Traffic management at landslide disaster in West Sumatera and its impact to passenger and drivers

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Abstract. West Sumatra is one of Indonesia province that always experiences landslides during the rainy season. Based on data from BNPB, in the last 10 years, 166 landslides have occurred in West Sumatra. The landslide materials covers partially and even the entire road wide, so it interferes the traffic flow activities in the lane. This study aims to identify traffic management that is carried out in the landslide disaster zone, the impacts arising from landslides are identified. The study was conducted by exploring the experiences of drivers and passengers when using vehicles in the West Sumatra. Structured questionnaires were created and distributed online and directly to respondents. From the results of data analysis, it was obtained that landslide most often occurred in the Padang-Solok road at Sitinjau Lauik region and in Padang-Pariaman road at Silaiang region. These two routes have high traffic flow. Majority of landslide materials are soil, it causes traffic congestion. Traffic management by opening and closing one-way roads is a type that is mostly conducted to reduce traffic congestion, this activity is carried out by the police and the people around the location. The most impact that experienced by driver and passenger during waiting for cleaning the landslide material were tired and loss of time.

1. Introduction
Geographically, Indonesia is located between two oceans and two continents at equator. It has a rainy season and a dry season, the weather always changing, between those two conditions. The extreme weather always occur every year, this conditions are potential cause’s natural disasters. Land slide is one of the disaster that always occur during rainy season. West Sumatra has high frequency of landslide disasters during rainy season, this is because most of West Sumatera area is part of Bukit Barisan hills. Landslide could occur if structure and stability of soil is disturbed [1]. Risdiyanto stated that landslide could occur as fallen soil and landslide [2]. Factors that could affect landslide is slope of soil, type of land cover, rainfall, geology structure, human activity [3,4,5].

The landslide disaster that occur at road network could impede traffic flow and affecting economic and social activities at that regions, see Figure 1. Nandi stated that the impact of landslide at traffic flow, i.e. fatalities, cut off road access [6]. The types and frequency of disasters that occur in West Sumatera during 2010 - 2019 is shown in Figure 2.

From Figure 2, it can be seen that the number of natural disasters in West Sumatra in 2010 - 2019, where the number of floods was 249, landslides 166 events, tornadoes 154 events, 1 tsunami, 16 droughts, 14 tidal waves, forest and land fires with 9 incidents, and earthquakes with 7 events. From this figure, landslides is the second highest disaster after the flood. Based on this data, the landslide disaster should be identified and monitored continuously, because it could affect transportation activities if occur
at road network. This paper presents the results of research regarding the characteristics of landslide disasters, traffic management that is carried out at landslide disaster zone and the impacts felt by passengers and drivers.

![Figure 1. Landslide disaster in West Sumatera [7]](image1)

![Figure 2. Disaster in West Sumatera during 2010-2019 [8]](image2)

2. Research method
This study used qualitative and quantitative approaches. The data was acquired from the experiences of drivers and passengers who have experienced landslide disasters during travel in West Sumatera for 4 years ago. Two methods of data collection: the first method was an online survey, and the second method was a direct survey at Aur Kuning bus terminal, Basko to Ulak Karang area, Malindo Service Pool, Pasar Raya Padang, UNP students, and Unand students. Online surveys are easy to conduct, but the respondent could not be controlled, compared with direct surveys, it is needed more effort to obtain the data.

Structured questionnaires have been developed to capture the experience of respondents during landslide disasters. The data include respondents' profiles, characteristics of landslides, traffic management at landslide disaster zones, and the impact of landslide disasters on passengers and drivers. From an online survey, a total of 101 respondents were collected, and from a direct survey, 150 respondents were collected. The data was analyzed using Microsoft Excel and SPSS applications.

3. Result and discussion

3.1 Respondent characteristic
From the data collection, it has been collected 251 respondents, where 5.4% of respondents are living outside of West Sumatera Province, the data was included because they know the location of landslide disasters. The characteristic of respondents is shown in Table 1.

