Landslide Disaster Engineering in Tourism Potential Area

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Abstract. Regional developments in Indonesia have much potential to sustain regional living and environment, especially in tourism. Some regional areas have natural resources such as panoramic landscape, coastal zone, agricultural area, forest, rivers, waterfall, and even natural theme park as their selling point which become a tourism trend. However, these regions also face the risk of the excessive exploitation of natural resources. One of the risks found in the highland region, where the main attraction point is the landscape view, yet it is most likely to be vulnerable to the landslide. To prevent a natural disaster such as landslide, disaster engineering is one of the solutions. This research aims to develop suitable disaster engineering for regional with tourism potential as its main development sector. Certain articles are reviewed thoroughly to get the conclusion of what is the most suitable disaster engineering for regional development. The result of the research shows that disaster risk prevention is the most important aspect and possibly can be done by vegetation, infrastructure, and landscape engineering. In conclusion, regional development that uses natural resources utilisation in the highland region for panoramic-based tourism and landslide disaster prevention must be work simultaneously.

Keywords: tourism, landslide, disaster, regional, engineering

1. Introduction

The characteristic and potentials of a region determine certain sectors which lead to regional development. Most of the regions in Indonesia use agricultural as the main sector to develop its region. The other regions use fishery and tourism as its main sector. Tourism itself has a role in regional economics through sectors which contribute to tourism values in GDP [1]. Tourism components such as attraction, amenity, and accessibility are utilised as tools to develop economic development [2]. Tourism potential area is an area that has resources to become a tourism attraction. The resources can be natural, built, cultural, human, or social resources which can be utilised as attraction and develop it as a tool for regional development.

Tourism potentials are spread in various places whether it is a natural or human-built environment. Tourism attractions in many regions are commonly natural resources. Generally, the conflict between the exploitation of natural resources as tourist attractions and ecological environment protection is inevitable [3]. Natural resources are commonly used for tourism attractions due to the local community used to utilise it and those activities may be some attractions to other people with different lifestyle [4]. However, exploit natural resources as tourism attractions can backfire when it is lead to disaster risk where the region unable to set the limit of exploitation. The exploitation of natural resources for tourism without a development plan can become a threat and pressure toward the unique local environment [5].

The exploitation of natural resources leads to disaster risk in the area, including tourism potential area. The disasters which risk tourism area may vary, one of them is a landslide. Landslide disaster risk commonly mitigated by prepared tourism organisation, that will be resulting in tourism destination resilience [6]. Landslide
prevention is started from identifying geological feature which includes the possibility of failure mechanism and deformation characteristic. Those can be determined by monitoring surface displacement and groundwater level. Landslide occurs when the groundwater level rises, it will be adding the confined water uplift pressure where tuff layer strength is decreased which leads to surface slide [7]. Landslide occurrence commonly concentrated in a specific area which has a high elevated slope and has annual rainfall higher than 1.000 mm [8]. Therefore landslide disaster engineering is needed in the development plan of the regions which have tourism potential area to maintain tourism sustainability [9].

Tourism sustainability can be damaged by natural disaster including landslide. Landslide affects tourism by disabling the tourism area which leads to tourist reduction [8]. Tourist reduction disturbs tourism activity where the tourism economy is the first thing that is affected. Landslide disaster engineering is important to maintain tourism sustainability in the disaster risk area as seen on Figure 1.

