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Analysis of the Impact of Landslides and Floods on Train Travel Graph Operation Patterns and Signaling Systems on the Mandai-Garongkong Line

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Abstract: Floods and landslides are natural disasters that have a major impact on transportation modes, especially in the land transportation sector. As a result of the disaster, many land travel routes were hampered and in the case of the railway sector, it had a very significant impact. The existence of floods and landslides resulted in the train operating system not running properly. This study aims to analyze the impact of floods and landslides on Train Travel Graph operating patterns and the effect on the railway signaling system by using the scoring method to obtain the results of mapping the level of flood and landslide risk and qualitative methods by analyzing documents and interviewing resource persons in order to obtain accurate information related to the cases that occur at each station. In this study, focusing on the province of South Sulawesi, in the Makassar Pare Pare railway project, there are several flood and landslide events that have occurred and the most significant impact on the Train Travel Graph operation pattern and signaling system are in the case of floods at Maros station and landslides at KM 72 in the Mandalle and Tanete Rilau station areas. The incident resulted in the cessation of train operations and the disconnection of the railway operation line which was supposed to be the Mandai Garongkong line but was cut off and ended at Mandal station. This incident can finally be handled by turning off all component functions in the railway interlocking system in flood handling. By using gutters and gabions in the KM 72 area to minimize the occurrence of further landslides and the crossing method carried out on Fiber Optic cables to keep the cable away from the risk of landslides.

Keyword: Floods, Landslides, Signaling, Train Travel Graph

INTRODUCTION

Trains are one of the most efficient and effective modes of transportation in transporting passengers and goods. There are many advantages of trains as land transportation when compared to other land transportation (Hamzah et al., 2018). In the context of mass transportation, trains have a high carrying capacity and can reduce congestion on the highways (Wijayanto, 2019). According to the Regulation of the Minister of Transportation Number 121 of 2017, railway signaling systems are divided into two main categories: conventional systems and communication-based systems, commonly known as Communication Base Train Control, which are much more modern (Indonesia Ministry of Transportation, 2017). This signaling system uses communication between on-board and trackside equipment for the operation and control of the train. The CBTC system utilizes wireless communication technology to realize two-way and real-time data transmission between trains and ground sub-systems (Aptana et al., 2023). Thus, railways not only serve as a means of transportation but also as an integral part of a sustainable transportation infrastructure. Then, in the era of rapid urbanization, the need for reliable public transportation is increasingly urgent (Wijayanto, 2019). Railways, also one of the solutions, not only offer speed and efficiency but also contribute to the reduction of carbon emissions. With the increasing number of users, it is important for the railway system to adapt to new challenges, including climate change and natural disasters that could affect its operations. This shows that the sustainability and resilience of the rail transportation system must be a top priority in its planning and management. Natural disasters in the form of landslides and floods are the most dominant in Indonesia. The National Disaster Management Agency of the Republic of Indonesia reported that more than 95% were hydrometeorological disasters such as floods, landslides, and tornadoes, with many fatalities caused by floods and landslides (Ridwan et al., 2022).

One of the operational challenges in railways is that weather anomalies in certain seasonal periods can cause extreme weather and trigger hydrometeorological disasters, such as floods, landslides, and strong winds. One of the cases of extreme weather with a big impact is the flood and landslide that occurred in Semarang on March 13, 2024 (Amri et al., 2024). Landslides and floods are two natural disasters that are very dangerous for train travel, as they can cause damage to rails, bridges, and other supporting infrastructure. According to research by Pandiangan et al., (2019), landslides can cause soil collapse around train lines, potentially resulting in fatal accidents. In addition, flooding can submerge the rails and supporting facilities, thereby disrupting train travel and increasing the risk of accidents (Santoso et al., 2020). Therefore, a deep understanding of the impact of these natural disasters is essential to maintain the continuity of railway operations. The risks faced by the railway system include infrastructure damage due to landslides and floods (Pandiangan et al., 2019). In addition, research by Santoso et al. (2020) identified that high rainfall can worsen soil conditions, increasing the risk of landslides (Santoso et al., 2020). It is well known that the intensity of extreme rainfall increases more strongly with global average surface temperature than with average rainfall, as the latter, on a global scale, is constrained by energy constraints (Suhadi et al., 2023). Some relevant research that discusses the impact of natural disasters on railway operations includes research by Agastya and Imron (2020) which discusses the planning of sediment control buildings on railway bridges in Madiun, showing the importance of infrastructure to reduce the impact of erosion. Research by Pandiangan et al., (2019) also analyzed post-landslide handling on the Purwokerto-Kutoarjo crossing, highlighting the importance of a good drainage system. In addition, research by (Wibawanto et al., 2022) has not analyzed the risk of rail damage due to extreme weather, suggesting that high rainfall can cause infrastructure damage (Nur et al., 2024). Research by Santoso et al. (2020) emphasizes the importance of geological monitoring to prevent landslides, while (Nugroho et al., 2024) discusses the need for contingency plans for natural disasters in railway operations.

This research entitled "Analysis of the Impact of Landslides and Floods on Gapeka Operation Patterns and Signaling Systems on the Mandai-Garongkong Line" is very important to be carried out. With the increasing frequency of natural disasters, it is important to understand how landslides and floods affect the pattern of railway operations, particularly in the context of Train Travel Graph. The purpose of this study is to analyze the impact of natural disasters on the signaling system and train operation pattern on the Mandai – Garongkong line. This research is expected to provide recommendations to improve the resilience of the railway system to natural disasters. Based on the results of relevant research, train operators are advised to improve monitoring and early warning systems related to extreme weather (Nugroho et al., 2024). This is important to reduce the risk and impact of natural disasters on railway operations. This research is also relevant to government policies in terms of the development of sustainable and disaster-safe transportation infrastructure. With the right data and analysis, the government can formulate more effective policies in dealing with disasters (Ministry of Transportation of the Republic of Indonesia, 2011). The role of stakeholders, including local governments, train operators, and the community, is very important in the implementation of research results. Cooperation between all parties is needed to create a transportation system that is resilient to disasters (Nugroho et al., 2024). Overall, this study aims to provide a better understanding of the impact of landslides and floods on railway operations. Thus, it is expected to improve the safety and efficiency of the railway transportation system in Indonesia (Pandiangan et al., 2019).

