Moving Asset Tracking Using GPS Sensor and Internet of Things

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Abstract— ***Moving assets, such as buses, trucks, and trains, are important productive assets, especially in the transport industry. Effective tracking of these assets is essential to optimize operations, ensure safety, and minimize costs. However, traditional tracking methods often lack real-time monitoring, which leads to inefficiencies and potential risks. This research proposes a mobile asset tracking system with a special focus on railway assets and leverages GPS technology for real-time positioning and IoT for data transmission to a cloud-based data center. A prototype of the system was successfully developed using hardware connected to a GPS device that continuously transmits location data. In this paper, an application for visualization management has also been developed to display asset data and track asset positions in real time. Performance evaluation was conducted using the RAMS (reliability, availability, maintainability, and safety) framework, which showed an average update interval of 49 seconds, a system availability rate of 94% for one month, and better maintainability due to the plug-and-play nature of the GPS-based system. Although long-term safety improvements require further study, the proposed system improves on existing navigation methods by providing real-time tracking and increasing operator awareness. These findings highlight the potential of GPS and IoT integration in improving asset tracking and operational efficiency in the transport sector.***

***Keywords**— GPS, Internet of Things, moving asset, moving asset tracking, transportation*

***Abstrak*— Aset bergerak, seperti bus, truk, dan kereta api, merupakan aset produktif yang penting, terutama dalam industri transportasi. Pelacakan yang efektif terhadap aset-aset ini sangat penting untuk mengoptimalkan operasi, memastikan keselamatan, dan meminimalkan biaya. Namun, metode pelacakan tradisional sering kali tidak memiliki pemantauan waktu nyata yang menyebabkan inefisiensi dan potensi risiko. Penelitian ini mengusulkan sistem pelacakan aset bergerak dengan fokus khusus pada aset kereta api dan memanfaatkan teknologi GPS untuk penentuan posisi secara *real-time* dan IoT untuk transmisi data ke pusat data berbasis *cloud*. Sebuah prototipe sistem berhasil dikembangkan dengan menggunakan perangkat keras yang terhubung ke perangkat GPS yang secara terus menerus mengirimkan data lokasi. Dalam makalah ini, sebuah aplikasi untuk manajemen visualisasi juga telah dikembangkan untuk menampilkan data aset dan melacak posisi aset secara *real-time*. Evaluasi kinerja dilakukan dengan menggunakan kerangka kerja RAMS (*reliability*, *availability*, *maintainability*, *and safety*) yang menunjukkan interval pembaruan rata-rata 49 detik, tingkat ketersediaan sistem sebesar 94% selama satu bulan, dan pemeliharaan yang lebih baik karena sifat *plug-and-play* dari sistem berbasis GPS. Meskipun peningkatan keselamatan jangka panjang memerlukan studi lebih lanjut, sistem yang diusulkan meningkatkan metode navigasi yang ada dengan menyediakan pelacakan waktu nyata dan meningkatkan kesadaran operator. Temuan ini menyoroti potensi integrasi GPS dan IoT dalam meningkatkan pelacakan aset dan efisiensi operasional di sektor transportasi.**

Kata Kunci—**aset bergerak, GPS, Internet of Things, pelacakan aset bergerak, transportasi**

I. INTRODUCTION

The movement of assets such as trucks, buses, and trains plays a critical role in logistics, public transportation, and railway operations. Without proper tracking, managing these moving assets becomes highly challenging, leading to inefficiencies, security risks, and operational uncertainties.

One of the primary issues was the difficulty in determining the exact location of a moving asset at any given time. Fleet operators, logistics managers, and railway authorities had to rely on manual communication methods, such as phone calls or radio updates from drivers, which were often unreliable and prone to errors. Without real-time tracking, it was difficult to estimate arrival times accurately, leading to inefficiencies in scheduling, delayed deliveries, and customer dissatisfaction [1]. In the case of trains, station operators had no precise way to know if a train was on schedule or delayed, impacting the entire rail network. Real-time tracking of public bus movement may help passengers plan their travel and reduce stress due to uncertainty [2].

