Route Warning System for Monitoring and Accident Prevention in Road Transport

Deby Triana Anjelina, Faris Humami, Mokhammad Rifqi Tsani

Study Program of Automotive Engineering Technology, Politeknik Keselamatan Transportasi Jalan, Tegal, INDONESIA

E-mail: debytriana8@gmail.com, farishumami@pktj.ac.id, rifqi@pktj.ac.id

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ABSTRACT

Special vehicles transporting B3 are known to have higher risk accidents compared to accidents in ordinary vehicles. Based on the news of accidents involving fuel tankers in Candisari Semarang and Karangpucung Cilacap, the accidents that occurred were caused by drivers who were not ready to face changes in the type of geometric. Therefore, additional features are needed on tank cars that can provide delivery route mapping and provide notifications (risk journey) when passing through blackspot location. By applying the fuzzy c-means method, route safety identification can be carried out through data grouping based on traffic condition factors as well as accident data. The results of this study are in the form of a route warning application that can detect accident-prone points and provide notifications at a distance of 600 meters before the vulnerable point. This application provides notifications at 20 points on the delivery route to PT Anugerah Makmur Sejahtera. This application can be monitored by the company using web monitoring that is integrated with the route warning application in real time. After going through three tests, this application is feasible to use for adding safety features to tank cars.

Keywords: accidents; blackspot location; B3 vehicles; safety vehicle; route warning; fuzzy c-means.

INTRODUCTION

Transportation in Indonesia has an important role as a means to connect various regions and facilitate the movement of people and goods (Liun *et al.*, 2022). Commonly used modes of transportation include motorcycles, passenger cars, buses, freight cars, and special vehicles such as tank cars, which are specifically designed to transport large amounts of liquid or fuel (Saputra, 2021). The safety aspect of the use of special vehicles is very important, considering the definition of safety according to (PM 26 2015, 2015) is a circumstance in which everyone is spared the risk of accidents that may be caused by humans, vehicles, roads, or the environment. Data from the National Police Center shows that Central Java, especially the jurisdiction of the Central Java Police, has a significant accident rate, with the human factor being the main cause of accidents (Pusiknas Polri, 2023).

Examples of accidents involving special vehicles such as tank cars often occur, such as the case of an accident that occurred on Jalan Dr. Wahidin, Semarang, which caused fatalities and serious injuries (Didiet Cordiaz, 2022).A similar accident was also recorded in East Tayem Village, Karangpucung, Cilacap, involving a fuel tanker and a minibus (Setyo Anggraeni, 2022). Curved and downhill road conditions are often a major factor in this kind of accident, where notifications from route warning applications using the fuzzy C-means (FCM) method can help improve driver concentration and reduce the risk of accidents (Winarni, 2018). The FCM method is used to identify blackspot location by grouping data based on traffic conditions and accident history, thereby providing the necessary information for drivers to anticipate dangerous situations and take appropriate precautions during the trip (Indra Firmansyah *et al.*, 2023). Route Warning System aims to map and notify drivers of risk journeys for PT Pertamina Patra Niaga Integrated Terminal Cilacap tankers to improve safety during distribution using an Android-based application.

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RESEARCH METHODS

This study uses the fuzzy c-means method. The following are the stages of this research:

Flowchart

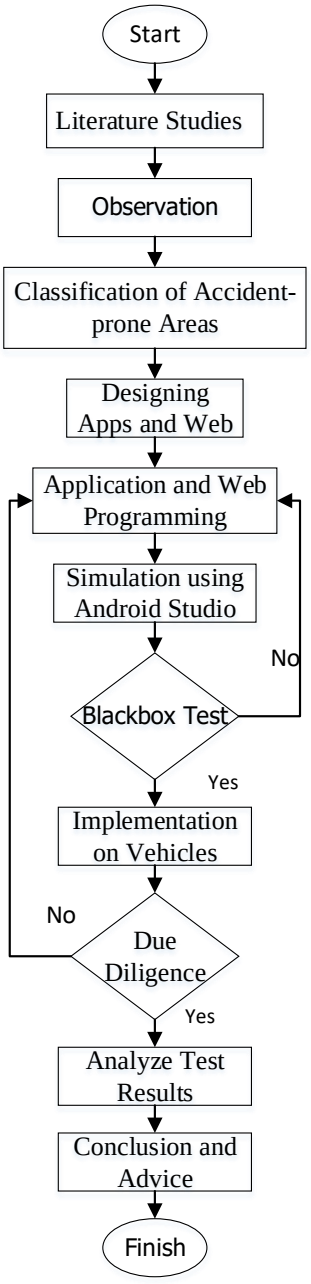

Figure 1. Flowchart

The study of literature aims to develop the theoretical aspects of research, with a focus on theoretical foundations, frameworks of thought, and hypotheses. The researcher refers to valid sources to compile research on the mapping method of blackspot location and route warning applications, including traffic accident data, blackspot location, B3 vehicles, route warning systems, and fuzzy logic concepts. By detailing the literature, researchers build a solid foundation for the research and implementation of route warning applications.

Observation

Field observation is an important element in application development, which involves direct observation of the object or situation that will be used to create the application. In this study, observations were made by monitoring the distribution routes of tank cars and collecting accident data from the local police to ensure that the application could provide accurate and relevant information.

Classification of Blackspot location

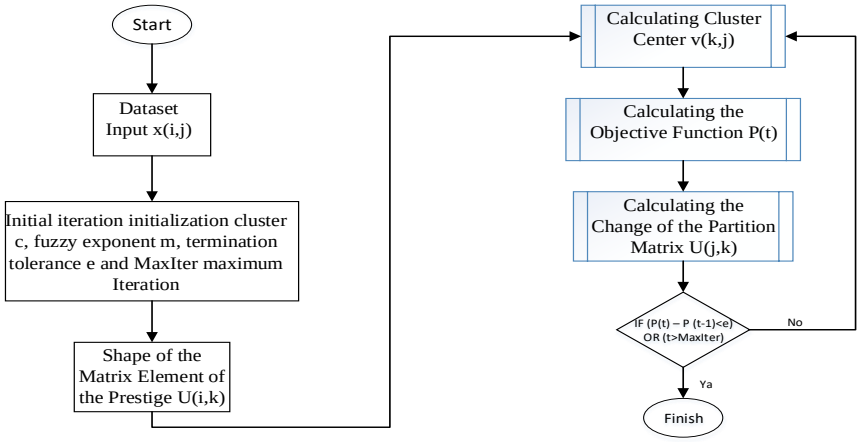

Figure 2. Fuzzy Logic Flowchart

Determining blackspot location on the route to be passed can be done using the Fuzzy C-Means method (FCM)(Ristanto, Utami and Susyanto, 2021). The FCM method determines blackspot location through data grouping based on clustering(Sugianti et al., 2023). To find blackspot location, the Fuzzy C-Means method is used as follows (Chowdhary *et al.*, 2020):

1. Dataset Input
   The data set entered is in the form of accident data and road conditions of the regency/Cilacap City that were passed by the tank car of PT Pertamina Patra Niaga Integrated terminal Cilacap to PT Anugerah Makmur Sejahtera. The LPG delivery route from PT Pertamina Patra Niaga Integrated Terminal Cilacap passes through 9 points in vulnerable areas in Cilacap Regency/City and 11 points in the Banyumas area.

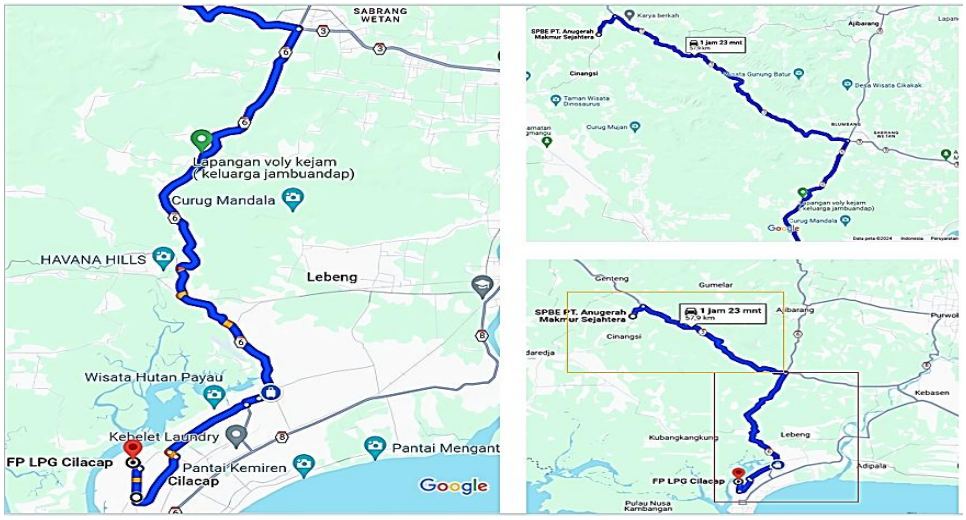

Figure 3. Tanker Truck Distribution Route

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1. Initial Iteration Initiation
   In this research, the author inputs:
   Number of Clusters : 3
   Maximum Iteration : 10x
   Fuzzy exponents : 2

