Risk Journey Management Strategy for Route Hazard Mapping of Tank Trucks in Fuel Distribution in the Central Java Region

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Abstract

PT Pertamina Patra Niaga, a state-owned enterprise in Indonesia, specializes in the downstream oil and gas sector, with a primary focus on fuel distribution across the nation via land and sea. Land transportation, carried out using tank trucks, presents unique challenges due to the high risk of accidents. To address these challenges, PT Pertamina Patra Niaga conducted a Route Hazard Mapping (RHM) and Risk Journey Management (RJM) study. The study identified key factors contributing to tank truck accidents: human error, vehicle condition, and environmental factors. Mitigation strategies include driver training and health assurance to reduce human error, regular maintenance and inspections to ensure vehicle condition, and RHM and RJM to identify and mitigate environmental hazards along routes. Implementing these recommendations is expected to significantly reduce the risk of tank truck accidents and enhance the safety of PT Pertamina Patra Niaga's fuel distribution operations.

***Keywords**: Tank Trucks, Risk Journey Management, Route Hazard Mapping, Accident.*

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A. INTRODUCTION

PT Pertamina Patra Niaga is a company engaged in the trade of refined petroleum products, with one of its activities being the distribution of fuel oil (BBM) across Indonesia via land and sea routes. Land distribution is carried out using tank trucks, which face various challenges, including accidents influenced by human factors, tank truck roadworthiness, and environmental factors. Human factors are addressed by enhancing human resource capacity through training and ensuring the physical and mental health of the drivers. Tank truck roadworthiness is maintained through roadworthiness inspections, while environmental risks are mitigated by route risk assessments using Route Hazard Mapping (RHM) and Risk Journey Management (RJM).

The main causes of traffic accidents are human factors, road and environmental conditions, and vehicle factors. Human factors are the most dominant, with many accidents resulting from driver error, such as fatigue, reduced alertness, or lack of knowledge about vehicle technology. Road and environmental conditions, including weather, land use, and traffic characteristics, also influence driver behavior. Traffic mix and poor road conditions can cause driver fatigue and discomfort. Advances in automotive technology, while improving vehicle performance, have increased speeds and consequently the risk and severity of accidents. Human factors affecting accident severity include driving knowledge, skills, physical condition, behavior, and use of protective gear. Vehicle factors include lighting, braking, and collision protection design. Road and environmental conditions, such as surface quality, geometric design, and roadside environment, also significantly impact accident severity. Limited access to maintenance, difficult victim evacuation, and lack of emergency facilities can worsen accident outcomes.

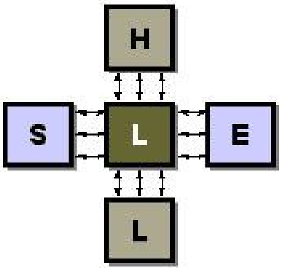

Figure 1 Shell Model by Prof. Elwyn Edwards

A traffic accident model developed by Frank H. Hawkins examines the interaction between humans and other components. This model is based on a proposal by Professor Elwyn Edwards, known as the SHELL Model, as shown in Figure 1. The model is named after its components, representing the interaction between the driver (Liveware):

1. Software: laws, regulations, rules, manuals, SOPs, and others
2. Hardware: vehicles, roads, road facilities
3. Environment: weather, roadside activities, and others
4. Liveware: field officers, mechanics, other road users

Transporting hazardous materials such as fuel requires careful planning and management due to the risks involved. Tankers, especially those used for fuel distribution, face many hazards during transport, ranging from road conditions to potential accidents and environmental hazards. The complex road system and various geographical features of Central Java, Indonesia make the logistics of fuel distribution even more difficult. Ensuring a safe and efficient fuel supply is critical not only to meet the region's energy needs, but also to minimize risks to the environment and public health.