![Figure 1. The Need Cause of Landslide Disaster Engineering](image)

Landslide occurrence in the world is concentrated in the Asia Pacific. The Asia Pacific has 48.4% cases in the world but dominate the causalities by 71.6%. It means countries in the Asia Pacific have less awareness of landslide disaster management and prevention [10]. The detailed data can be seen in Table 1. This research is important to describe a framework to prevent landslide disaster, especially in Indonesia.
Table 1. Landslide Occurrence in the World

| Region         | Cases | %    | Death | %    |
|----------------|-------|------|-------|------|
| Europe         | 39    | 12.3 | 687   | 3.9  |
| Asia Pacific   | 153   | 48.4 | 12614 | 71.6 |
| Americas       | 87    | 27.5 | 3153  | 17.9 |
| Africa         | 33    | 10.4 | 987   | 5.6  |
| Middle East    | 4     | 1.3  | 176   | 1    |
| **Total**      | 316   | 100.0| 17617 | 100  |

2. Research Method

Tourism sites are a part of the spatial pattern in a region, which also affected by the resilience of the ecological and social system [11] as seen on Figure 2. Landslide disaster engineering in tourism potential area analysed based on an extensive and detailed review on literature researches. Disaster prevention includes disaster engineering (ecological) and risk reduction (social). Disaster engineering divided into three categories: vegetation, infrastructure, and landscape. Each category assessed by at least four articles. As for risk reduction and disaster management, it is analysed by eight articles based on the important aspects in reducing the risk of landslide in tourism potential area.

Figure 2. Highland Tourism Potential Area Landslide Prevention

2.1 Landslide Disaster Engineering

Landslide prevention is not only to prevent the disaster but also will maintain the tourism sustainability aspects especially the environment. When the environment is maintained, the economic and social will following after. [12]. By preventing landslide in tourism potential area, the environment will be sustained and remain as it is while the economy from the tourism can be run when the environment is not changed, this will lead to social sustainability which utilises tourism as its social livelihood.

Indonesia is one of the countries in the world that has a tropical climate. All years contained two seasons: the dry season and rainy season. Every year in October to April, Indonesia faces the rainy season. This season is a challenge for everyone in the country along with the increasing disaster vulnerability, including landslide.

One of the landslides caused is rainfall that hit a steep slope and makes the surface slide [13]. Engineering the surface can prevent the landslide occurrence. In landslide disaster engineering, there are three aspects which
modify the surface to maintain the strength of the slope. The three aspects are vegetation, infrastructure, and landscape as seen on Figure 3. Each aspect is chosen based on their influence toward the physical engineering of landslide disaster.

![Landslide Disaster Engineering](image)

**Figure 3. Landslide Disaster Engineering Aspects**

Vegetation or land cover is very influential in some disaster event, including landslide. In most case, the number of landslide occurrence is less in the vegetation-covered area [14]. Therefore, an area with high landslide vulnerability will become resilient if the vegetation of an area is maintained.

Infrastructure is integrated with the vegetation-covered area to prevent vegetation loss in infrastructure development. Besides the vegetation cover, detailed geomorphic mapping is also important in infrastructure development along with hydrogeological mapping to recognise the landslide potential area [15]. Therefore, to prevent the loss caused by a landslide, sustainable development and infrastructure need to be planned well. In preparation for the development, the process also has to consider the landscape of the area.

Landscape also has a role in landslide occurrence where the short slope has a higher risk of landslide occurrence rather than a large slope due to cohesive strength [16]. Landscape also has a role in landslide occurrence where the narrow slope has a higher risk of landslide occurrence rather than wide slope due to cohesive strength [16]. In landslide vulnerable areas, the tourism sites often to be in the high area where the slopes are various. The development of a highland tourism area should examine the landscape variation due to the safety and landslide resilience tourism area.

### 2.2 Landslide Risk Reduction

To achieve the successful landslide disaster management in the tourism sector, it needs well collaboration between each stakeholder [17]. Landslide disaster management has some aspects which important to reduce landslide risk, namely governance, risk assessment, knowledge, education, preparedness, and response [18] as seen on Figure 4. Each aspect represents the ability of the social community around tourism sites with landslide vulnerability.