From Table 1, it is shown that the majority of respondents are from West Sumatera, where the gender ratio is almost similar between male and female. They are active people as students and drivers. Most of the respondents are car passengers during landslide disasters occur, then followed as car drivers.
### Table 1. The characteristic of respondent

| Characteristic                               | Percentage of respondent |
|----------------------------------------------|--------------------------|
| The origin of the respondent                | West Sumatera (95.6%), Others (5.4%) |
| Gender                                       | Male (50.3%), Female (49.7%) |
| Age                                          | < 20 years (3.3%), 20-35 years (65.7%), 36-50 years (21.5%), 51-65 years (8.3%), > 65 years (1.2%) |
| Occupation                                   | Student (47.4%), Driver (23.1%), Businessman (15.9%), Private staff company (6.0%), Government official (3.2%), Bus operator (2.0%), House wife (1.6%), Parking officer (0.4%), Others (0.4%) |
| Status of respondent at landslide disaster zone | As car driver (27.6%), As car passenger (47.7%), As motorcycle driver (18.7%), As motorcycle passenger (4.9%), As local people (0.9%) |

#### 3.2 Landslide characteristic

Landslide disasters have varied condition, these would affect different traffic control and impact in the site. Therefore, this condition should be identified. This below the characteristic of landslide disaster.

#### 3.2.1 Landslide disaster locations

Locations of landslide disasters could affect different impact to traffic flow, different locations of landslide would be different road geometric and environment condition, this would affect of traffic management implementation scenarios. Every implementation of traffic management would affect different impact to traffic flow. Figure 3 shows the locations of landslide disaster.

![Figure 3. Landslide disaster locations](image-url)

Based on the Figure 3, it is indicated that majority landslide disaster that experienced by respondent is at Sitinjau Lauik and Silaing area. These areas are hilly and has high cliffs on the side of the road, the soil around that area is soft and prone to landslides during the rainy season.
3.2.2 Landslide types. In this study, the type of landslide is devide into 6 types as shown in figure below, these types are devided based on the soil volume that covered on the road surface and the origin of soil that slide. The material of landslides are also identified, because it will affect clearing time. From data analysis, the distribution of respondents experience of landslide is shown in Figure 4.

![Landslide types](image)

Figure 4. Landslide types

It is shown in Figure 4 that most landslide disaster that experienced by respondent is landslide type 1 and 2, then type 3. In landslide type 1 and 2, landslide material cover road surface, but there is a lane that could be use for traffic flow. Traffic flow still could move but with limited speed. However, in landslide type 3, all road surface is covered by landslide material, traffic vehicle should wait for landslide material cleaning. If landslide location is near the location of equipment for removing landslide material, the vehicle is not waiting for long time.

3.2.3 Landslide materials. Effect of landslide is not only affected by the pattern of landslide that cover road surface or destroyed road based, but also affected by the type of landslide material. The type landslide material will influence duration of material clearing. Figure 5 shows the distribution of landslide material that identified by respondent.

Figure 5 shows the types of material that the respondents saw when a landslide blocked their vehicle. It is shown that soil is the highest seen by respondent. The other landslide materials that were usually found were soil and stone, then soil and tree. These materials are commonly found along the road in West Sumatera. Most areas of West Sumatera are part of Bukit Barisan terrain, these areas are hilly and part of those areas are soft soil.
Figure 5. Landslide material

3.2.4 Landslide material clearing duration. Impact of landslide disaster to traffic user strongly affected by duration of landslide material clearing. Duration that experienced by respondent is displayed in Figure 6.

Figure 6. Landslide material clearing duration

Figure 6 shows that the highest frequency of landslide material clearing duration is between 3-6 hours, then less than 3 hours. This duration is for clearing landslide type 1 dan type 2, the material partially covered road surface, this materials are usually soil, stone and tree (Figure 5). In order to reduce traffic problems, Farradyne stated that traffic management at landslide zone should follow the process of incident management such as detection, verification, response, location management, traffic management [9], this process could reduce the duration of landslide material clearing and traffic release.

3.2.5 The institution that manage landslide disaster. During landslide occur, there are people who clearing landslide material, control traffic flow and sometimes repair road base or help traffic accident caused by landslide. Based on the experience of respondents, the institution or person who manage at landslide zone is shown in Figure 7.
Figure 7. The institution who manage landslide disaster zone

Based on respondent choice, it can be identified the institution or person who manage at landslide zone, Figure 7 indicate that police, local people and BPBD are the most often found in the site. Police manage traffic flow, local people usually help BPBD to remove landslide material, sometime local people control traffic flow. If there is an accident at landslide zone, ambulance with nurse will help at the site. BPBD manage the landslide disaster zone is safe for traffic flow and landslide disaster recovery work properly.