Another significant problem was the inability to detect route deviations and unauthorized stops [3]. In truck logistics, for example, drivers could take longer or alternate routes for personal reasons, resulting in increased fuel consumption and extended delivery times. Some drivers might even make unauthorized stops or detours, causing delays and increasing the risk of cargo theft. In public transportation, bus drivers might deviate from assigned routes, leading to unreliable service and passenger inconvenience [4]. Similarly, in railway operations, train stoppages at unauthorized locations could pose security risks and disrupt traffic flow. Without tracking information, it is sometimes difficult for colleagues or relatives to know the last position [5]. It is related to the pick-up plan or plans that have been scheduled in a certain schedule.

Security concerns were also a major issue before the adoption of GPS and IoT-based tracking systems. The lack of a proper tracking mechanism made asset theft or misuse easier to execute without immediate detection. Stolen trucks or hijacked cargo were often difficult to recover since there was no automated system to trace their movements. In the case of bus and train operations, the absence of tracking increased the risk of unauthorized access, vehicle misuse, and potential hijackings. Additionally, logistics companies faced challenges in ensuring that goods were delivered to the correct locations, as manual tracking systems were prone to human errors. Some of them report about legally moving fuel from trucks [6].

Operational inefficiencies were another major consequence of not having a GPS tracking system. Without a real-time tracking mechanism, route optimization was nearly impossible, forcing logistics companies to rely on static route planning that did not consider real-time traffic conditions. Also, not having real-time tracking can cause financial fuel loss [7]. It often resulted in longer travel times, unnecessary fuel consumption, and higher operational costs [8]. In railway networks, dispatchers had to rely on estimated schedules without knowing the exact position of trains, leading to inefficient train spacing and increased congestion.

Furthermore, the lack of automated tracking also meant that fleet maintenance was reactive rather than proactive. The vehicles would only receive maintenance after visible issues arose, increasing the likelihood of breakdowns and unplanned downtime. Without IoT-enabled tracking systems, it is not easy to monitor the condition of vehicles in real time, leading to higher repair costs and reduced fleet reliability [4].

By addressing these challenges through the implementation of GPS and IoT technology, fleet operators can improve asset visibility, enhance security, optimize routes, and streamline maintenance processes [9]. Tracking solutions provide real-time insights, reduce risks, and ensure greater efficiency across various industries that rely on moving assets.

By addressing these challenges, an effective asset-tracking system can significantly improve transportation management, enhance security, and optimize operational efficiency. Whether in logistics, public transport, or railway systems, reliable tracking solutions are essential for ensuring the smooth and efficient movement of assets across various industries [10]. Ultimately, the goal of this research is to create a reliable and efficient tracking solution. In previous research, we have succeeded in developing a navigation system to assist train movement for machinists [11]. In this paper, we propose moving the asset tracking system to a dashboard so management will be able to monitor the real-time position and movement of all assets. Additionally, the system will allow them to review and assess whether the asset movements align with the planned routes and schedules.

A. Moving Assets

Moving assets can be considered productive assets because they can produce services in the form of fleet services [12]—for example, buses, trucks, trains, and heavy vehicles. Therefore, moving assets need to be managed well, especially during operation. This is the importance of asset tracking [13]. A good operating system also needs to be implemented in order to minimize costs arising from errors in operation or maintenance management [14].

Management needs to be carried out with the support of good facilities and infrastructure to provide a good management and operating system. One of the supports for infrastructure is the provision of good tracking. With good tracking, training operational management will also be good. Apart from that, important things related to accidents will be minimized. In transportation, with good management, it can be proposed with holistic Transportation Asset Management (TAM) [15].