Route risk mapping is an important part of risk management, which aims to identify and mitigate potential risks on tankers. By mapping threats, logistics companies can develop strategies to avoid or address risks and thus improve safety and operational efficiency. This study focuses on the development of a Risk Journey Management strategy that integrates a route risk map for tankers in the fuel distribution sector in Central Java

B. LITERATURE REVIEW

The transportation and disposal of hazardous materials (HazMats) have become critical concerns. Consequently, researchers and government agencies exercise great caution in identifying potential risks associated with transporting hazardous materials. Moreover, the impacts on human health and the environment are thoroughly analyzed. Transporting hazardous materials constitutes a significant portion of production costs and involves substances such as explosives, flame retardants, oxidizers, toxic gases, and radioactive materials. Exposure to these substances can harm the environment, damage crops and livestock, and pose severe risks to human health. Every day, large quantities of HazMats are transported via highways, railroads, pipelines, and waterways (Leonelli et al., 1999, 2000; Muhlbauer, 2006; Oggero et al., 2006; Gagliardi et al., 2007; Elvik & Voll, 2014; Torretta et al., 2014).

Over the past two decades, numerous studies have sought to evaluate the risks associated with transporting hazardous materials (Yang et al., 2010). These studies primarily focus on ensuring safe transport through pipelines (Citro & Gagliardi, 2012), railways (Liu et al., 2013; Saat et al., 2014), and roadways (Fabiano et al., 2002, 2005; Yang et al., 2010). Research on HazMat transportation generally revolves around three core aspects. The first involves methods to enhance emergency response based on factors such as road conditions, weather, and traffic (Fabiano et al., 2005). The second focuses on crash risk mapping and analytical procedures using historical data to uncover patterns, including accident frequency, impacts, and contributing factors (Fabiano et al., 2002; Yang et al., 2010). The third aspect emphasizes decision-making strategies to optimize vehicle selection (Guo & Verma, 2010) and route planning (Fabiano et al., 2002). Traffic accidents involving hazardous substances can significantly damage road infrastructure, cause societal harm through economic and environmental impacts, and endanger human lives. Therefore, understanding the frequency and consequences of such incidents is crucial. These factors depend on the nature of the incident, the severity of injuries (Hong et al., 2014), and road type (e.g., streets, highways, or urban roads) (Adler et al., 2013; Amezaga et al., 2015).

Hazardous material transportation is inherently linked to safety and environmental concerns, necessitating its consideration as a distinct issue from general transportation. Traditional hazard management often employs risk-based models to describe the likelihood and consequences of undesirable events (Erkut & Verter, 1998; Covello & Merkhofer, 1993). Demographic, climatic, and cultural factors further emphasize the need for careful monitoring of such transports (Bianco et al., 2013). To mitigate the adverse effects of hazardous material incidents, various regulations have been implemented over time. Risk assessment and evaluation of hazardous material transportation first emerged in the 1970s (Shappert et al., 1973).

Risk analysis for transporting hazardous materials is especially critical in urban areas to determine the optimal routes that minimize associated risks. Barilla et al. defined risk as the anticipated consequences of an activity. The primary approach to risk assessment is ensuring safe transport by reducing risks during the transportation process. Additionally, risk analysis considers two key elements—risk and cost—to achieve safety and economic feasibility. Selecting the most appropriate route is vital for minimizing the number of affected individuals and reducing travel time and distance to lower costs (Barilla et al., 2009). Alruqaibi et al. (2018) conducted a study focusing on risk and cost analysis for hazardous material transportation and its impact on the environment and population in Kuwait. The study aimed to classify available routes as either hazardous or safe based on a risk-cost algorithm.

C. METHOD

1. Risk

Risk can usually be related to the possibility or probability of unexpected events. Risk can also be interpreted as a combination of the likelihood and severity of damage or loss (Ridley, 2008). Some definitions of risk are as follows (Darmawi, 2004):

a. Risk is the possibility of loss (risk is the possibility of loss) used to indicate a situation where there is an open possibility of loss or loss.
b. Risk is the possibility of loss (Risk of the option of loss), i.e. the probability of an event is between zero and one.
c. Risk is uncertainty (Risk is uncertainty) means that risk is associated with uncertainty.

