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Official Vehicle Movement Monitoring System Using Dijkstra's Algorithm on GPS and Real-Time Notifications

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Abstract: *Official vehicle management requires an efficient, accurate, and integrated monitoring system to support transparent and responsive operations. This research aims to design and implement a Police Department Vehicle Management Information System (SIPAKAD) based on GPS, the Dijkstra algorithm, and Firebase Cloud Messaging (FCM). The research method used was an experimental quantitative approach, through software development that was repeatedly tested to obtain actual data. The independent variables in this study were the use of GPS, the Dijkstra algorithm, webhooks, and FCM, while the dependent variables included vehicle monitoring efficiency, optimal travel time, and operational response speed. The results showed that the integration of GPS with the Dijkstra algorithm was able to display vehicle positions in real time while providing recommendations for the shortest route visualized on a digital map. A comparison between the algorithm-calculated route and the actual GPS data revealed very small differences in distance and travel time. Accuracy evaluation using the Mean Absolute Percentage Error (MAPE) resulted in a low error value, demonstrating the system's accuracy and reliability. Furthermore, FCM integration allows for automatic notification of departure, arrival, and emergency status (SOS) instantly to drivers and administrators. This feature improves communication effectiveness, accelerates decision-making, and enhances operational safety. Thus, this research successfully presents a superior official vehicle monitoring system compared to previous research, integrating real-time position monitoring, route optimization, instant notifications, and safety features in a single platform. SIPAKAD is expected to become an applicable solution that supports efficiency, security, and transparency in the management of official vehicles and other sectors with similar needs.*

Kata kunci: GPS, Dijkstra's Algorithm, Firebase Cloud Messaging, Vehicle Monitoring System, SIPAKAD.

INTRODUCTION

Monitoring operational vehicles is a crucial aspect of logistics management, particularly in agencies with a large number of vehicles and complex routes, such as the Army. However, current systems are not yet integrated, making it difficult for managers to obtain accurate information, track vehicle positions in real time, and prevent misuse of official vehicles.

Previous research emphasized the importance of utilizing IoT-based GPS technology to improve tracking accuracy, although real-time data integration challenges remain. GPS is also considered insufficient on its own, requiring combination with route-finding algorithms, such as Dijkstra, which has been shown to reduce trip weight by up to 35% and increase operational efficiency.

Furthermore, modern monitoring systems require real-time notification support so that managers and drivers can immediately receive information about departures, arrivals, and emergencies. The implementation of Firebase Cloud Messaging (FCM) has proven effective in increasing speed and user satisfaction. Furthermore, the use of webhooks for GPS data collection can reduce data processing latency, supporting more efficient integration of IoT-based vehicle monitoring systems.

Based on these needs, SIPAKAD (Police Police Official Vehicle Management Information System) was developed with the research title "Official Vehicle Movement Monitoring System Using Dijkstra Algorithm on GPS and Real-Time Notification". SIPAKAD is designed as an integrated platform that not only provides the actual vehicle location, but also supports distance estimation, travel time, fuel consumption, and automatic notifications to improve efficiency, accuracy, security, and responsiveness in official vehicle management.

This research draws on several key concepts that support the development of an operational vehicle monitoring system. Geographic Information Systems (GIS) is a technology used to collect, manage, and display spatial data. In the context of this research, GIS enables real-time visualization of vehicle positions, optimal route analysis, and more accurate and structured monitoring of fleet movements. Furthermore, the Global Positioning System (GPS) module plays a role in determining the geographic position, direction, and speed of an object's movement with a high degree of accuracy. This module is a key component in supporting Internet of Things (IoT)-based systems because it provides location data that can be directly integrated into the monitoring system.

To support GPS performance, a GPS server is required, acting as a data processing center. This server not only provides real-time vehicle position information and stores trip history but can also be integrated with third-party systems through mechanisms such as webhooks. This integration is further strengthened by Machine-to-Machine (M2M) IoT technology, which enables automatic communication between devices without human intervention. This allows for the direct and rapid exchange of vehicle position and status data, supporting operational decision-making.

In terms of route optimization, this research utilizes the Dijkstra algorithm, a shortest path finding method proven effective in determining optimal routes from one point to another. Implementing this algorithm can reduce travel time and improve the efficiency of official vehicle travel. Furthermore, the system integrates Firebase Cloud Messaging (FCM) as a means of sending real-time, cross-platform notifications. FCM plays a crucial role in accelerating communication between vehicle operators and drivers, including information on departures, arrivals, and emergencies.