Moreover, tracking moving assets is not only essential for operational efficiency but also plays a crucial role in ensuring security and regulatory compliance to minimize accidents [9]. In logistics and public transportation, real-time asset tracking helps operators monitor fleet movements, prevent route deviations, and reduce unauthorized use. Moreover, this solution can be integrated with Intelligent Transportation Systems (ITS) [16]. For instance, tracking trucks and buses allows fleet managers to ensure that drivers follow designated routes, adhere to schedules, and avoid unnecessary delays [17]. Additionally, in railway operations, precise tracking of trains enables better scheduling, reduces congestion, and optimizes rail network usage[18]. By integrating GPS and IoT technology, moving asset tracking provides valuable data that can be used for predictive maintenance, reducing unexpected breakdowns and enhancing overall asset lifespan [19]. This integration, which also contributes to sustainable fleet management by optimizing fuel consumption and reducing carbon emissions. All kinds of assets can also be tracked together using multiple tracking in a smart integration system [17].

B. Tracking Moving Asset

Tracking moving assets involves the use of advanced technologies such as GPS, IoT, cloud computing, and data analytics to monitor the location, movement, and condition of assets in real-time [20]. The implementation of tracking systems plays a crucial role in optimizing fleet management, improving operational efficiency, and enhancing security by minimizing risks such as loss, theft, or unauthorized use. By integrating GPS technology, real-time location data can be continuously collected, allowing fleet managers to monitor vehicles and ensure that they operate within designated routes [18], [21]. In addition to GPS, IoT devices are often embedded in vehicles to gather additional data, such as speed, fuel consumption, engine performance, and environmental conditions, providing deeper insights into asset utilization and operational efficiency [22]. The collected data is then transmitted via various communication networks, including cellular (4G/5G/6G), Wi-Fi, LoRaWAN [23], or satellite communication, ensuring reliable tracking even in remote areas with limited network coverage. The technology can be used in the latest technology, such as 6G, which is also embedded with machine learning and blockchain [24]. Also, it will lead to a discussion about the security of IoT for vehicle tracking [25].

The architecture of a moving asset tracking system generally consists of multiple interconnected components. GPS sensors installed on vehicles continuously capture location data, which is then transmitted through communication networks to a cloud-based server. The server processes and stores the data, filtering out any errors to ensure accuracy. A monitoring dashboard provides a user-friendly interface where fleet managers can visualize asset movements, analyze historical tracking data, and generate reports. Additionally, artificial intelligence and data analytics are often integrated to enable predictive maintenance, route optimization, and anomaly detection [19], [24]. By analyzing real-time and historical movement patterns, the system can offer recommendations to enhance operational efficiency and reduce unnecessary fuel consumption.

The working mechanism of asset tracking systems follows a structured process where GPS sensors and IoT devices installed in vehicles continuously collect real-time data. This data transmitted via wireless networks to cloud-based platforms that process and store the information. Once processed, the data is analyzed and displayed through a dashboard that allows fleet operators to monitor vehicle movements, track efficiency, and detect potential issues. The system can also generate real-time alerts and notifications for critical situations such as route deviations, unauthorized stops, excessive idling, or potential breakdowns, enabling fleet managers to take immediate action when necessary.

Several tracking solutions have already been implemented across different industries to enhance asset management. In logistics, many fleet management platforms such as Geotab, Fleet Complete, and Verizon Connect offer real-time tracking for trucks and delivery vehicles, helping companies optimize delivery routes and improve fuel efficiency, for example, for supply chain [24], [26]. In the railway industry, conventional navigation systems integrate GPS tracking with automation to prevent collisions and derailments, ensuring passenger safety and reducing operational risks [11]. Public transportation networks also benefit from GPS tracking by providing real-time location updates through applications, allowing passengers to plan their trips more efficiently. Recent advancements in technology have further improved asset tracking capabilities by incorporating machine learning algorithms for predictive analytics and blockchain technology to secure and transparent tracking records. These innovations continue to drive improvements in fleet management, ensuring safer, more efficient, and more sustainable transportation systems.

II. METHODOLOGY

A system engineering approach was employed to develop this system. The methodology used for system development is illustrated in Figure 1. For the test case, we use the train as a moving asset vehicle.