The above is based on the fact that railways are a mode of transportation that has a position in the field of land transportation. Railway infrastructure includes all the physical elements necessary to support railway operations, including rail lines, stations, bridges, tunnels, and operating facilities. This infrastructure also includes a signal and communication system that ensures the safety and efficiency of train travel (Legros, 2012). In terms of operating facilities, there are several categories included in the railway system, namely signals, telecommunications, and electricity. Trains are one of the mass transportation that is in demand by the public. A train is a means of transportation that uses propulsion, either independently or in a series with other trains, which move on a rail line specifically for train travel (Cyril Sumarahardhi & Budhi Santoso, 2023). Signaling systems are also vulnerable to a variety of risks, including floods and lightning strikes. Flooding can damage signaling equipment and cause disruption to the system, while lightning strikes can disrupt electronic signals. Addressing the failure of the signaling system due to these risks requires significant time and effort. In railways, there are many signal slogans used by the masses in terms of departing trains using slogan 35, and for the slogan aspect 7,6,5 to regulate the pattern of train movement. Signal is an aspect that can be categorized as a component that determines the operational pattern of the train and is directly related to Train Travel Graph where this graph is always determined from the beginning to regulate the pattern of train movement so that it runs according to the desire. Signaling systems are one of the very important telecommunication devices in the railway industry. Its function is to provide signals in the form of colors or shapes to regulate train travel and state that the signaling system ensures the safety and smooth movement of trains by regulating the schedule, speed, and position of the train (Cyril Sumarahardhi & Budhi Santoso, 2023).

Telecommunication is any transmission, transmission, and/or reception of any information in the form of signs, signals, writings, images, sounds, and sounds through wire, optical, radio or other electromagnetic systems (Moro et al., 2008). Telecommunication is also an aspect used to communicate between drivers with PK, Engineers with PPKA or PK with PPKA and PPKA with OCC which must continuously have relevant connectivity related to the train operating pattern. In meeting the needs of rail travel and safety, Indonesian railways must be able to keep up with the development of global railway technology needed to ensure the safety of train travel, which originally the communication system still used VHF frequency analog radio (150-174) with many frequency channels can be upgraded to a Digital Mobile Radio (DMR) technology communication system to be the choice of train control system based on urban train communication and long-distance trains, and the installation of Automatic Train

Protection (ATP), as well as improving signaling systems using Safety Integrity Level (SIL) (Sitorus et al., 2022). The power supply in question is the source of voltage for all train operating devices used. Starting with PLN's source that supplies power to the station and to the ER (Equipment Room) room which is where the brain of all train operation patterns is located. In the ER room, there are shelves that have their own systems, starting from shelves for telecommunications to shelves for interlocking systems. And in the power supply, it is also directed to the supply of backup power, namely batteries and emergency power supply, namely generators. With that, the influence of electricity or POWER SUPPLY plays an active role in providing energy supply for all kinds of devices needed in the railway system as well as power supplies as well as outdoor equipment in the form of signals, electric money order drives, facility detectors, transmission media and protection systems (Wibawanto et al., 2022).

Then, flooding is a disaster caused by high rainfall for a long period of time. The risk that occurs due to flooding can damage all systems around the affected area. Landslides are also disasters caused by high rainfall activity over a long period of time. Responsiveness is a series of actions taken immediately/immediately after a disruption to provide the best level of service during a disruption, ensure public safety, provide alternative travel options to reach destinations and meet the basic livelihood needs of affected communities. Survival is the ability of a system to translate from normal/planned (i.e. 100%) system performance to a disrupted state, i.e. gracefully declining. In practice, when a disturbance occurs, the system can undergo different degradations, such as failing completely at once, or slowly reducing performance until it finally reaches a disturbed state of tune. Recovery is the ability of the system to return from a disrupted state to its original state. Depending on the disruption, recovery can last a few hours (e.g. due to vehicle damage) to several weeks (e.g. due to severe flooding or tsunami). During certain types of disturbances or disasters, it can eliminate some conditions of resilience (Fauzi, 2019). For example, after a large-scale earthquake, rail traffic can be cut off altogether, so there is no survival. Mitigation represents an upgrade of infrastructure, especially vulnerable ones, with new links and nodes to improve the ability to resist intrusions. Preparedness is considered when mitigation is too expensive, and certain disruption effects are expected. For example, planning for response actions in advance can be assumed as part of a preparedness strategy (Nugroho et al., 2024). In this case, transportation management carried out in the railway system always starts with planning, operating patterns and also maintenance (Ramesh, 2021). In the scope of planning in the railway system, it begins with the arrangement of the building scope that will be used Planning is a process to determine the right future actions, through a sequence of choices, taking into account the available resources (Indonesia Ministry of Transportation, 2017). Because in this aspect the development must be carried out thoroughly about where the line will be built, the station points to be built, the road access that will be passed to lead to the station, and how the transportation mode system will be sustainable with the construction of the railway system. Responsiveness planning in railways is sometimes referred to as contingency planning (Nugroho et al., 2024).

In the operating pattern phase, the aspect that must be considered is the number of modes of transportation that will be used and the time that will be used (Badwi et al., 2020). In the context of this operating pattern, related to the placement of the Operating Facility aspect must be strategically considered about its location and functionality. Because if not, there will be an event such as an example of voltage drop (Undervoltage) which in some cases is quite frequent and how to do it, the voltage that must be emitted must be more than the voltage that will be applied by the device (Roy & Mitra, 2020). Therefore, the layout of aspects and devices must be carefully considered so that the system can run as planned and in accordance with the regulations that have been set (Nugroho et al., 2024). In the aspect of maintenance, the most important factor that must be prepared is competent human resources. In this case, the planner must be able to choose human resources who will then be assigned to be operators in running and maintaining all the devices that have been built (Baillie & Decker, 2022). In terms of maintenance, there is a component that must be made in accordance with the regulations and analysis of the device used, namely about the maintenance aspects related to the form and a medium that is prepared to obtain maintenance data and test data of systems and devices. There is a regulation stipulated by PM 44 of 2018 which regulates signaling (Minister of Transportation of the Republic of Indonesia, 2018).