2. Shape of Partition Elements
   (Suciati, 2021) (Suciati, 2021)
   a. Calculate the cluster center

$$v_{k_j} = \frac{\sum_{i=0}^{n} ((\mu_{ik})w * x_{i_j})}{\Sigma(\mu_{ik})_{i=0}^{w}} \quad (1)$$

   Where:
   V : cluster center
   x(i j) : parameter ke-i

   b. Calculating objective functions

$$P_t = \Sigma_{i=2}^{n} \Sigma_{k=2}^{c} \left\{ \left[\Sigma_{i=2} \left(x_{ij} - v_{ij} \right)^2 \right] (\mu_{ik})w \right\} \quad (2)$$

   Where Pt: the value of the objective function of the iteration

   c. Calculating partition matrix changes

$$\mu_{ik} = \frac{\left[\Sigma_{j=2}^{m} (x_{ij} - v_{ij})^2 \right]^{\frac{-2}{\omega-2}}}{\Sigma_{k=1}^{c} \left[\Sigma_{j=1}^{n} (x_{ij} - v_{tg}) 2 \right]_{\omega.2}^{\frac{-2}{}}} \quad (3)$$

   d. Determining the Rule Base
   In the context of Fuzzy C-Means (FCM), "rule base" usually refers to the rules or criteria used to interpret the results of clustering. With the condition IF (|P(t) – P (t-1)|<e) OR (t>Maxlter)(Hatrik and Vatresia, 2022).

Aplication Design and Web

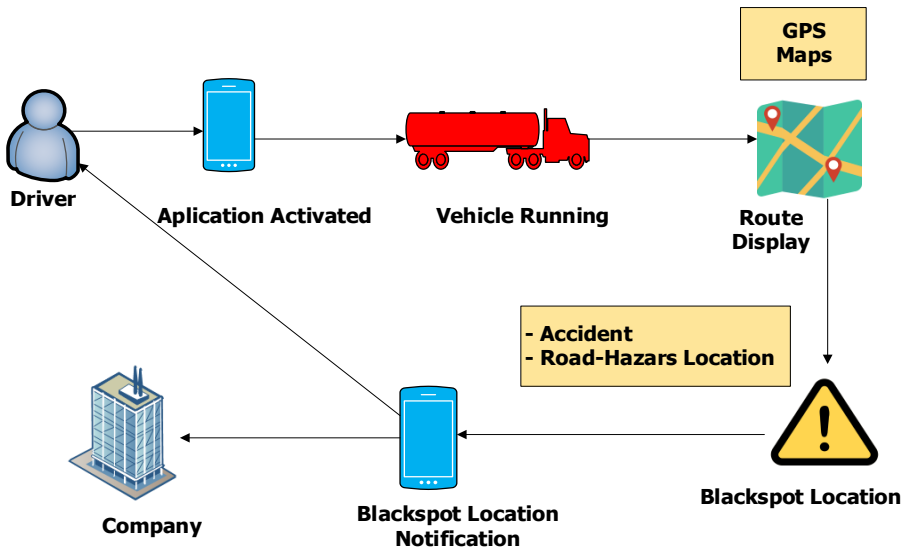

Figure 4. Application Design

The performance flow of the route warning application begins by activating the Android-based application on the tank car by AMT, so that the Android-based GPS carried is automatically connected to the fleet function at PT Pertamina Patra Niaga Integrated Terminal Cilacap. This fleet function allows monitoring the location of tank cars that are in operation. After the route warning application is activated, AMT can see the mapping of the operational area to be passed and analyze the state of the route to be taken, by inputting GPS through the route map application. During the trip, AMT will receive notifications from route warnings containing travel instructions and warnings related to conditions such as sharp bends, steep descents, based on accident data and road conditions. This warning system provides notifications to drivers when approaching dangers and travel risks, by providing warnings at a distance of 600 meters before the intended point, as well as allowing companies to monitor the distribution process of goods in real-time.