A. Requirement Identification

It is essential to identify the existing conditions and requirements first to support this system. A prototype system was successfully developed using hardware connected to a GPS device, which continuously transmits location data. This device can be called a GPS Tracker system.

Each moving asset, such as a truck, bus, or train, can be equipped with a GPS tracker, as seen in Figure 2. A GPS tracker periodically transmits data, for example, every minute. This data received by a server, where it is recorded and processed, allowing the asset's movement to be monitored in real time. The transmitted data includes the asset ID, current position (longitude and latitude), and logging time.

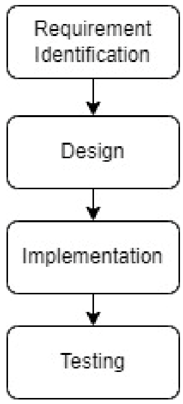

Fig. 1 Methodology

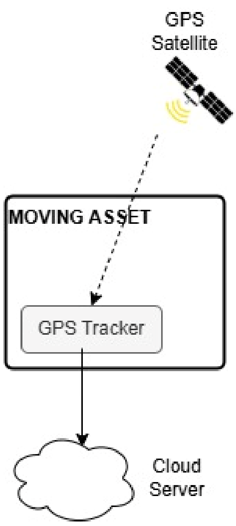

Fig. 2 Proposed system for moving asset

In this case of implementation, we use the train as a moving asset. So, we must know and plot about the railway track. So, we must make sure also that the asset is always on track. Also, we must know about some points of interest (POI), such as the station.

B. Design

In the next stage, system design is carried out. The proposed architecture of this system can be seen in Figure 3 to support the implementation of the proposed tracking system.

Every moving asset, such as trains that are equipped with a GPS Tracker, will receive signals from GPS satellites to obtain its current position. The current position of each train will be sent to the cloud server at certain periods, for example, every 10 seconds. Data collected on the server will be broadcast/pulled by the train and displayed as a navigation aid for the machinist. With this system, real-ticket position information from various trains will be known by other trains.

Position and speed information sourced from GPS will later be sent to the cloud server using Internet of Things (IoT) technology. In certain contexts, other sensors are placed and sent along with the train position data. The internet communication media used can use cellular technology or Wi-Fi at several points.

The design of the user interface for the tracking system display can be seen in Figure 4. In this image, several things can be seen, such as the track (railway), red stations, and green trains.

With the visualization of each moving asset's position, management can monitor the real-time location and movement of all assets. It allows them to track which assets are operating according to their designated routes and schedules and identify any deviations. By providing a clear overview of asset movements, the system enhances operational efficiency and ensures better decision-making when managing transportation logistics.

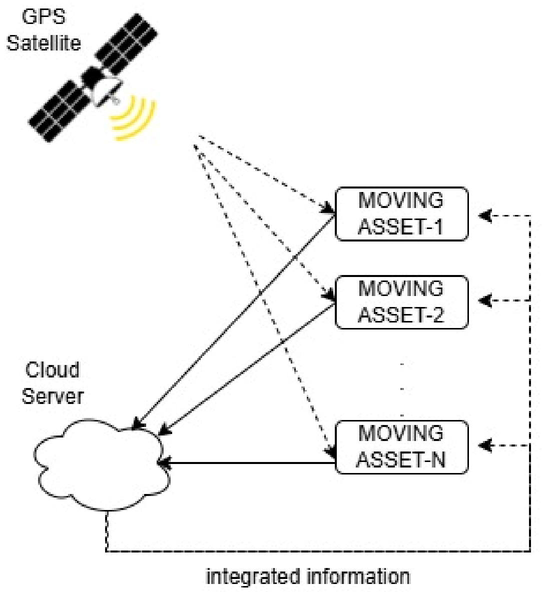

Fig. 3 System architecture

III. Result and Discussion

This section discusses the results of the implementation and testing of the proposed system. The testing was carried out in real-time in Indonesia for commuter train operations in the West Java region only. There are 12 trains equipped with GPS Tracker capabilities. On this track, there are 40 stations.