METHOD

This study uses a qualitative method of descriptive data with the aim of obtaining in-depth data about the possibilities and events that have occurred related to floods and landslides, then from several references by using document studies to also be able to observe and in interviews to obtain direct data evidence which will then be processed into a conclusion of concrete data that can be used as reference material and for scoring methods or aspect mapping geological of the potential for floods and landslides to allow to anticipate the impacts that will occur if there is an approach to the signaling system. Using the overlay method, data is collected related to rainfall and altitude data in the station area, then the data is then analyzed by creating an overlay to get a weighting value which is then reclassified to get the level of landslide vulnerability. And by using the scoring method in mapping flood and landslide area maps with weighting techniques and scoring analysis is carried out to obtain the level of vulnerability to landslides in the area across Makassar Pare pare. The parameters used in this study are annual rainfall which is processed using soil type, altitude, and rainfall data (Mukhlisa et al., 2023). By using this method, results will be obtained about the potential for flooding and landslides on the Mak par train crossing. And also how the consequences of floods and landslides have the potential on the signaling system and the flow of the Railway, whether it has a significant impact or will have a sustainable impact if there is a high potential for rainfall. Component damage is one of the factors anticipated in the event of floods and landslides.

Table 1. Data Score and Weight of Flood Analysis

Parameters	Classes	Scores	Weight
Land elevation	0 – 12.5 m	6	0,20
	12,5 – 25 m	5	
	25 - 50 m	4	
	50 - 75 m	3	
	75 - 100 m	2	
	>100 m	1	
River buffer	< 25 m (high risk)	3	0,15
	25 - 100 m (moderate risk)	2	
	100 - 250 m (low risk)	1	
Soil Texture	Fine	5	0,20
	Moderately fine	4	
	Moderate	3	
	Moderately coarse	2	
	Coarse	1	
Rainfall	>3000 (very wet)	5	0,25
	2500 - 3000 (wet)	4	
	2000 - 2500 (quite wet)	3	
	1500-2000 (dry)	2	
	< 1500 (very dry)	1	
Land cover	Water body	5	0,20
	Residental area	4	

	Paddy field and aquaculture pond	3
	Plantation area	2
	Forest	1

Source: (Prabowo & Rahman, 2023)

Tabel 2. Data Score Dan Bobot Analisis LongsorSource

Parameters	Classes	Scores	Weight
Soil type	Litosol	3	0,10
	Fluvisol	2	
	Kambisol	2	
	Luvisol	1	
Rainfall	>3000 (very wet)	5	0,30
	2500 - 3000 (wet)	4	
	2000 - 2500 (quite wet)	3	
	1500-2000 (dry)	2	
	< 1500 (very dry)	1	
Land cover	Paddy field	5	0,20
	Plantation area	4	
	Forest	3	
	Residental area	2	
	Water body and aquaculture pond	1	
Land slope	>45% (very steep)	5	0,20
	30-45% (steep)	4	
	15-30% (medium steep)	3	
	8-15% (slightly sloping)	2	
	0-8% (flat)	1	
Geology	Volkanik rocks	3	0,20
	Sedimentary rocks	2	
	Alluvial rocks	1	

Source: (Sholikhan et al., 2019)

Table 3. Total Flood Risk Level

Number	Flood Risk Level	Total
1	Safe	1.85 - 2.65
2	Low Risk	>2.65 - 3.25
3	Medium Risk	>3.25 - 4.05
4	High Risk	>4.05 - 4.85

Source: Zafira et al., (2024)

Table 4. Total Landslide Risk Level

Number	Landslide Risk Level	Total
1	Safe	2.00 – 2.60
2	Low Risk	>2.60 – 3.20
3	Medium Risk	>3.20 – 3.80
4	High Risk	>3.80 – 4.40

Source: Zafira et al., (2024)

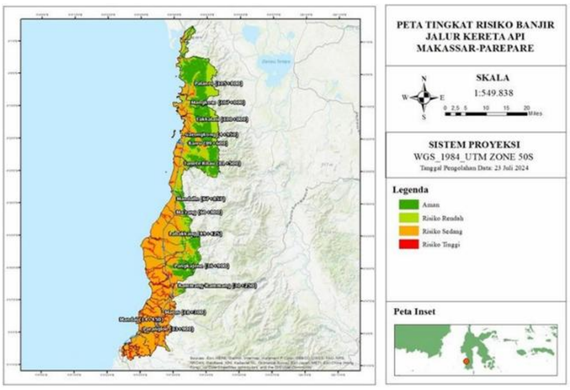
Measurement and data collection were carried out in the Makassar Pare Pare Train crossing project area. By mapping the geological map pattern, accurate data will be obtained that indicates the potential for floods and landslides that will occur. By knowing the potential disasters that will occur with the data sources obtained, it is possible to prevent or surround the train signaling components which have the potential to disrupt the train running system and affect the flow in the train travel chart.

RESULTS AND DISCUSSION

Based on the results of the flood and landslide analysis research by Zafira et al., (2024) it is known as follows:

1. Mapping Flood and Landslide Analysis

a. Flood Analysis Mapping



Source: Zafira et al., (2024)

Figure 1. Flood Risk Level

Areas with a high risk of flooding are areas near river areas such as in Bontoa District, Lau District, Maros Baru District. Examples of areas with a moderate risk of flooding are Mandalle District, Ma'rang District, and Tamalanrea District. Examples of areas with a low risk of flooding are the eastern area of Balusu District, the eastern area of Mallusetasi District, and the eastern area of Soppeng Riaja District. An example of an area that is safe from flooding is the eastern area of Bungoro and Minasatane Districts. The railway line from Parangloe Station (13+900) to Palanro Station (115+800) passes through areas with flood classes "High risk" and "Medium risk" (Zafira et al., 2024).

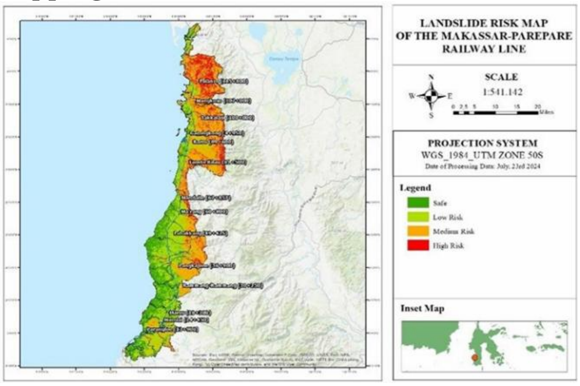
Table 5. Flood Risk Classes

Class	Area (Ha)
Safe	37190.67
Low Risk	28538.32
Medium Risk	93555.26
High Risk	4459.445

Source: Zafira et al., (2024)