Blackbox Test

Black box testing is a test that is carried out to evaluate software inputs and outputs without paying attention to the details of the software code structure (Nurfathullah, 2024). System functions are generally designed to achieve a specific goal in an efficient and effective manner, and require coordination and collaboration between their elements to function properly (Haryanto, 2023). In addition, the blackbox test on the route warning application is carried out to ensure the consistency of the application's performance when implemented on vehicles/tank cars (Cui *et al.*, 2022). Blackbox testing begins by designing a test scenario that is tailored to several possible situations. Furthermore, test the application according to the scenario that has been created to produce test data that can prove the feasibility of the created application (S Supriyono, 2020).

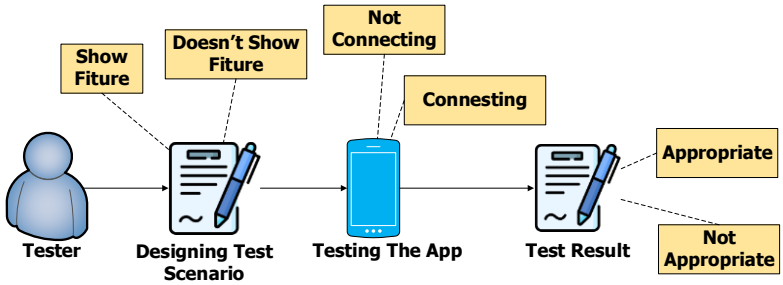

Figure 5. Blackbox Test Scheme

Implementation on Vehicles

The implementation of Android-based route warning applications on tank cars significantly improves the safety and efficiency of fuel distribution. By placing the android in the tangka car, this application, receives real-time warnings about the potential risk of accidents or unsafe road conditions during distribution trips, as well as utilizing accident data from the local police to provide alert notifications when passing routes with a high accident history.

Due Diligence

The feasibility test of the application is a critical step after the implementation of route warning on vehicles. The author conducted a feasibility test to ensure that this application is able to provide effective notifications when vehicles cross blackspot location and can run routes according to what has been inputted. The feasibility test process was carried out through three experiments adjusting to three types of tank cars at PT Pertamina Patra Niaga Integrated Terminal Cilacap. The results of this series of tests are expected to prove the consistency and accuracy of the application's performance in providing warnings and guiding vehicles appropriately.

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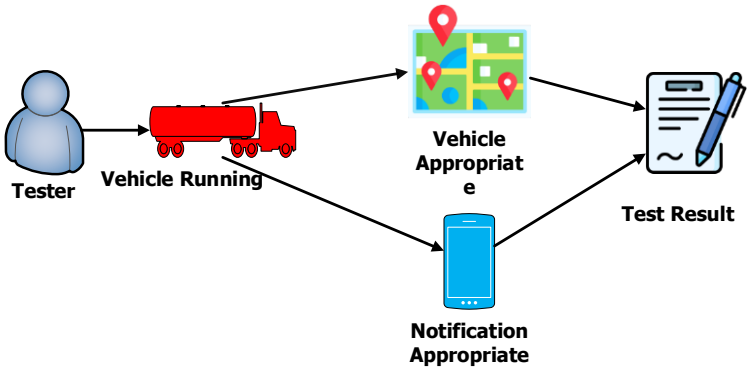

Figure 6. Feasibility Test Scheme

Figure 5 is a diagram of the feasibility test scheme of the application when it has been implemented using a tank car. The test is carried out when the vehicle is running to test the consistency of the route and notifications provided by the application. The results of the test are then analyzed.

RESULTS AND DISCUSSION

Classification of Blackspot Location

The input data set includes accident data from 106 locations in Cilacap Regency/City for 5 years, namely 2017, 2018, 2019, 2020, and 2021. This accident data was obtained from the local police. It was recorded that the highest number of accidents occurred in 2021 with 294 accident cases in Cilacap Regency/City. The lowest accident rate was recorded in 2020 with 103 accident cases. In 2017 there were 175 accident cases, which then decreased in 2018 to 107 cases, but rose again in 2019 with 176 accident cases.

From the accident data set obtained, the data is then processed using the calculation of fuzzy c-means according to equations (1), (2) dan (3) up to 7 iterations. The calculation of fuzzy c-means stops in the 7th iteration because it is in accordance with the set rule base, which is (Pt-(Pt-1)) < the smallest error value (0.1). The next step is to determine the cluster in the data using the maximum value of the degree of membership in the iteration. The following is the result of the calculation of the rule base of Iterations 1 to 7.