2. Hazard

Hazards are situations or activities that can cause harm to people or physical or mental disorders that are identified as arising from and/or aggravated by work activities or work-related situations (OHSAS 18001, 2007). A hazard is a source of potential harm or a situation that can cause harm (Cross, 1998). Something is considered a source of danger if it risks having a negative outcome.

3. Hazard Geometric Metode

Risk management risk analysis is a process that assesses the impact and likelihood of identified risks. This process is carried out by structuring risks according to their impact on project objectives. The scale used in the Australian Standard/New Zealand Standard (AS/NZS) is shown in Table 1 below:

Table 1. Risk Matrix

LEVEL	**PROBABILITY (LIKELIHOOD)**				
	1	**2**	**3**	**4**	**5**
5 Catastropic	M	M	H	H	H
4 Significant	L	M	M	H	H
3 Moderate	L	6	M	M	H
2 Minor	L	L	M	M	M
1 Insignificant	L	L	L	L	M

An alternative approach is needed to provide road users with information about hazards on road sections that do not meet technical standards and to give instructions on how to avoid these hazards. Additionally, road facilities should be designed to mitigate the impact if an accident is unavoidable. This approach exemplifies how hazards and risks can be well-described and a mitigation program can be effectively and efficiently developed to reduce the risk of accidents and decrease fatalities if accidents occur.

4. Survey/Data Collection

The next step in the activity is the data collection survey. The research was conducted with field observations. The field survey was carried out by a team of tank truck driving trainees and a team from the KNKT road geometry evaluation group. According to the big Indonesian dictionary, observation is careful study. Thus, it can be concluded that observation is an activity during which information is gathered by making immediate mappings of environmental conditions in order to obtain a clear picture of the observed object. The observations made in this study are direct interview in the field to determine the danger points based on survey and directly on selected routes. Data is collected at the predetermined danger points based on the parameters defined right at the beginning. These parameters are:

a. Hazard Zone (Side Activity)
b. Long and Steep Descents
c. Long Downhill
d. Steep Downhill
e. Dangerous Curves
f. Limited Visibility
g. Long and sharp climb
h. Long incline
i. Sharp incline
j. Super Flat Elevation

The logical framework for developing a hazard control program for roadways is shown in Figure 2. This framework clarifies the existing situation of problematic areas and their priorities, establishes a structure for policy decisions, and identifies mitigation strategies. Complete and accurate hazard and risk data are essential for identifying problems, evaluating, and assessing the effectiveness of actions. Therefore, improving the hazard database is a top priority in developing safety programs, particularly those related to road safety in Indonesia.