Along the Makassar-Parepare railway line, the "High risk" class has an area of 4459.445 Ha, the "Medium risk" class has an area of 93555.26 Ha, the "Low risk" class has an area of 28538.32 Ha, and the "Safe" class has an area of 37190.67 Ha.

b. Landslide Analysis Mapping



Source: Zafira et al., (2024)
Figure 2. Landslide Risk

Areas with a high risk of landslides are highland areas with high land slopes such as in Barru District, Balusu District, Mallusetasi District, and Soppeng Riaja District. Examples of areas with a moderate risk of landslides are the central areas of Balusu District, Bontoa District, and Minasatane District. Examples of areas with a low risk of landslides are the central area of Bungoro District and the middle area of Labakkang District. An example of an area that is safe from landslides is the western area of Segeri District, Marang District, Labakkang District, Bungoro District, 132 | Page https://greenationpublisher.org/JGIT, Vol. 2, No. 3, August - October 2024 Pangkajene District, Maros Baru District, Lau District, and Bontoa District. The railway line from Parangloe Station (13+900) to Mandalle Station (67+857) passes through areas with "Safe" and "Low risk" landslide classes. Meanwhile, the railway line from Mandalle Station (67+857) to Palanro Station (115+800) passes through areas with "Medium risk" and "High risk" landslide classes (Zafira et al., 2024).

Table 6. Flood Risk Classes

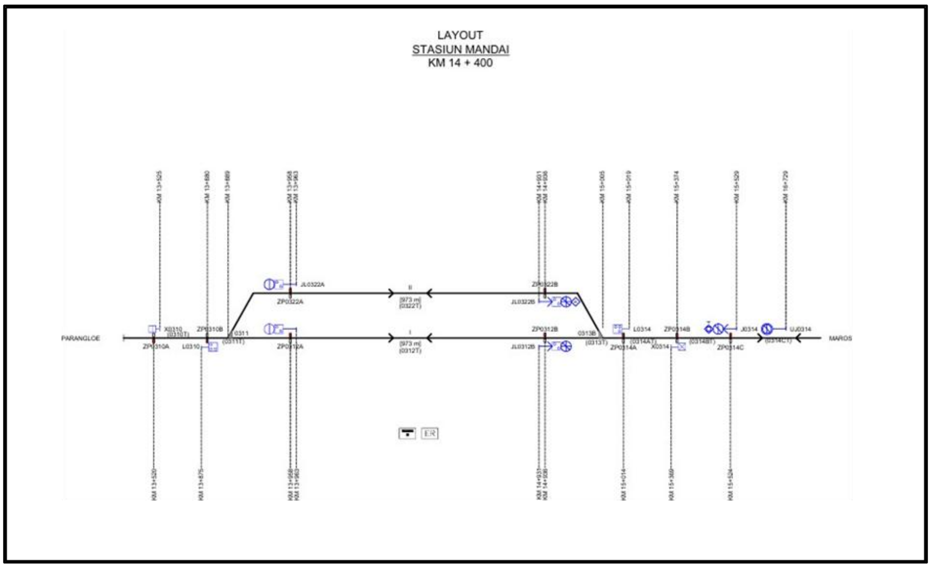
Class	Area (Ha)
Safe	26222,07
Low Risk	54344,16
Medium Risk	69296,58
High Risk	13880,72

Source: Zafira et al., (2024)

2. Analysis of The Occurrence of Each Station

The following is the signaling layout at eleven stations of the Mandai to Garongkong line.

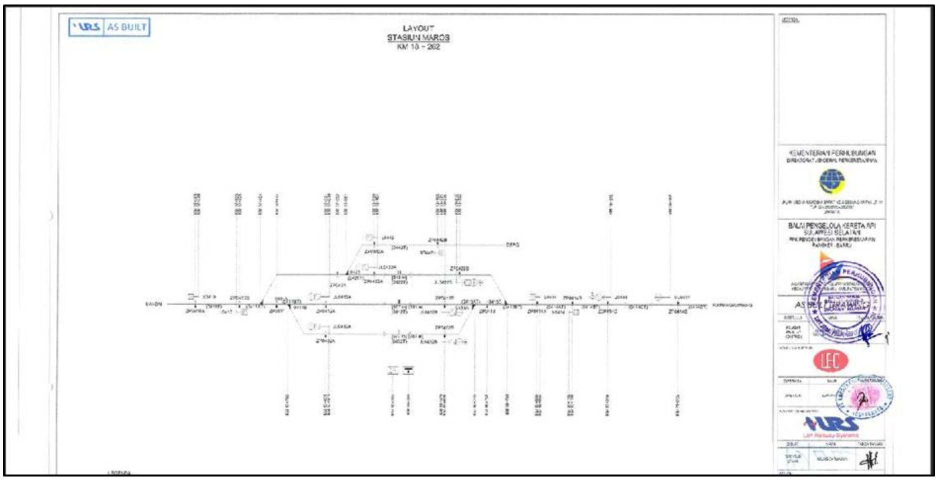
a. Mandai Station



Source: PT CRI (2025)
Figure 3. Mandai Station Layout

Mandai Station is a station in the Makassar Pare Pare project located at KM 1 which is a station located at the beginning of the railway line. In the case at Mandai station, there has only been a landslide at KM 15 + 500 which occurred on a small scale with handler in the form of making a barrier made of an arrangement of rocks or commonly called gabions which are functioned so that the soil left over from the landslide does not fall.