Table 1. Rule base Result

Iterasi	P(x)	P(y)	(Py-Px)
1	0	2048,503	2048,503
2	2048,503	2340,032	291,5292
3	2340,032	3062,589	722,5571
4	3062,589	3958,003	895,414
5	3958,003	6121,22	2163,217
6	6121,22	6966,9	845,6797
7	6966,9	6422,177	**-544,723**

Based on the calculation using the equations (1), (2), and (3), it can be concluded that there are 42 roads that are included in cluster 1 with a very dangerous category, 26 roads that are included in cluster 2 with a dangerous category, and 38 roads that are included in cluster 3 with a safe category.

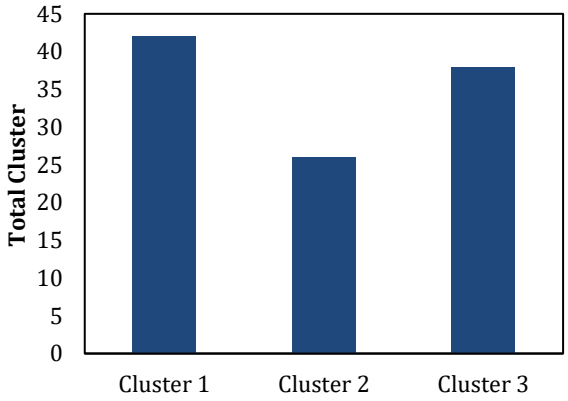

Figure 7. Clustering Blackspot location

From 3 clusters of blackspot location, the author surveyed the condition of the road passed by the tank car to PT Anugerah Makmur Sejahtera. So it can be concluded that there are 20 points of blackspot location that are inputs in the route warning application.

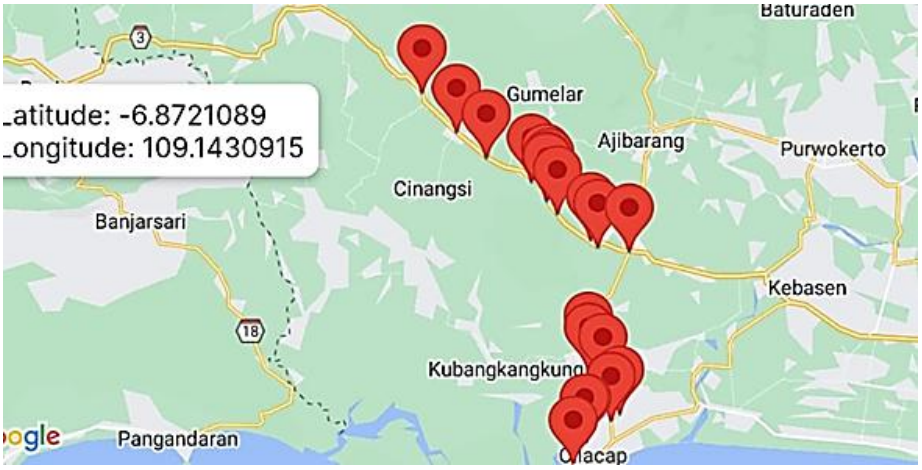

Figure 8. Blackspot points

Blackspot points are inputted based on several considerations of real conditions. These considerations include intersections with high traffic volumes and complex road geometry. In addition, additional obstacles such as markets and railway crossings are also taken into account.