Previous research has shown various approaches to vehicle monitoring and route determination. Mukhlis et al. (2022) used the A* algorithm for tourist route search, but their system did not support real-time data. Salamun et al. (2023) developed an Android application to track vehicle positions based on GPS and the Google Maps API, but without calculating the fastest route or estimating fuel consumption. Setiawan et al. (2024) utilized geolocation and Firebase Cloud Messaging for tracking street vendors, but without optimal route analysis. Meanwhile, Andrean et al. (2022) modified the Ant Colony Optimization algorithm with Fuzzy C-Means, which was effective in simulations but has not yet been implemented on real vehicles. Perayoga et al. (2023) used the Dijkstra algorithm for tourist route search, but their system was not real-time and had not been integrated with notifications. Several other studies, such as Pratama et al. (2020), Maysarah et al. (2022), and Mandasari et al. (2022) discusses GPS-based vehicle monitoring and official vehicle management information systems, but focuses more on position tracking or administrative management. This study reveals a research gap: the lack of a system that comprehensively integrates GPS, Dijkstra's algorithm, and Firebase Cloud Messaging to provide real-time monitoring, route optimization, and automatic notifications in a single, integrated platform.

. With the existing background, this research focuses on how to design and integrate a GPS-based official vehicle monitoring system with the Dijkstra algorithm to display real-time positions, analyze the effectiveness of the algorithm in calculating and comparing actual routes with the shortest route to improve travel time efficiency, and develop a notification system capable of providing departure, arrival, and emergency (SOS) information through Firebase Cloud Messaging integration. The purpose of this research is to produce an accurate, efficient, and responsive monitoring system that can support the management of operational vehicles in a more transparent and measurable manner. The benefits of this research are expected not only to be felt by institutions, in the form of increased efficiency, security, and communication effectiveness in fleet management, but also for researchers who gain experience in applying GPS, IoT, and real-time notification technology as applicable solutions to real problems. Thus, this research is expected to make a significant contribution to the development of modern vehicle monitoring systems, as well as become a foundation for similar innovations in various sectors that require intelligent and integrated transportation management.

RESEARCH METHOD

This research was conducted in the Laboratory, Workshop, and Student Work Unit of the Telecommunications Department of the Army Polytechnic, Batu City, for nine months, from November 2024 to July 2025. The research method used was an experimental method with a quantitative approach, where system testing was conducted repeatedly to obtain valid results. The variables studied consisted of independent variables, namely the use of GPS technology, the Dijkstra algorithm, webhooks, and Firebase Cloud Messaging; and dependent variables, namely vehicle monitoring efficiency, optimal travel time, and operational response speed.

The research stages were systematically structured, starting from initial data collection, needs analysis, system design, system creation and implementation, evaluation, and performance testing. The system was designed as an integrated architecture involving a GPS module, GPS server, webhook listener, database, interactive map-based information interface, and Firebase Cloud Messaging for real-time notifications. The data used came from two sources: primary data in the form of direct observations and vehicle GPS data, and secondary data in the form of literature, scientific references, and historical operational data.

To ensure accuracy and reliability, the system was tested using live field testing techniques and the Mean Absolute Percentage Error (MAPE) method to assess the difference between system estimates and actual data, particularly in calculating travel distance and travel time. The system's expected specifications include real-time location monitoring, optimal route calculation using the Dijkstra algorithm, automatic notification delivery via FCM, user-friendly interface, and trip history storage.

RESULT

The research results show that the design and integration of an official vehicle movement monitoring system was successfully realized through the combination of GPS and the Dijkstra algorithm within the SIPAKAD platform. This system is capable of displaying vehicle positions in real time on an interactive digital map, where the starting and destination points of a trip can be entered by the user and automatically converted into geographic coordinates. To address the issue of designing and integrating a real-time official vehicle movement monitoring system, this sub-chapter discusses the application of the Dijkstra algorithm combined with GPS data in the SIPAKAD system. This integration aims to provide accurate and dynamic vehicle position information by displaying the shortest path from the starting point to the destination while simultaneously updating the vehicle's location directly through an interactive digital map. This approach ensures that every vehicle movement can be monitored efficiently and transparently by system users.