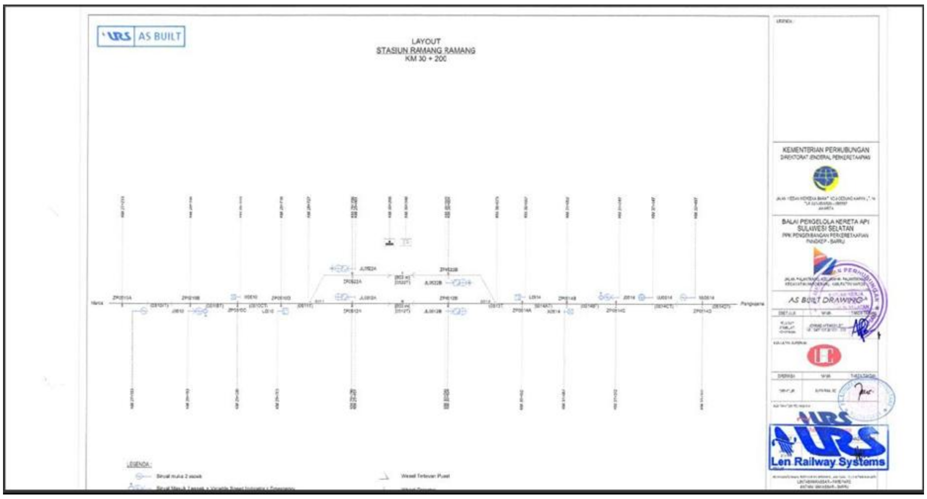
b. Maros Station



Source: PT CRI (2025)
Figure 4. Maros Station Layout

At the Maros station, there was a disruption of signal operation during a flood because the ER (Equipment Room) where the controller of the Persinyalan interlocking system was built was not at a safe height in the event of a flood disaster. With areas that have been determined at KM (13+900) to KM (15+800) through areas with flood classes "High risk" and "Medium risk". The floods that occurred in March resulted in the signaling system having to be shut down. In that way, the signaling system is inactive and has an impact on train travel being disrupted. With the handling of the flood, the ER (Equipment Room) finally had to be turned off for a while until the flood receded.

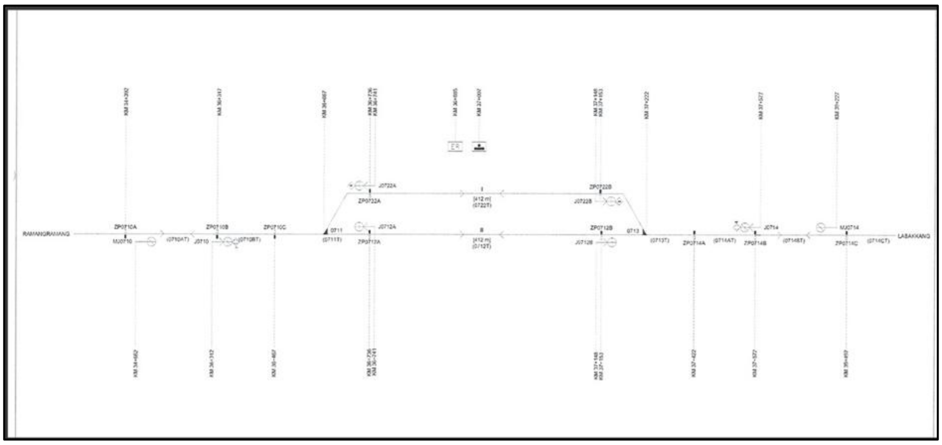
c. Rammang rammang Station



Source: PT CRI (2025)
Figure 5. Rammang Rammang Station Layout

Rammang-rammang Station is a station located in Maros regency which is located close to Rammang Rammang tourism. Surrounded by many cliffs and many rivers that pass around the tourist attraction. Rammang Station has a moderate flood risk level because its crossing is in an area of 93555.26 Ha and in some cases in the Rammang area there is rarely flooding due to its proximity to the main river position.

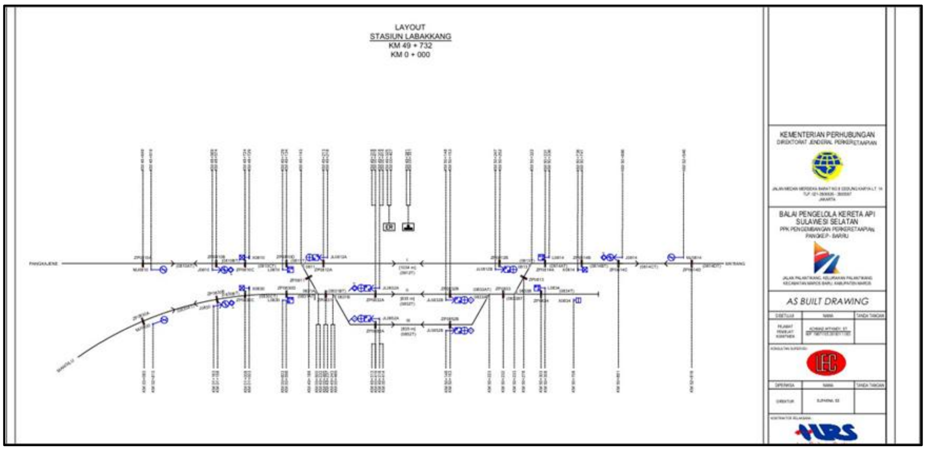
d. Pangkajene Station



Source: PT CRI (2025)
Figure 6. Pangkajene Station Layout

Pangkajene Station is a station that has a somewhat different construction form from the station in other early KM because with the construction of the rail that is somewhat higher than the vehicle line, it affects the construction that must be higher in order to align with the rails. At Pangkajene station, floods and landslides rarely occur because the station's position is quite far from the potential for floods and landslides. So for Pangkajene station, there are no cases of floods or landslides.

e. Labakkang Station

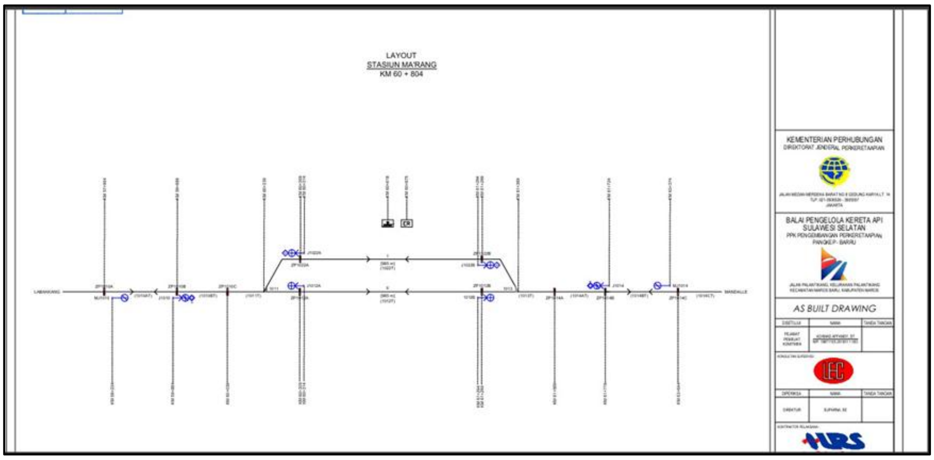


Source: PT CRI (2025)