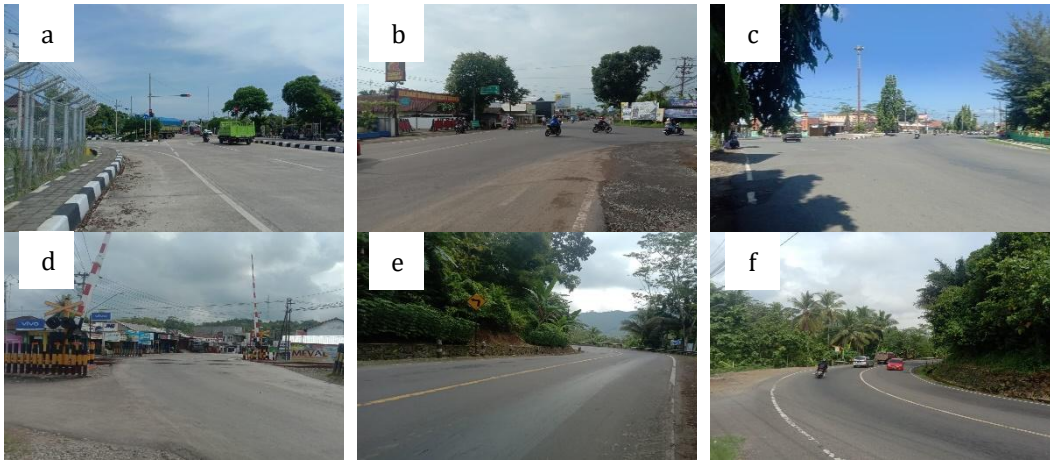

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Figure 9. Blackspot locations

Application and Web Interface

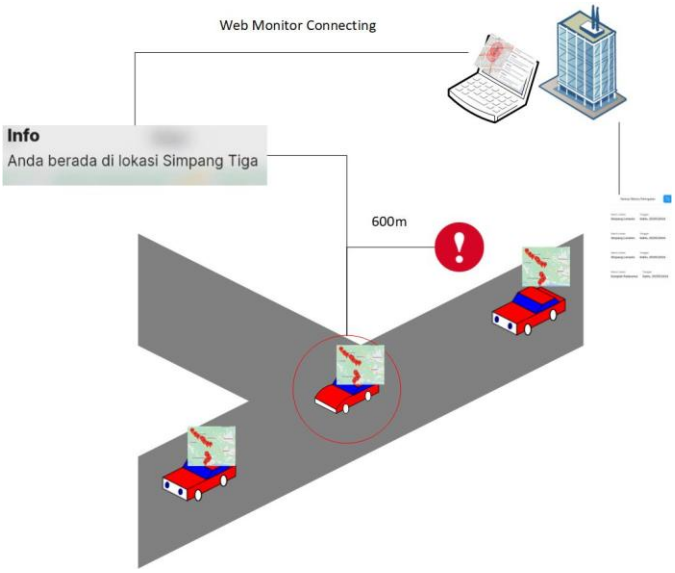

Figure 10. Application Interface Schema

Figure 9 shows what the route warning application looks like when implemented on a vehicle. Drivers can access this application before the delivery of products from PT Pertamina Patra Niaga Integrated Terminal Cilacap. When a vehicle approaches an accident-prone point within 600 meters, the app provides notifications connected to the company's web monitor for real-time monitoring. The alert history can be accessed through the history menu on the app and the web.

The map menu on the Route Warning application displays the route of the tank car of PT Pertamina Patra Niaga Integrated Terminal Cilacap to PT Anugerah Makmur Sejahtera, including accident-prone points. Users can access their profiles and data on blackspot location through the Blackspot location feature, as well as view travel history through the warning history feature. Users who have stopped or deactivated as a drivers can log out so that the app can be accessed by other users.

Application Testing

1. Blackbox Testing
   The test results of the Route Warning application interface elements can be seen in the table below. The test aims to ensure that all features and interface elements work as expected.

The test results show the effectiveness and suitability of the application's functionality with the specified specifications.

Table 2. Blackbox Test Results

Input	Expected Results	Results
Home	Displaying the login page dashboard	Appropriate
User Profile	Display user identities	Appropriate
Company Profile	Displays Company Profile Description	Appropriate
Maps	View travel route maps and notifications	Appropriate
History	Displays the history of notification points and travel dates	Appropriate
Total History	Displays the number of histories that have been passed	Appropriate
Blackspot location	Displays a list of blackspot location based on clusters	Appropriate
Logout	Displays a confirmation spash screen to log out and exit the app if you approve it	Appropriate