The Dijkstra algorithm then calculates the shortest path from the departure point to the destination, which is visualized directly on the map interface. In addition to displaying vehicle locations, the system also features a documented route data storage feature in a trip log, allowing for transparent and structured monitoring of all operational activities. With this design, SIPAKAD has proven to provide more efficient monitoring than manual methods, as vehicle movements can be monitored dynamically and accurately.

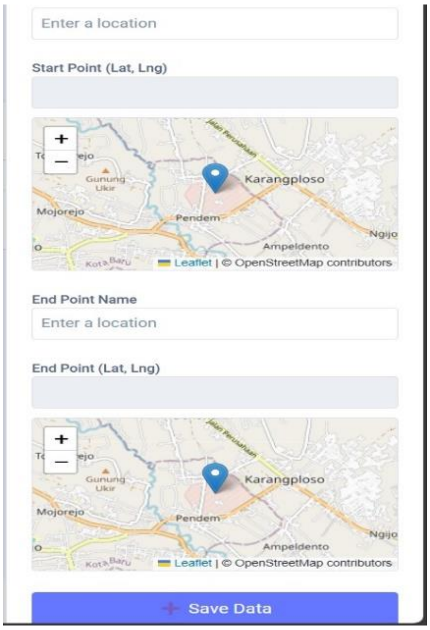

Figure 1. Home Page of Djikstra (Personal Documentation, 2025)

In terms of route calculation effectiveness, test results indicate that the Dijkstra algorithm is capable of producing distance and travel time estimates that are very close to the actual GPS data. Comparisons between the Dijkstra calculation results and the actual distances in the field show relatively small differences, averaging only a few meters to hundreds of meters on certain routes, with travel time differences of approximately 0–5 minutes.

Table 1. Real Distance Compared to Djikstra Closest Distance

No	Starting Point	Destination	Real Distance (km)	Dijkstra's closest distance (km)	Distance Difference (km)	Actual Travel Time (min)	Djikstra Estimated Time (min)	Time Difference (min)
1	POLTEKAD	UMM	10	10,24	0.24	26	21	5
2	POLTEKAD	JATIM PARK 3	8,6	8,64	0,04	19	19	0
3	POLTEKAD	ORANGE PIZZA	6,3	6,3	0	13	12	1
4	POLTEKAD	PASAR KARLOS	4,3	4,26	0,14	11	10	1
5	POLTEKAD	KOPI SEKAR PUTIH	2,8	2,78	0,12	8	7	1

The error rate calculation using the Mean Absolute Percentage Error (MAPE) also showed a low error rate, indicating that the system's route and travel time estimates are reliable. These results confirm that the Dijkstra algorithm is not only capable of determining the shortest route theoretically but also effectively applied in a real-world context to improve the efficiency of official vehicle travel

Table 2. Error Value of Djikstra Route

No	Starting Point	Destination	Error value
1	POLTEKAD	UMM	0,19%
2	POLTEKAD	JATIM PARK 3	0%
3	POLTEKAD	ORANGE PIZZA	0,7%
4	POLTEKAD	PASAR KARLOS	0,9%
5	POLTEKAD	KOPI SEKAR PUTIH	0,12%

Meanwhile, real-time notification was successfully implemented through the integration of Firebase Cloud Messaging (FCM). The system sends automatic notifications to drivers and administrators regarding various trip statuses, from assignment acceptance, departure, arrival at the destination, and return. Furthermore, the system is equipped with an SOS feature that drivers can activate in emergency situations. Once the SOS button is pressed, a priority notification is immediately sent to the administrator and marked in the operational log for quick follow-up. The notification display on the SIPAKAD Mobile application and the admin dashboard displays an informative and responsive interface, enabling efficient communication between drivers, administrators, and the guard post. With this integration, SIPAKAD functions not only as a monitoring system but also as a real-time communication tool that strengthens the security and safety of official

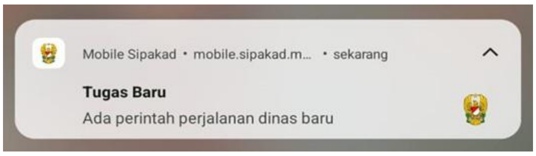

Figure 2. Notification Display (Personal Documentation, 2025)