Figure 7. Labakkang Station Layout

Labakkang Station is one of the stations that has a branch of the railway line, namely towards Mangilu station. Labakkang station has experienced flooding but the impact of the flood only affects the access road to the station. With that, Labakkang Station confirmed that there are no cases or events that affect the signaling system or affect the train operating pattern. The position of the station that is built higher than the ground level provides the advantage to reduce the risk of flooding.

f. Ma'rang Station

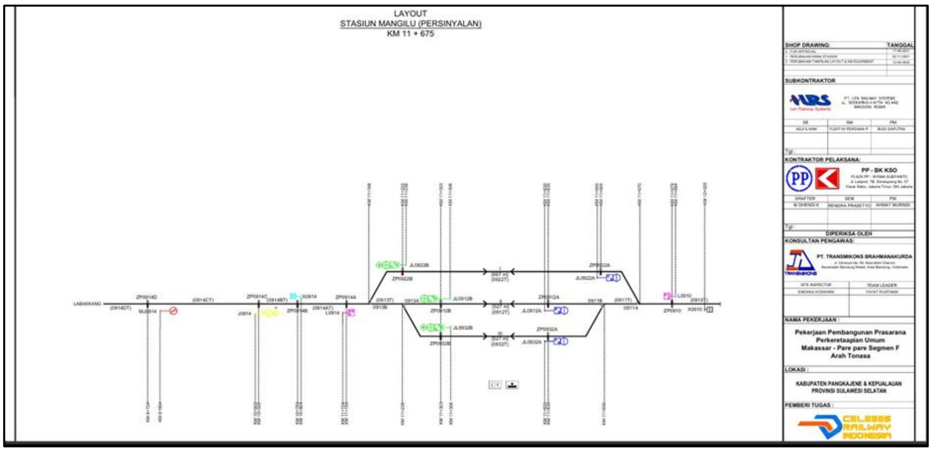


Source: PT CRI (2025)

Figure 8. Ma'rang Station Layout

Likewise, at Ma'rang station, if a flood occurs, it only impacts the area around access to the station that is disrupted, therefore Ma'rang station is confirmed to have never experienced flooding which affects the signaling system and also disrupts the train operating pattern.

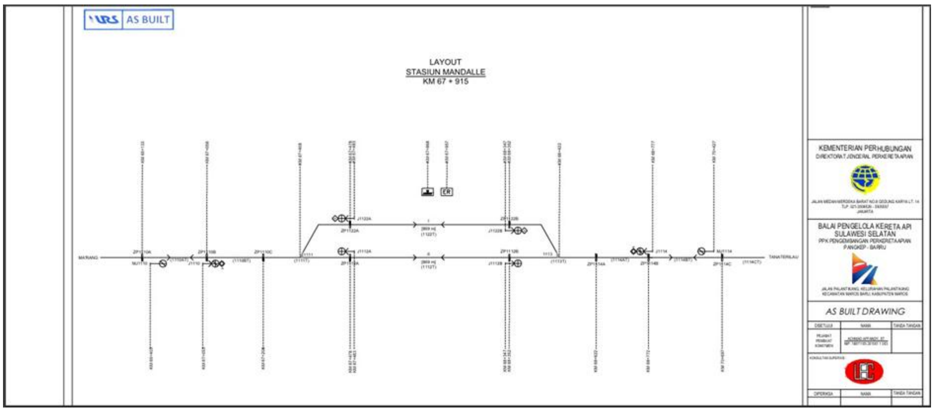
g. Mangilu Station



Source: PT CRI (2025)
Figure 9. Mangilu Station Layout

Mangilu Station is one of the stations whose train route is adjacent to one of the Tonasa cement factories and a location adjacent to several cliffs and river flows. At Mangilu station, there has also never been a flood or landslide because the location of the station is in the "Safe" class area, so it can be confirmed that the Mangilu station area has never experienced floods or landslides.

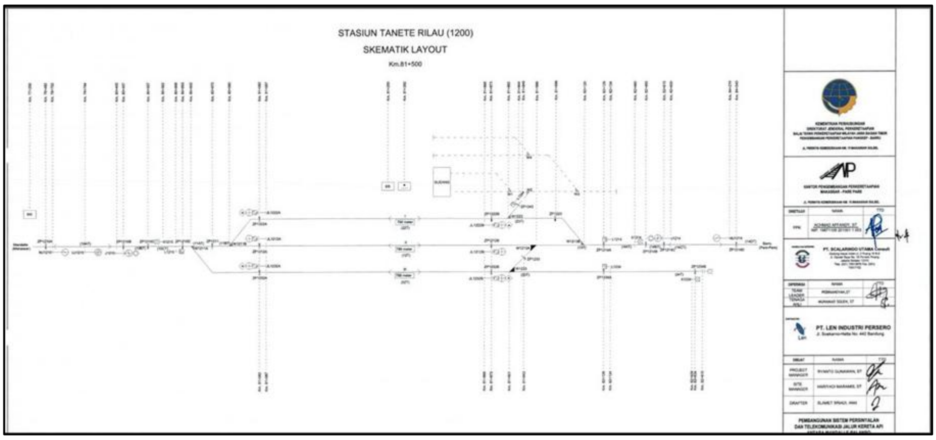
h. Mandale Station



Source: PT CRI (2025)
Figure 10. Mandale Station Layout

At Mandale station, several flood events occurred due to the position or location of the station which was at a moderate level if we look at the results of flood mapping. In the avalanche event at KM 72 Mandele finally became the last stop at that time because the line that was supposed to go to Garongkong station was finally cut off and could not be passed.

i. Tanete Rilau Station

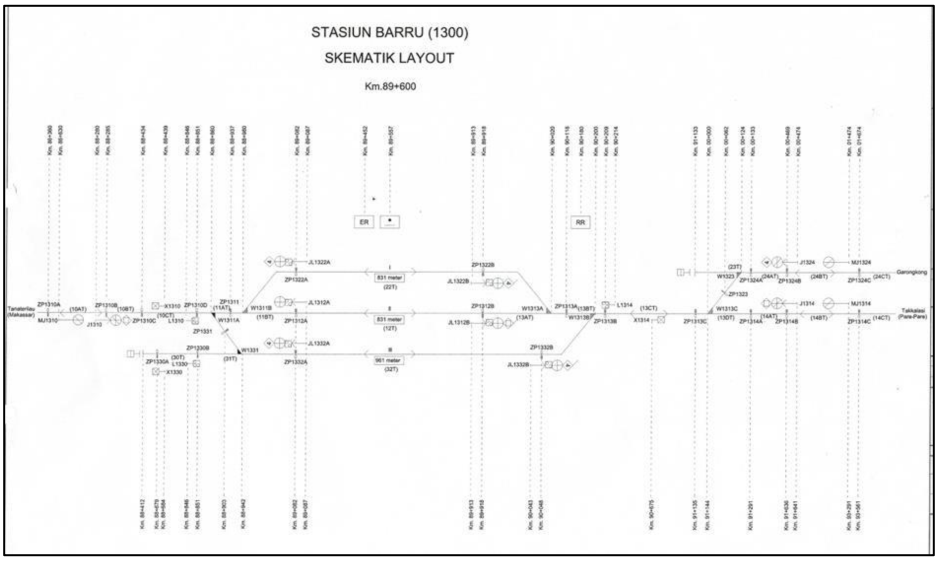


Source: PT CRI (2025)