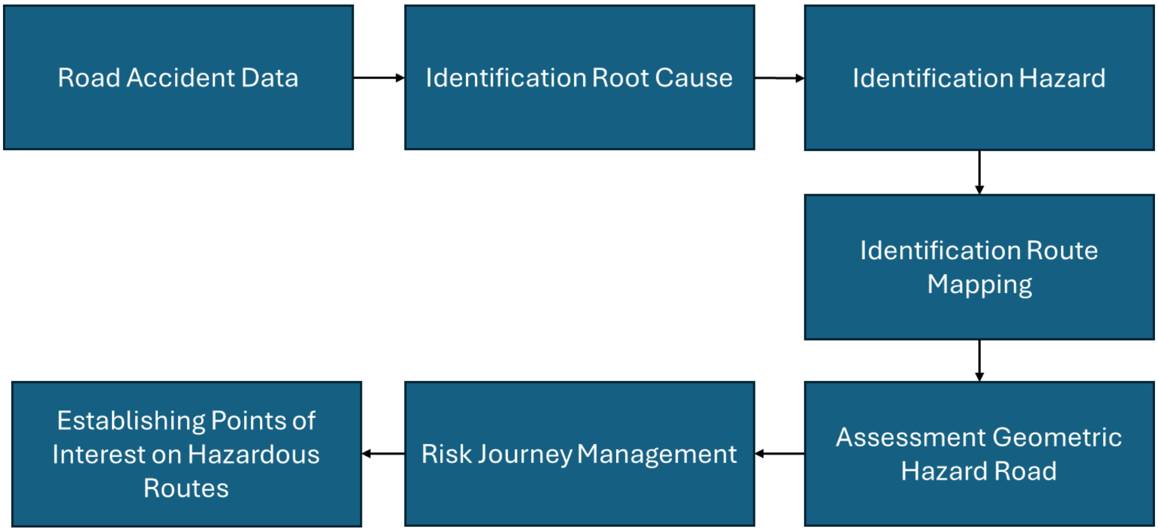

Figure 2. Model Risk Journey Management

Hazard mapping along transportation routes is a vital tool in risk management, particularly for the distribution of hazardous materials. This process involves:

a. Data Collection gathering data on road conditions, traffic patterns, accident history, and environmental factors. This data can come from governmental sources, geographic information systems (GIS), and historical records.
b. Hazard Identification identifying specific hazards such as high-traffic areas, sharp turns, steep gradients, and areas prone to natural disasters (e.g., landslides, floods).
c. Risk Analysis and Mapping using tools and analyze the data. This helps in identifying high-risk areas and potential alternative routes. Advanced models can incorporate real-time data to provide up-to-date hazard maps.
d. Implementation integrating hazard maps into route planning and navigation systems. Drivers and logistics managers can use these maps to avoid hazardous areas or prepare for potential risks.

Effective hazard mapping can significantly reduce the risk of accidents and improve the overall safety and efficiency of fuel distribution operations.

5. Research Location Objectives

The research sites are located in 5 (five) Fuel/Integrated terminals are FT Tegal, FT Rewulu, FT Maos, FT Boyolali and IT Semarang. The details of the route are as follows:

a. Route 1: FT Rewulu - Yogyakarta - Gunung Kidul - Wonosari
b. Route 2: FT Rewulu - Yogyakarta - Sleman - Magelang - Temanggung
c. Route 3: FT Maos – Cilacap
d. Route 4: FT Maos - Wangon - Ajibarang - Bumiayu - Slawi
e. Route 5: FT Maos - Wangon - Banyumas - Purbalingga - Banjarnegara - Wonosobo - Temanggung
f. Route 6: FT Tegal - Pemalang - Randudongkal - Moga - Belik

g. Route 7: FT Tegal - Slawi
h. Route 8: FT Tegal - Brebes - Losari
i. Route 9: IT Semarang - Kendal - Weleri - Banyuputih - Batang - Pekalongan - Kajen
j. Route 10: IT Semarang - Demak - Kudus - Pati - Rembang
k. Route 11A: IT Semarang - Demak - Kalinyamatan - Jepara - Kembang - Keling
l. Route 11B: IT Semarang - Demak - Kudus - Pati – Tayu
m. Route 12: FT Boyolali - Kartosuro - Surakarta - Sragen - Ngawi – Magetan
n. Route 13: FT Boyolali - Kartosuro - Surakarta - Sragen - Purwodadi - Blora - Cepu
o. Route 14: FT Boyolali - Ampel - Salatiga - Bawen - Ambarawa - Bedono
p. Route 15A: FT Boyolali – Sukoharjo - Wonogiri - Ngadirojo - Purwantoro
q. Route 15B: FT Boyolali – Sukoharjo - Wonogiri – Ngadirojo - Griwoyo - Pacitan

The primary objectives of this study are:

a. To identify and categorize potential hazards along fuel distribution routes in Central Java. This involves analyzing road conditions, traffic patterns, environmental factors, and Hazard Zone.
b. To develop a comprehensive route hazard mapping system for tank trucks. The mapping system should provide real-time data and predictive analytics to assist in route planning and risk management.
c. To propose a risk journey management strategy that integrates route hazard mapping. The strategy should include preventive measures, emergency response plans, and continuous monitoring mechanisms to ensure the safe transit of fuel tank trucks.