A. Implementation Results

The prototype result of the system developed is an application that can display the position of commuter trains in West Java, as shown in Figure 5. The list of all assets can be seen in Figure 6.

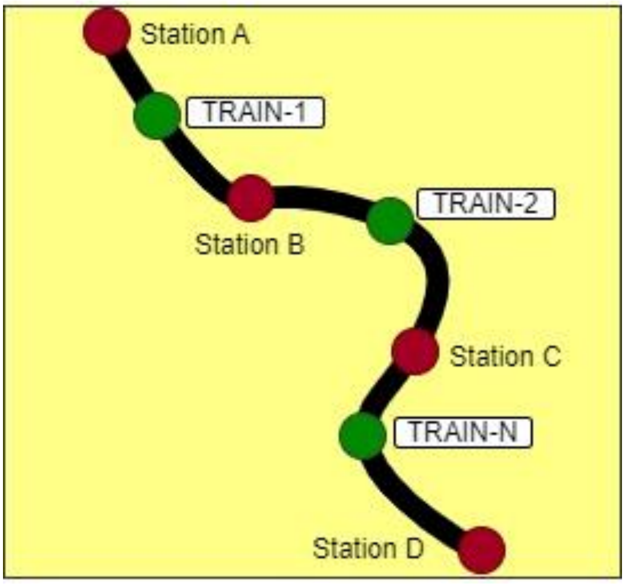

Fig. 4 Example of the system's user interface for train

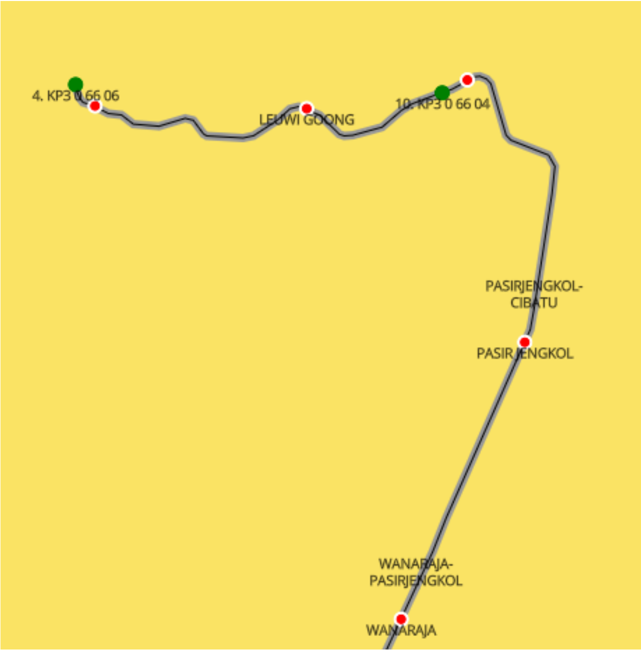

Fig. 5 Example of moving asset tracking on a map

The tracking application was implemented by integrating GPS data from each train and transmitting it to a central server via IoT communication. This data is then processed and visualized on a dashboard that allows management to monitor the movement of each train in real-time. For example, we know the position of the train with ID KP3 0 66 11 and KP3 0 66 04 (Figure 5). For example, if a train deviates from its scheduled route or experiences an unexpected stop, the system will highlight the anomaly, enabling operators to take immediate corrective actions. Additionally, the application allows users to filter train movements based on schedules, routes, or specific timeframes, ensuring better operational control. The tracking system also records historical movement data, which can be used for performance analysis and route optimization. Through this implementation, management gains greater visibility over train operations, ensuring efficiency and improved asset utilization.

B. *Testing*

This system was tested to see how capable it was to navigate or see the position of this train and also the positions of other trains around it. The data was taken for approximately one month in January 2024. One example of a shipping data log can be seen in Figure 7. The log sends data in the form of timestamps, latitude, longitude, and speed.

Based on the timestamp or log time information, the average delivery rate for one train will be obtained.