Figure 11. Tanete Rilau Station Layout Picture

Tanete Rilau Station had a disturbance when a landslide occurred at KM 72 after Mandele station.The impact of the landslide resulted in several stations after Mandele in the direction of Garongkong station being disconnected. The path from Mandele to Tanete was broken at KM 72, the incident occurred in November 2024.

j. Barru Station

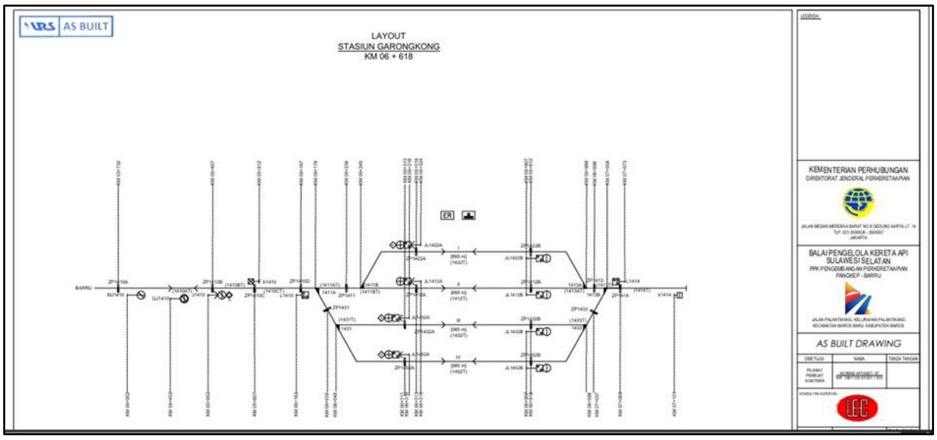


Source: PT CRI (2025)

Figure 12. Barru Station Layout

At Barru station, floods and landslides occur several times, but in flood cases it does not have much effect on the signaling system. The landslide that occurred at KM 72 also had a significant impact on Barru station which resulted in the station not operating for a certain time.

k. Garongkong Station



Source: PT CRI (2025)

Figure 13. Garongkong Station Layout

At Garongkong station, which is located in a coastal location that is quite close to the sea, but only has a moderate level of flood risk. The event that has occurred in the flood does not affect the signaling and also the operating pattern of the train travel chart from Garongkong station.But in the Landslide event that occurred at KM 72 resulted in a break in the operating pattern of the train travel chart that was supposed to be heading to Garongkong Station but only stopped at Mandale station.

3. Pembahasan

Table 7. Events of Floods and Landslides at each station

No	Stasiun	Banjir	Longsor	Waktu
1	Mandai (MDI)	-	1	10 Desember 2024
2	Maros (MRS)	2	-	24 Desember 2024 14 Februari 225
3	Rammang-Rammang (RMG)	-	-	-
4	Pangkajene (PKJ)	-	-	-
5	Labakkang (LKK)	-	-	-
6	Ma’rang (MRG)	-	-	-
7	Mangilu (MGU)	-	-	-
8	Mandale (MDL)	-	1	22 Desember 2024
9	Tanete Rilau (TAN)	-	1	22 Desember 2024
10	Barru (BAR)	1	-	14 Februari 2025

Source: Researcher (2025)

In the results that have been obtained at each station, floods occurred 2 times in the area around Maros station and 1 time in the area around Barru station. And in landslides several times occurred in the Mandai station area, KM 71 + 300 in the Ma'rang station area, KM 71 + 700 and KM 72 + 200 in the Mandale and Tanete Rilau station areas (Izat, 2025). The flood that occurred at Maros station had an impact on the Equipment Room (ER), resulting in the signaling system finally having to be turned off because it would have an impact on the components in the room. As a result, the signaling device could not be operated for a while and the train operation also ended up not operating on that day either. The landslide that occurred at KM 72+ was the worst landslide incident in the Makassar Pare Pare Railway project. As a result, the route that previously led to Garongkong station was finally cut off, which finally the train was required to only arrive at Mandale station.

Table 8. List of Landslide Prone Locations

No	Track	Location		Length (m)	Status
		Start	End		
1	MDI-MRS	15+400	15+600	200	Normal
2	MDI-MRS	16+750	16+850	100	Waspada
3	MRS-RMG	19+000	19+100	100	Siaga
4	MRS-RMG	25+300	25+500	200	Waspada
5	RMG-PKJ	32+750	32+800	50	Waspada
6	MDL-TAN	71+300	72+700	1400	Awas
7	MDL-TAN	73+300	74+000	700	Waspada
8	MDL-TAN	75+500	76+800	1300	Siaga
9	MDL-TAN	80+000	80+600	600	Waspada
10	BAR-GAR	01+000	01+200	200	Siaga
11	LKK-MGU	08+500	08+600	100	Waspada

Source: Researcher (2025)

a. Flood Handling

One of the first ways of handling the flood problem is to shut down all the devices that have the potential to be submerged, starting with the disconnection of every operating device. In the case of flooding that occurred at Maros station, the first order that must be done is to deactivate the device on the telecommunication rack and then continue with the disconnection of the CPR (Central Processing Rack) rack where the function of all train system operations, continues on the BCR (Block Control Rack) rack, and on the MPR (Multi Purpose Rack) rack, after that the disconnection of the MDP (Main Distribution Panel) system) and the last one at the voltage source from PLN. After all systems are turned off, the responsible party then provides information for the next handling that can be done, namely by planning to rebuild the ER (Equipment Room) because in the current position, the room is not aligned with the position of the rails where the height is below the rails (Sandi, 2025).

b. Landslide Handling

Then, for one of the handlings carried out for the landslide problem at KM 15+500, a barrier or gabion was made, which was positioned under the avalanche so that it would not flow further down. By making a kind of gutter to divert water that falls from above along with the mud so that it can flow directly down and not hit the rails (Izat, 2025). And in handling landslides, the Crossing method is also carried out on the Fiber Optic cable line in the loose area with a general theory, basic theory, so that the cable is safe, under the rails, not crossed anything, protected from external interference (Tegar, 2025).