D. RESULTS AND DISCUSSION

1. Hazard Fatigue

A traffic accident refers to an unforeseen and unintentional event involving vehicles or road users. Such incidents are significantly affected by the state of the vehicle driver (Himawan et al., 2022). The driver's condition greatly affects work productivity, so if the driver's physical condition deteriorates, work productivity may be reduced.

Deterioration of the organism is different, one of which is work fatigue. Fatigue/fatigue is a condition in which a person feels extremely exhausted and this condition can affect anyone without exception. Fatigue while driving is one of the factors that can lead to the risk of an accident due to reduced attention. Symptoms of burnout are symptoms that affect work, such as decreased alertness and alertness, impaired and impaired perception, antisocial thoughts or activities, inappropriateness in the environment, depression, lack of energy and inability to work. An initiative. Symptoms often associated with the above include headache, dizziness, decreased lung and heart function, loss of appetite and indigestion. In addition to the mentioned symptoms of exhaustion, there are also non-specific symptoms such as anxiety, behavioral changes, restlessness and sleep disturbances (Maurits, 2010).

A survey method was conducted to identify hazard fatigue using interviews and questionnaires with fleet fuel/integrated terminal inspectors, tank truck crews (AMTs) and service station clerks. The purpose of the measurement method used is to identify road geometric hazards and fatigue hazards per foot traveled by the AMT.

When determining dangerous fatigue by calculating travel time, AMT is asked for several parameters when data is collected through a combined method, namely interviews and the use of Google Maps. Interviews were conducted with each AMT via FT and at least 10 people were interviewed. Determine the duration of the trip using Google Maps. Based on the results of the interview, the travel time is then calculated. The travel time formula is as follows:

$$Journey\ Time = Travel\ time + \ loading\ time + \ unloading\ time$$

After doing the calculations, the results of the trip PT Pertamina Patra Niaga regional Central Java time can be seen in tables 2 and 3.

Table 2. Hazard Fatigue PT Pertamina Patra Niaga RJBT

No.	FT/IT	Journey Time				Number of Respondents	SIOD DATA
		0-4	4-8	8-12	>12		
1	FT Rewulu	4%	49%	38%	9%	125	42%
2	FT Maos	13%	21%	48%	18%	160	30%
3	FT Tegal	7%	57%	24%	12%	42	8%
4	IT Semarang	2%	21%	57%	20%	49	9%
5	FT Boyolali	3%	21%	14%	62%	29	17%
	Total Respondent					405	

Table 2 shows the results of Hazard Fatigue based on Journey Time calculations (surveys & interviews) and based on actual SIOD data, which from the results of Hazard Fatigue identification have calculation gaps due to differences in assessment schemes. However, the potential Hazard Fatigue in each location has a contributing factor to fatigue in the tank car crew (AMT).

Table 3. Hazard Fatigue

No.	Name FT/IT	Route	*Journey Time* (Hour)	Travel Time (Hour)	Category
1.	FT Rewulu	1	10,00	6,00	Yellow
		2	10,50	6,50	Yellow
2.	FT Maos	3	5,50	2,00	Green
		4	12,00	8,50	Red
		5	12,00	8,50	Red
3.	FT Tegal	6	6,50	5,00	Green
		7	4,00	2,00	Green
		8	9,00	5,50	Yellow
4.	IT Semarang	9	13,75	10,00	Red
		10	9,75	6,00	Yellow
		11A	10,00	8,50	Yellow

		11B	8,00	6,50	Yellow
5.	FT Boyolali	12	11,25	7,00	Yellow
		13	10,00	8,00	Yellow
		14	9,75	6,00	Yellow
		15A	13,75	9,00	Red
		15B	16,75	13,00	Red