DISCUSSION

GPS and Dijkstra Algorithm Integration Analysis

The integration of GPS and the Dijkstra algorithm in the SIPAKAD system has proven to provide a comprehensive solution for monitoring official vehicles. GPS provides real-time location data, while the Dijkstra algorithm calculates the shortest route based on the received coordinates. This advantage allows the system to not only display vehicle positions but also provide optimal route recommendations that can improve travel efficiency. Compared with previous research that focused solely on GPS tracking or route finding without real-time integration, SIPAKAD presents a more comprehensive approach by combining both functions. Actual test results show that the system's calculated routes closely approximate actual routes, allowing the effectiveness of the shortest path to be empirically tested.

Accuracy of Distance and Travel Time Estimates

Comparison of system estimates with actual data demonstrates a high level of accuracy. The Mean Absolute Percentage Error (MAPE) calculation yields a relatively small error, concluding that SIPAKAD's distance and travel time estimates are quite accurate. This demonstrates the effectiveness of the Dijkstra algorithm in a real-world operational context, not merely theoretical calculations. However, several factors can influence the difference between estimates and actual travel, such as unforeseen road conditions, traffic congestion, and driver behavior in the field. However, these differences are generally insignificant and do not reduce the system's reliability in supporting official vehicle travel planning.

Real-Time System Flexibility

One of the key advantages of SIPAKAD is its ability to automatically adjust travel routes when a vehicle deviates from the recommended route. The real-time route recalculation feature allows the system to consistently provide the fastest route to the destination based on the vehicle's current position. This flexibility is crucial in official vehicle operations, as field conditions frequently change and require rapid adaptation. With automatic route updates, the system maintains travel efficiency while ensuring that vehicles can always be redirected to optimal routes. Consequently, operational coordination is improved, and the risk of delays due to route deviations is minimized.

Real-Time Notifications (FCM)

Firebase Cloud Messaging (FCM) integration provides significant added value to the monitoring system. Real-time notifications enable instant communication between drivers and administrators, from departure and arrival status to return. Furthermore, the system ensures that every change in trip status is immediately recorded in the operational log, thus enhancing vehicle administration transparency. This effective communication directly impacts work efficiency, as decision-making can be made more quickly. Furthermore, the availability of notifications also enhances safety by allowing relevant parties to immediately be aware of evolving travel conditions.

SOS Feature

The SOS feature integrated into SIPAKAD is a crucial innovation in improving the operational safety of official vehicles. With this feature, drivers can quickly report emergencies through the app, which immediately triggers a priority notification to the administrator. Complete emergency information is also displayed in the operational log, including a description of the incident and geographic location. This feature allows for a faster and more targeted response to critical situations, thus enhancing the safety of both drivers and vehicles. The significance of this feature lies in its ability to provide additional protection not found in previous monitoring systems.

Comparison with Previous Systems

Compared to previous research, SIPAKAD exhibits more comprehensive advantages by integrating GPS, the Dijkstra algorithm, and Firebase Cloud Messaging into a single platform. Previous research generally focused on only one aspect, such as GPS-based vehicle tracking without route optimization, or shortest route finding without real-time support. SIPAKAD successfully addressed this gap by presenting an integrated system that not only monitors vehicle position but also provides optimal route calculations, dynamic route updates, and instant communication via notifications. With broader coverage and applicability, SIPAKAD is a superior and more relevant solution to support modern and efficient official vehicle management.

CONCLUSION

This research successfully designed and implemented the SIPAKAD system integrated with the Dijkstra algorithm and GPS to monitor the movement of official vehicles in real-time through interactive maps with high accuracy. The test results showed an average MAPE of 1.03% for distance and

10.25% for travel time, with the largest distance difference of 0.24 km and a travel time difference of around 4 minutes influenced by route deviation, traffic conditions, and variations in driver speed. In addition, the integration of Firebase Cloud Messaging (FCM) was effective by providing seven types of travel notifications as well as an SOS feature for emergency reporting. However, the system still has limitations such as the lack of active warnings when vehicles depart from the route, not considering actual traffic conditions in time estimation, and only relying on FCM as a notification channel. Therefore, further development is recommended by adding real-time warnings of route deviations, traffic data integration, and alternative communication channels such as SMS or WhatsApp to make the system more adaptive, reliable, and suitable for operational needs in the field.

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