C. *Discussion*

The analysis used in relation to the implementation of GPS for train navigation can refer to factors such as RAMS (reliability, availability, maintainability, and safety). RAMS evaluation analysis was carried out both quantitatively and qualitatively based on experience in the field for the system being developed.

1) *Reliability*

The level of reliability of this system can be calculated based on how quickly the train communicates its position to the cloud server. It usually depends on the settings or configuration of the equipment installed on the train. In the example in the image above, the average period for the system to update is around 49 seconds.

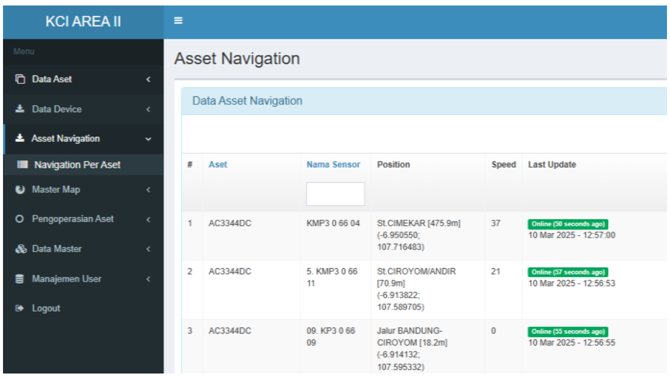

Fig. 6 List of moving assets (train)

2) *Availability*

The level of availability of a system can be calculated on how consistently reliable the system is. As long as the cloud server can still receive data continuously and there are no blank deliveries, the availability level can still be said to be good. Based on data obtained in the field during 1 month, the level of availability of the system is around 94%.

3) *Maintainability*

The level of maintainability cannot be measured from the proposed system. However, if we talk about the maintainability of a GPS-based system, because this technology is more practical, equipment such as GPS trackers and navigation systems will be plugged and played in the train cabin. So that if there is damage or repairs, it can be replaced with a new tool. Of course, the level of maintainability of the proposed system is better than that of conventional signalling systems where equipment is installed on railways.

4) *Safety*

Similar to maintainability, safety cannot be directly measured as it requires long-term observations over 5-10 years. However, based on literature studies and previous discussions, the proposed tracking system enhances transportation safety by providing real-time visibility of asset movements. By continuously monitors the position and movement of each asset, and potential risks such as unauthorized route deviations, unexpected stops, or delays can be detected early. It allows management to take proactive measures to ensure operational safety. Additionally, real-time tracking helps in emergency response situations by providing precise location data, enabling faster interventions and minimizing potential accidents or disruptions in transport operations.

IV. Conclusion

This research has proposed the use of GPS as a tracking system for moving assets, specifically trains. Performance evaluation using the RAMS framework demonstrated that the

#	Sensor Name	Log Time	Lat	Long	Speed
	10. KP3 0 6				
1	10. KP3 0 66 04	2024-03-27 05:02:51	-7.099738	107.980220	0.12964
2	10. KP3 0 66 04	2024-03-27 05:01:33	-7.099760	107.980245	0.14816
3	10. KP3 0 66 04	2024-03-27 05:00:05	-7.099783	107.980263	0.01852
4	10. KP3 0 66 04	2024-03-27 04:59:26	-7.099783	107.980263	0.05556
5	10. KP3 0 66 04	2024-03-27 04:58:46	-7.099783	107.980263	0.12964
6	10. KP3 0 66 04	2024-03-27 04:58:07	-7.099772	107.980297	0.11112
7	10. KP3 0 66 04	2024-03-27 04:55:30	-7.099723	107.980223	0.05556
8	10. KP3 0 66 04	2024-03-27 04:54:50	-7.099720	107.980250	0.03704

Fig. 7 Example of data logger

system achieves an average update interval of 49 seconds and a system availability rate of 94% over one month. Additionally, the plug-and-play nature of the GPS-based system improves maintainability compared to conventional railway monitoring systems. While long-term safety improvements require further study, the proposed system enhances train operations by providing more accurate real-time positioning, assisting decision-making, and increasing overall situational awareness for railway management.

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