In 90 subsections 2 and 4 of the Traffic Law No. 22 2009 states that 8 (eight) hours a day is the longest working time of drivers of shared vehicles with mandatory breaks every 4 driving hours. However, under certain conditions, drivers may be assigned a maximum working time of 12 (twelve) hours per day, which must also include at least 1 (one) hour of rest. PT Pertamina Patra Niaga offers AMT a maximum working limit of 12 hours a day, 12 hours a day, 8 hours off and a maximum of 6 consecutive working days.

In addition to the route-based hazard fatigue survey, a total of 405 respondents were also conducted for the fuel terminal and integrated terminal at five FT and IT locations in the RJBT area. Based on Table 27, there are still lines with a travel time of more than 12 hours, or 73 respondents, or 18% of AMT RJBT 405 respondents. From this data, we can see that all RJBT fuel terminals and integrated terminals still have AMTs with operating hours exceeding the rules of the government and PT Pertamina Patra Niaga. The lowest travel times of more than 12 hours were found at FT Rewulu, namely 9%, and the most frequent travel times of more than 12 hours were found at FT Boyolali, namely 62%. This should be a concern for all parties, as fatigue is the number one cause of accidents in Indonesia. If the driving time of AMT is more than 12 hours, 2 AMT 1 and a rest place must be used in the 1st shift AMT driving, and the second driver sleeps in the cabin, this is done so that AMT 1 does not get tired. so that it can prevent accidents.

2. Implementation of Hazard Geometry

Atypical road geometry conditions are one of the factors that can cause accidents. The geometry of the road is influenced by the topographic conditions of the area and the condition of the highway. D. I Yogyakarta and Central Java Provinces have different topographic conditions, including mountainous areas and highlands. Thus, the grade or slope of the road contour varies between 5% and 25% when the road is of limited width. Road geometry is a plan that must be adjusted according to current regulations, so that the correct cross-section of the road provides safety and comfort to road users.

The geometric parameters that most influence the number of traffic accidents are the slope and the radius of the curve, and the number of traffic accidents is also greatly influenced by the speed of the vehicle. The perception mapping method is used to identify hazard factors based on road geometry. Details of the results of RJBT's geometric hazard monitoring are provided in Table 2:

Table 4. Identification Hazard RJBT

Hazard Type	**Route**																	**Total**
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11A**	**11B**	**12**	**13**	**14**	**15A**	**15B**	
Accident-Prone Areas (Side Activities)	6	10	6	11	13	7	4	8	4	8	5	4	4	6	2	4	3	105
Long and Steep Descents	-	8	-	10	4	4	-	-	-	-	-	-	-	1	7	2	-	36
Long Descents	-	-	-	-	-	-	-	-	3	-	-	2	-	-	-	-	2	7
Steep Descents	2	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	3
Hazardous Turns	-	-	2	6	10	4	-	-	-	-	-	-	-	2	-	2	10	36
Limited Visibility	-	2	-	-	-	2	-	-	-	-	-	-	2	-	-	-	-	6
Long and Sharp Ascents	4	2	-	11	4	7	-	-	-	-	-	-	-	1	9	4	2	44
Long Ascents	-	-	-	-	-	-	-	-	2	-	-	2	-	-	-	-	-	4
Sharp Ascents	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1
Flat Super Elevation	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	3
Total	12	22	8	38	31	24	4	8	9	8	5	10	6	10	18	12	20	245

Ten groups of geometric hazards have been identified in this report. Geometric hazard groups include: 1) Hazard Zone; 2) Long and steep descent; 3) long derivative; 4) sharp decline; 5) long and steep slope; 6) Long rise; 7) Steep slope; 8) Limited visibility; 9) Dangerous curves; and 10) Smooth transfer. Based on the results of the survey, the most dangerous route is FT Maos - Wangon - Ajibarang - Bumiayu - Slawi Route 4, which has a total of 38 hazards with 11 accident-prone area descriptions, 10 lengths. and steep descents, 11 long and steep climbs and 6 dangerous turns. Meanwhile, the route with the least geometric risk is Route 6 on the FT Tegal - Pemalang - Randudongkal - Moga - Belik route.

