	✓	✓			✓		✓		✓

C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

DATA AVAILABILITY

The data that support the findings of this study are available from the corresponding author upon reasonable request.

REFERENCES

[1] J. Brady and M. O'Mahony, "Development of a driving cycle to evaluate the energy economy of electric vehicles in urban areas," *Applied Energy*, vol. 177, pp. 165–178, Sep. 2016, doi: 10.1016/j.apenergy.2016.05.094.

[2] A. Gebisa, G. Gebresenbet, R. Gopal, and R. B. Nallamothu, "Driving cycles for estimating vehicle emission levels and energy consumption," *Future Transportation*, vol. 1, no. 3, pp. 615–638, 2021, doi: 10.3390/futuretransp1030033.

[3] Z. Jing, T. Wang, S. Zhang, and G. Wang, "Development Method for the Driving Cycle of Electric Vehicles," *Energies*, vol. 15, no. 22, p. 8715, Nov. 2022, doi: 10.3390/en15228715.

[4] G. Amirjamshidi and M. J. Roorda, "Development of simulated driving cycles for light, medium, and heavy-duty trucks: Case of the Toronto Waterfront Area," *Transportation Research Part D: Transport and Environment*, vol. 34, pp. 255–266, Jan. 2015, doi: 10.1016/j.trd.2014.11.010.

[5] M. Tutuianu *et al.*, "Development of the World-wide harmonized Light duty Test Cycle (WLTC) and a possible pathway for its introduction in the European legislation," *Transportation Research Part D: Transport and Environment*, vol. 40, pp. 61–75, 2015, doi: 10.1016/j.trd.2015.07.011.

[6] Y. Liu *et al.*, "Development of China Light-Duty Vehicle Test Cycle," *International Journal of Automotive Technology*, vol. 21, pp. 1233–1246, 2020, doi: 10.1007/s12239-020-0117-5.

[7] R. Ma, X. He, Y. Zheng, B. Zhou, S. Lu, and Y. Wu, "Real-world driving cycles and energy consumption informed by large-sized vehicle trajectory data*," Journal of Cleaner Production*, vol. 223, pp. 564–574, 2019, doi: 10.1016/j.jclepro.2019.03.002.

[8] S. Mafi, A. Kakaee, B. Mashadi, A. Moosavian, S. Abdolmaleki, and M. Rezaei, "Developing local driving cycle for accurate vehicular CO2 monitoring: A case study of Tehran," *Journal of Cleaner Production*, vol. 336, p. 130176, Feb. 2022, doi: 10.1016/j.jclepro.2021.130176.

[9] T. Settey, J. Gnap, F. Synák, T. Skrúcaný, and M. Dočkalik, "Research into the impacts of driving cycles and load weight on the operation of a light commercial electric vehicle," *Sustainability (Switzerland)*, vol. 13, no. 24, p. 13872, Dec. 2021, doi: 10.3390/su132413872.

[10] Z. Sun, Z. Wen, X. Zhao, Y. Yang, and S. Li, "Real-world driving cycles adaptability of electric vehicles," *World Electric Vehicle Journal*, vol. 11, no. 1, p. 19, Mar. 2020, doi: 10.3390/WEVJ11010019.

[11] A. J. Baird and R. N. Pedersen, "Analysis of CO2 emissions for island ferry services," *Journal of Transport Geography*, vol. 32, pp. 77–85, Oct. 2013, doi: 10.1016/j.jtrangeo.2013.08.007.

[12] B. Semab, K. M. J. Iqbal, S. Amir, and M. A. U. R. Tariq, "Development of greenhouse gas emissions baseline and identification of carbon offset cost for maritime vessels of a developing country," *Frontiers in Environmental Science*, vol. 10, Jan. 2023, doi: 10.3389/fenvs.2022.1076585.

[13] M. F. A. Osman and H. Hassan, "GPS and GSM-based vehicle tracking system," *Progress in Engineering Application and Technology*, vol. 5, no. 1, pp. 23–31, 2024.

[14] H. K. Naji, I. Marin, N. Goga, and C. Taslitschi, "Novel design and implementation of a vehicle controlling and tracking system," *International Journal of Advanced Computer Science and Applications*, vol. 11, no. 7, pp. 427–433, 2020, doi: 10.14569/IJACSA.2020.0110756.

[15] S. S. Tummanapally and S. Sunkari, "Smart Vehicle Tracking System using GPS and GSM Technologies," *SSRN Electronic Journal*, 2021, doi: 10.2139/ssrn.3884903.

[16] E. A. E. Shahiran, I. N. Anida, J. S. Norbakyah, and A. R. Salisa, "Development of Penambang Boat Driving Cycle to Evaluate Energy Consumption and Emissions," in *IOP Conference Series: Materials Science and Engineering*, vol. 1068, no. 1, p. 012008, Mar. 2021, doi: 10.1088/1757-899x/1068/1/012008.

[17] T. Markel *et al.*, "ADVISOR: A systems analysis tool for advanced vehicle modeling," *Journal of Power Sources*, vol. 110, no. 2, pp. 255–266, 2002, doi: 10.1016/S0378-7753(02)00189-1.

[18] S. N. Shivappriya, A. Dinesh, A. K. Sanjayram, A. J. Jones, J. V. Jalaja, and R. Dhivyapraba, “E-Vehicle Performance Analysis using MATLAB ADVISOR Tool,” in *2nd International Conference on Advancements in Electrical, Electronics, Communication, Computing and Automation, ICAECA 2023*, IEEE, Jun. 2023, pp. 1–6, doi: 10.1109/ICAECA56562.2023.10200251.
[19] R. S. Saputra, “Development of Learning Media Simulation of Automatic Garden Lights Using the Proteus Application,” *International Journal of Research in Community Services*, vol. 3, no. 2, pp. 71–77, 2022, doi: 10.46336/ijrcs.v3i2.270.
[20] A. A. Bin Ariffin, N. H. A. Aziz, and K. A. Othman, “Implementation of GPS for location tracking,” in *Proceedings - 2011 IEEE Control and System Graduate Research Colloquium, ICSGRC 2011*, Jun. 2011, pp. 77–81, doi: 10.1109/ICSGRC.2011.5991833.
[21] N. A. A. Rahman *et al.*, “GSM module for wireless radiation monitoring system via SMS,” *IOP Conference Series: Materials Science and Engineering*, vol. 298, no. 1, p. 012040, Jan. 2018, doi: 10.1088/1757-899X/298/1/012040.
[22] S. Kelly and A. W. Macfarlane, “Floating point arithmetic multiplication,” in *Electronic Engineering (London)*, vol. 46, no. 555, Elsevier, 1974, pp. 77–80.
[23] A. Godet, G. Panagakos, M. B. Barfod, and E. Lindstad, “Operational cycles for maritime transportation: Consolidated methodology and assessments,” *Transportation Research Part D: Transport and Environment*, vol. 132, p. 104238, Jul. 2024, doi: 10.1016/j.trd.2024.104238.
[24] A. Godet, J. N. Nurup, J. T. Saber, G. Panagakos, and M. B. Barfod, “Operational cycles for maritime transportation: A benchmarking tool for ship energy efficiency,” *Transportation Research Part D: Transport and Environment*, vol. 121, p. 103840, Aug. 2023, doi: 10.1016/j.trd.2023.103840.
[25] B. Borlaug *et al.*, “Estimating region-specific fuel economy in the United States from real-world driving cycles,” *Transportation Research Part D: Transport and Environment*, vol. 86, 2020, doi: 10.1016/j.trd.2020.102448.

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