Governance aspect manages the disaster mitigation by policy and planning including regulatory system. Risk assessment aspect manages data collection, vulnerability assessment, scientific and technical innovation mechanism. Knowledge aspect manages public awareness. Education aspect manages learning, culture, and research. Preparedness aspect manages the capacity of the community to be resilient in landslide events. Response aspect manages emergency resources, response, and recovery, including participatory building and voluntarism.
3. Result and Discussion

Landslide risks prevention divided by Landslide Risk Reduction and Landslide Disaster Engineering. Landslide risk reduction focused on minimalizing the risk of the landslide which contain six aspects which are governance, risk assessment, knowledge, education, preparedness, and response. While landslide disaster engineering focused on controlling the landslide by engineering methods. Landslide disaster engineering contains vegetable, infrastructure, and landscape. The detailed flowchart can be seen on Figure 5.

3.1 Landslide Disaster Engineering

Landslide disaster engineering contains three aspects. Engineering or modification to these aspects can reduce the possibility of landslide occurrences. Vegetation, Infrastructure, and Landscape are aspects of landslide disaster engineering. The detailed aspects can be seen on Figure 6.
3.1.1 Vegetation.
Ecological system failure is one of the significant causes of landslides. Vegetation loss can damage the balance of the system because there is no natural water binder. Maintaining and modification of vegetation cover as an ecological system can prevent landslide [14]. Although the ecological system can prevent landslide, an extreme form of landscapes still has landslide risk. Landscape modification on an extreme form by covering it with vegetation is one of the landslide prevention engineering [19]. However, not all plants can do engineering. There are some particular plants suitable for landslide prevention. Uproot herbs and stress-tolerant plants are the most common plants to prevent landslide [20]. Besides those plants, some other plants also have functioned as supporting plants. Planting trees and grass is the best landslide prevention support [21]. Vegetation is an important part of landslide prevention. Vegetation also can be a tourism attraction like biodiversity attraction. Therefore, it’s not only useful as disaster risk reduction but also as tourism sector booster.

3.1.2 Infrastructure.
Engineered infrastructure must be built in the landslide risk area. Some engineered way to build infrastructure which can handle the land movement is already researched [22–24]. Soil-rock nail and stone set is better to prevent landslide [15]. Another engineered material to strengthen the infrastructure also being found. Suspension of colloidal silica can increase the strength of infrastructure, therefore the stronger infrastructure can prevent the landslide better [25]. Infrastructures which need to be strengthened are the public infrastructures. Road, electricity, water, attraction, water, transport, and housing are the most vulnerable infrastructures during landslide occurrences. These infrastructures must be engineered to prevent bigger loss [26]. Moreover, engineered infrastructure must be included in pre-disaster strategic planning because usual infrastructure can be vulnerable in risk zone [27]. Infrastructure is an engineered solution for landslide prevention. For tourism, it also useful as a barrier to protect tourism site attraction and the tourist itself.

3.1.3 Landscape.
Landscape evolve and need modelling to make it suitable with landslide risk. The modelling landscape includes the elevation and angle [24]. The landscape takes a big part on landslide occurrences. Landslide size reflects the
distribution of hillslope geometries. Therefore, measurement of the landscape engineering must be on the perfect measurement to make suitable landscape formation type which can prevent landscape [16]. Surficial formation type is obtained by landscape segmentation. Landscape in landslide risk area must be measured before modify or maintain it [23]. Although modify landscape can give bigger safety on the landscape, not all landscape must be modified. Safe access to landslide area is maintained landscape so if the landslide occurred, distribution of logistic will not be a problem [28]. The landscape is also important because it’s the natural defender form for landslide when the landscape remains as it was before, there will be no landslide can affect that area. If tourism can respect the form, it will be fine.

3.2 Landslide Risk Reduction

Landslide risk reduction contains 6 aspects which can manage to minimalize the risk of landslide. Governance, risk assessment, knowledge, education, preparedness, and response are the aspects of landslide risk reduction. The detailed framework can be seen on Figure 7.