3.3 Traffic condition and traffic management

3.3.1 The condition of traffic flow. During landslide disaster at road network, traffic flow would move depending on the condition of landslide material that cover on road surface. If road surface is fully covered by landslide material, traffic flow should stop and wait for material clearing, but if road surface partially covered by landslide material, traffic flow still could move slowly at landslide zone. From data analysis, the condition of traffic flow during landslide disaster that seen by respondents during landslide disaster is as shown Figure 8.

Figure 6 shows that majority of traffic flow still could move at landslide disaster zone, this condition could be related with Figure 4, majority of landslide disaster covered partially road surface. Therefore, partially road surface could be use for moving traffic.
3.3.2 Traffic management. During landslide disaster, traffic flow may stop or still move depending on the condition of the landslide material covering the road surface. Changes in traffic flow conditions from two directions to one direction or stop, need to be controlled so the traffic flow could move easily at landslide zone after the material is cleaned. The type of traffic management that implemented at the landslide zone could be a road capacity management, traffic demand management and traffic priority management depending on the landslide material that covering at road surface, traffic volume, availability traffic control equipment and personnel that work at landslide zone. From the respondent information, the type of traffic control at the site is shown in Figure 9.

Figure 8. Traffic condition at landslide disaster zone

Figure 9. Type of traffic management at landslide disaster zone

Figure 9 indicates the type of traffic management that was conducted at landslide disaster zone, open and close the one way street is the highest found by almost 60% of respondent. This type of traffic management is conducted because about 70% landslide that occur is type 1 and type 2. At this landslide condition, there are a lane that still could be used for traffic flow, vehicle could move slowly at landslide zone. The other traffic management that is high enough experienced by respondent is rerouting of travel (27%), vehicle use other route to continue the travel, this is because landslide material block road lane as landslide type 3, 4, 5 and 6, total percentage of these types of landslide is about 28%. The percentage
of respondent have rerouting experience is almost similar with total percentage of landslide type 3, 4, 5 and 6.

3.3.3 Priority of traffic control. One of traffic management scenario is implementation of traffic control priority. This type of traffic management sometime is found at landslide disaster zone, this management is conducted to give priority to certain vehicle move first. It is because of the important purposes, such ambulance vehicle, or vehicle of head local government, the other priority is to certain vehicle, such as, priority to motorcycle and priority to truck. From data analysis, the priority traffic control at landslide zone could be seen in Figure 10.

![Figure 10. Priority traffic control at landslide disaster zone](image)

The experience about priority traffic control at landslide zone are explained in Figure 10, almost 53% of respondent are not assigned as priority vehicle, and about 47% ambulance and motorcycle are given priority to move first after landslide material clearing.

3.4 Impact of at landslide disaster
Landslide material that covered road surface could impede traffic flow if road width could be passed by vehicle. The vehicle wait for clearing landslide material. As explained in previous chapter, it would take time for clearing landslide material. The drivers and passenger wait for clearing process, this activities would impact as shown in Figure 11. In this survey, respondents could answer one or several options. This scenario to capture the condition that felt by passenger and driver in the site.

From Figure 11, it can be identified the impact of landslide disaster, the highest frequency of passengers and drivers saw that landslide disaster create long traffic jam, other passengers and drivers felt that they were feeling tired and lost of time because of landslide disaster. Passengers and drivers should wait for arriving the equipment then clean the landslide material until traffic flow could move at road lane passing the landslide zone, this process takes about 3-6 hours.
Figure 11. The impact of landslide disaster to passenger and driver
4. Conclusions
Based on the data analysis, it can be concluded that landslide disaster that occur at road network would impede traffic flow. Traffic flow would stop if landslide material cover road surface, vehicle should wait the clearing of landslide material or moving slowly. Duration of waiting time is depending on the volume of landslide material and method of clearing. Traffic flow would be managed depending on the condition of landslide disaster that cover the road surface. There are three traffic managements that could implemented in the site, traffic demand management, capacity management and priority management. The most traffic management that implemented during landslide disaster was traffic demand management, such as controlling traffic flow using open closed one-way road or manage in one-way road consecutively. The dominant impact of landslide clearing and traffic management to drivers and passenger are long queue and loss of time and tired waiting landslide clearing for about 3-6 hours.

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