3. Risk Journey Management Result

Information about the Risk Journey Management results of the above methods and assessments, below is an example of a Risk Journey Management report:

Table 5. Risk Journey Management RJBT

No.	Route	Point of Interest (POI)		
		Depart	Return	Total
1.	Route 1	6	6	12
2.	Route 2	11	11	22
3.	Route 3	4	4	8
4.	Route 4	19	19	38
5.	Route 5	16	15	31
6.	Route 6	12	12	24
7.	Route 7	2	2	4
8.	Route 8	4	4	8
9.	Route 9	5	4	9
10.	Route 10	4	4	8
11.	Route 11 A	3	2	5
12.	Route 11 B	5	5	10
13.	Route 12	3	3	6
14.	Route 13	5	5	10
15.	Route 14	9	9	18
16.	Route 15 A	6	6	12
17	Route 15 B	10	10	20

Table 5 provides information on hazard start point, hazard end point as a single travel path hazard series coordinates point and reference coordinate point POI as a voice command to the tanker. team (AMT). At the same time, Road Risk Assessment and Hazards provide detailed information on road geometry per trip. In the full cycle, integration between devices related to warnings or voice control was considered to anticipate drivers on the road, this could be even better.

E. CONCLUSION

Route Hazard Mapping and Risk Journey Management is superior to the current Risk Journey Management (Worksheet) in terms of accuracy, risk coverage, methods and data presentation. In addition, the route risk mapping function can be extended with a voice command (POI) integration program, so risk route management can be performed as a complete cycle. Based on the analysis results and analysis data discussion, the following conclusions can be drawn from the 2024 Route Hazard Mapping and Risk Journey Management study of the Central Java region:

1. There are 5 dangerous routes. fatigue when the tanker's travel time is more than 12 hours, so there is a risk that route planning will cause fatigue. In addition, the results of the interview also revealed that FT had a planned fatigue risk, namely on lines 4, 5, 9, 15A, 15B.
2. Geometric hazards on a route, we detect the presence of geometric hazards on each route as follows:
   a. Route 1: 12 hazards consisting of 6 going hazards & 6 returning hazards;

b. Route 2: 22 hazards consisting of 11 going hazards & 11 returning hazards;
c. Route 3: 8 hazards consisting of 4 going hazards & 4 returning hazards;
d. Route 4: 38 hazards consisting of 19 going hazards & 19 returning hazards;
e. Route 5: 31 hazards consisting of 16 going hazards & 15 returning hazards;
f. Route 6: 24 hazards consisting of 12 going hazards & 12 returning hazards;
g. Route 7: 4 hazards consisting of 2 going hazards & 2 returning hazards;
h. Route 8: 8 hazards consisting of 4 going hazards & 4 returning hazards;
i. Route 9: 9 hazards consisting of 4 going hazards & 4 returning hazards;
j. Route 10: 8 hazards consisting of 4 going hazards & 4 returning hazards;
k. Route 11A: 5 hazards consisting of 3 going hazards & 2 returning hazards;
l. Route 11B: 10 hazards consisting of 5 going hazards s & 5 Returning hazards;
m. Route 12: 6 hazards consisting of 3 going hazards & 3 returning hazards;
n. Route 13: 10 hazards consisting of 5 going hazards s & 5 Returning hazards;
o. Route 14: 18 hazards consisting of 9 going hazards & 9 returning hazards;
p. Route 15A: 12 hazards consisting of 6 going hazards & 6 returning hazards;
q. Route 15B: 20 hazards consisting of 10 going hazards & 10 returning hazards;

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