2. Due Diligence

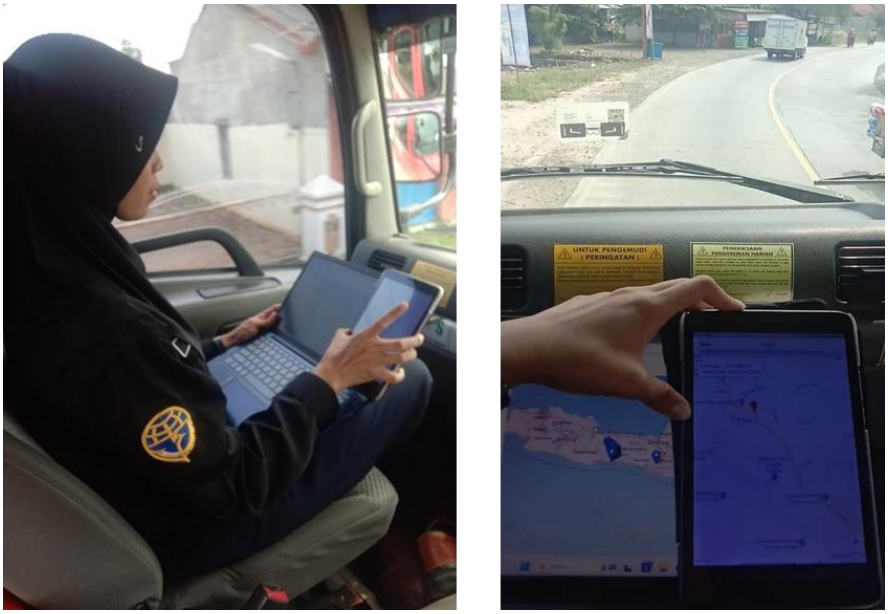

Figure 11. Implementation on vehicles

A feasibility test is carried out to ensure that the notifications on the route warning application work properly. In addition, this feasibility test was carried out to test the integration between the application and web monitoring that the company uses to monitor trips on operating tank cars.

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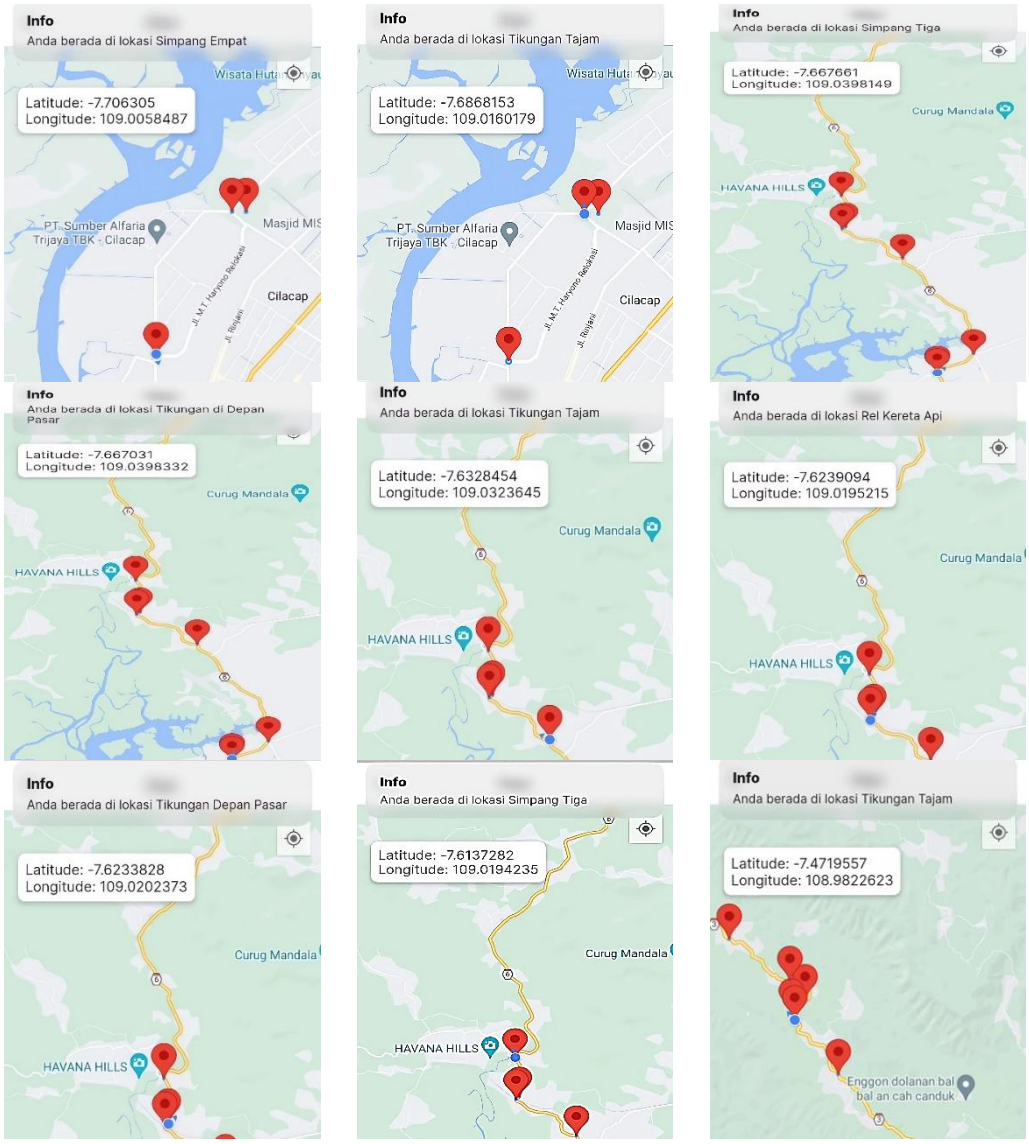