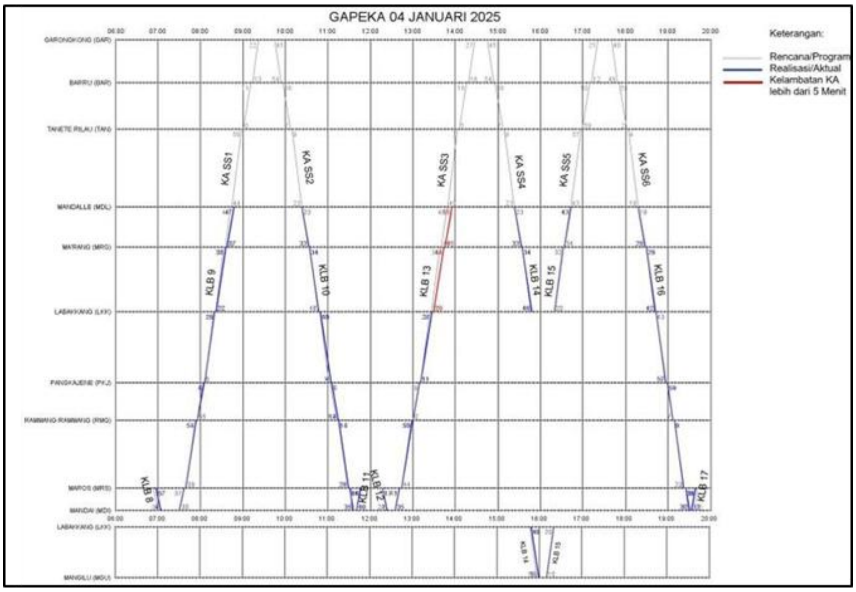
Source: Researcher (2025)

Figure 14. Penangan Longsor di KM 72

CONCLUSION

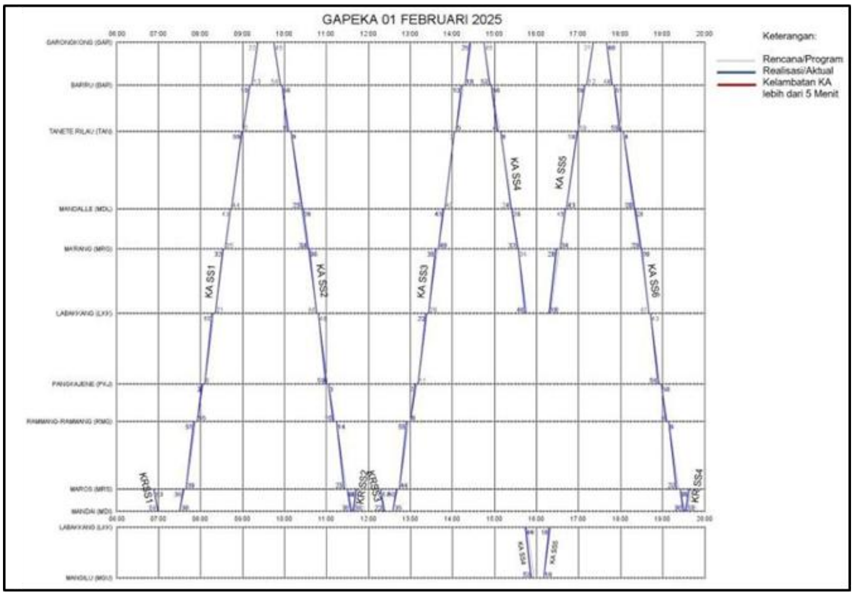
This study comprehensively discusses and analyzes how natural disasters, especially landslides and floods on the Makassar Pare Pare Railway crossing, have a significant impact on the operating pattern of the Train Travel Graph and the signaling system on the railway line connecting the Mandai and Garongkong areas. In this context, Train Travel Graph as the main guideline for scheduling and train travel is vulnerable to disturbances caused by extreme environmental conditions. Natural disasters such as landslides and floods have been proven to result in quite serious infrastructure damage. This damage is not only limited to the railways, but also signaling systems, as well as various other operational support facilities that are very crucial in ensuring the smooth and safe travel of trains. In some extreme cases, the disturbance even has the potential to cause fatal accidents, both for the crew and train passengers.

The results of this study confirm that a deep understanding of the potential and impact of natural disasters is very important for related parties, especially in maintaining the continuity of railway operation patterns and changes in Train Travel Graph flow. This knowledge can help operators and managers to be better prepared to face and manage risks arising from extreme weather conditions or geological disasters. Furthermore, this study also has high relevance to the direction of government policies in the development of the national transportation system. With changes due to facing weather conditions, changes were made to the train travel system, in which case there was a difference before and after handling on the crossing line due to the landslide that occurred at KM 72.



Source: PT CRI (2025)

Figure 15. Train Travel Graph Conditions after Landslide



Source: Researcher (2025)

Figure 16. Train Travel GraphCondition after Handling Return to Normal

Although this research has made an important initial contribution, further studies are needed to explore and develop monitoring system technology and early warning related to weather and geological conditions. This kind of system will be very useful in detecting potential hazards early and reducing the level of risk to the railway network. Therefore, future research is recommended to expand the scope of the analysis by considering geological and meteorological factors more comprehensively, including aspects of climate change, extreme rainfall, and soil structural conditions along the rail line. This approach is expected to be able to increase the resilience of the railway system to various uncertain environmental conditions. Overall, this research makes a meaningful scientific and practical contribution to our understanding of the influence of natural disasters on railway operations in Indonesia. It is hoped that the findings of this study can be the basis for decision-making in order to improve the safety, reliability, and efficiency of the railway transportation system. In addition, this research is also expected to encourage closer cooperation between the government, railway operators, research institutions, and the wider community in creating a resilient, adaptive, and sustainable transportation system to future disaster challenges.

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