3.2.1 Governance.

The equity and equality issues among the community are the most important thing from governance discussion on disaster occurrences. [29]. There is another important thing from the governance aspect to reduce the risk of landslide. Policy, planning, priorities and political commitment must be included in pre-disaster strategic planning to minimise landslide risk during the occurrences. Legal and regulatory systems are used to be a legal standing on distributing logistics on the occurrence. Integration with development policies and planning is important during a disaster occurrence not only landslide but also all type of disaster because development plant must be considering the disaster risk area, therefore disaster strategic planning must be integrated with development planning. Landslide pre-disaster strategic planning must include the integration with emergency response and recovery to make sure minimalization of the risk. Besides that, institutional mechanisms, capacities and structures also take part in disaster risk reduction by organising logistic distribution. Partnerships with a local institution to maintain the ecosystem of landslide risk area also can reduce the risk. Accountability and community participation of the partnership important to be maintained because it will help the community itself from landslide risk [18].

3.2.2 Risk Assessment.

Disaster risk assessment is an approach to find the negative impacts that may happen from a disaster [30]. Risk assessment is including the assessment of the disaster hazard, vulnerability, impact, and capacity. Data collection of hazard/risk and assessment is the first step of doing this aspect. Then the next step is the assessment of vulnerability/capacity and impact. In its calculations, the vulnerability assessment constituent variables depend on the scale of the study area [11]. The assessment then used to measure the strength of the disaster and vulnerability of the community itself. Scientific and technical capacities and innovation are needed to develop community resilience toward landslide disaster risk [18].

3.2.3 Knowledge.

Knowledge of the disaster commonly being taught in school, but experience commonly will give the knowledge of the physical vulnerability of the building. Landslide affects land and building, therefore knowledge about land and building during landslide must be known by the community [31]. The community must have public awareness and knowledge about the risk, prevention, and skills to cope with disasters. The public awareness and knowledge can reduce landslide risk if the community share it among themselves and teach each other about it. Information management and sharing among the community to spread the knowledge is the efficient landslide risk reduction [18].

3.2.4 Education.

Disaster education for the community for delivering the knowledge of landslide risk reduction is needed [32]. Education and training about disaster management, especially landslide disaster risk reduction, is the important thing to do to increase community resilience. Cultures, attitudes, and motivation are the support system for
education about disaster management. Learning and research from the local institution can improve education and develop contemporary landslide risk reduction [18].

3.2.5 Preparedness.
Preparedness and policy support are the main things in this aspect. The policy that is issued by the local government must be integrated with the preparedness of landslide risk. Early warning systems are the most important preparedness in the disaster risk area. Early warning system determines the preparedness of the disaster risk area. Besides the technical, preparedness also includes non-technical things. Organisational capacities of and coordination by local communities also determine the preparedness of certain risk area [18].

3.2.6 Response.
Response aspect is the aspect which used when disaster occurrence. Disaster recovery is the main thing of the response aspect [34]. Response aspect includes emergency resources and infrastructures. Logistic and human resources distribution managed in response aspect along with disaster infrastructure. Emergency response and recovery by local communities take part in response aspect by participation, voluntarism, accountability [18].
4. Conclusion

Tourism potential area has to make sure the sustainability of tourism itself. Sustainability includes protection from a natural disaster. Tourism potential area which utilises panoramic and natural resources commonly have landslide vulnerability. If the tourism potential area has landslide vulnerability, therefore it must consider the landslide risk. The tourism potential area can prevent landslide by landslide disaster engineering (physical) and landslide risk reduction (social). Landslide disaster engineering contains three aspects to prevent landslide which are vegetation, infrastructure, and landscape. While landslide risk reduction contains six aspects to minimize the impact of the landslide which are governance, risk assessment, knowledge, education, preparedness, and response. The landslide disaster engineering and landslide risk reduction are tools to protect landslide risk area which in the tourism potential area. Tourism potential area which protected from landslide can develop resilient tourism.

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