Figure 12. Feasibility Test Results

Figure 12 shows that the points that are included in blackspot location are functioning properly or as expected. This test is feasible or as expected because the application can provide notifications at the input point at a distance of 600 meters and will continue to sound as long as the application user is still in the area. In addition, this application is also integrated with web monitoring which can display the location, notifications and history of user alerts in real-time(Sanusi, Zaky and Afni, 2020).

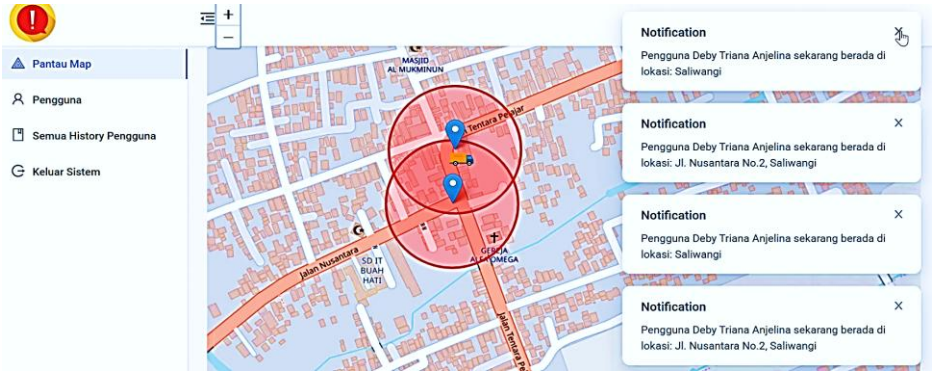

Figure 13. Web Notifications

The results of the feasibility test at all points show that this application is suitable and feasible to be implemented on tank cars as an additional feature of operating vehicles. The results of the feasibility test are presented in Table 3 below.

Table. 3 Results of the Feasibility Test

No	Location	Testing			Information
		1	2	3	
1.	Four-way Intersection Jalan MT. Haryono Lomanis	Yes	Yes	Yes	Proper
2.	Sharp Bend of Padaramai Complex	Yes	Yes	Yes	Proper
3.	Three-way Intersection Jalan Nusantara	Yes	Yes	Yes	Proper
4.	Front Corner of Saliwangi Market, Jalan Tentera Siswa	Yes	Yes	Yes	Proper
5.	Proliman Monument Jalan Madukara	Yes	Yes	Yes	Proper
6.	Sharp Bend of Tritih Lor Highway	Yes	Yes	Yes	Proper
7.	Jeruklegi Wetan Railway	Yes	Yes	Yes	Proper
8.	Front Corner of Cidungun Jeruklegi Wetan Market	Yes	Yes	Yes	Proper
9.	Three-way Intersection Jl. Raya Cilacap - Wangon	Yes	Yes	Yes	Proper
10.	Four-way Intersection Pecikalan Dua Wangon	Yes	Yes	Yes	Proper

CONCLUSION

From this study, it can be concluded that: 1) the risk journey on the route taken by the tank car at PT Pertamina Patra Niaga Integrated Terminal Cilacap can be mapped using the fuzzy c-means logic method. In the calculation using fuzzy c-means, the required inputs are accident data for 5 years and a survey of road conditions used to determine points that are included in the safe, dangerous, and very dangerous categories. This calculation resulted in 42 roads in Cilacap Regency/City that are classified as very dangerous, 26 roads in the dangerous category, and 38 roads in the safe category, 2) the mapping (risk journey) on the route taken by this tank car can be accessed using an Android-based application made using Flutter. This application can map blackspot location and provide notifications to users so as to add safety features for drivers. In addition, this application can be monitored by the company through real-time web monitoring.

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