The Determination of Lightning Disaster Hazard Index Using Analytical Hierarchy Process

Fathul Mahdariza
Department of Environmental Engineering, UIN Ar-Raniry
fathul.mahdariza@ar-raniry.ac.id

Abstract In order to minimize the losses caused by lightning, a lightning disaster management system is compulsory. It should provide lightning disaster information in an area to get the risk values of lightning strikes. One way is to establish a lightning disaster risk map. The disaster risk map consists of hazard map, vulnerability map and capacity map. However, lightning yet has not been included in the regulation guiding the establishment of risk map for several disasters in Indonesia. This study is conducted to develop a process to determine general hazard index for lightning disaster.
Keywords lightning, hazard, index, analytical hierarchy process

1. Introduction

Lightning has a major impact on human, as 24,000 deaths and 240,000 injuries are reported due to lightning annually worldwide (Holle and Lopez, 2003). Lightning strike does not always lead to death on human, which according to Berger (2007), 80% of human struck by lightning survived. The death total number is more accurate than injuries, although exact death total numbers showed inconsistency in several well-documented data (Lopez et al., 1993; Richey et al., 2007). The number of injuries also may be even higher due to lack of reports (Lopez et al., 1993). According to Holle (2008), large portion of world regions were assumed to have an annual lightning fatality rate of 6 deaths per million per year in comparison to rate in developed countries, which are 0.3 deaths per million per year.

In Aceh Province, Subulussalam City is considered as one of area with high lightning hazard. Since Subulussalam City is situated near equator line, the area is surrounded by warm and hot air. Furthermore, Subulussalam City is located at hilly area, in the foot of Bukit Barisan Mountain (Subulussalam City in Figures 2016, 2016), and hence the wind from the west coast of Sumatra that blows eastward blocked by the hills. Both factors give the tendency of the convective cloud development, resulting to the high occurrence of storm and lightning throughout the year.

According to data obtained from Disaster Management Agency of Subulussalam City, there are 6 deaths and 25 injuries caused by lightning strikes in the past 6 year in Subulussalam City. All deaths are occurred in 3 Sub-districts, which are: Penanggalan, Simpang Kiri and Sultan Daulat. The lightning also leads to economic loss such as the broken electronic devices, as well.

In order to minimize the losses caused by lightning, not only in Subulussalam City, but also in other area in Indonesia, a lightning disaster management system is needed. The system should provide lightning risk information in an area to get the risk values of lightning strikes. One common way is by establishing a lightning disaster risk map. The disaster risk map consists of hazard map, vulnerability map and capacity map. In Indonesia, the guideline for establishing a risk map for natural disaster is available in the Regulation of the Head of Indonesian National Disaster Management Agency Number 2 Year 2012. However, in the regulation, lightning yet has not been included into total 9 types of disaster. Hence, this study will develop a process to determine general hazard index, as one of three risk indexes, for lightning disaster.

2. Analytical Hierarchy Process for Lightning Hazard Index Determination

To establish the possible options in obtaining decision, one method can be used is Analytical Hierarchy Process (AHP), which was firstly introduced by Saaty in 1980. The AHP procedure was designed for complex problems in collective decisions (Gruenig and Kuehn, 2005). It is a measurement methodology by pair-wise comparison and relies on expert judgments to obtain priority scales.

Saaty established several organized steps in order to make a decision based on as followed (Saaty, 2008):

1. Problem definition and suitable knowledge determination.
2. Decision hierarchy structure establishment.
3. Pairwise comparison matrices construction.
4. The weight of priorities determination.

For lightning hazard index determination, the first step is conducted through literature review, accordingly. Based on Husni (2004), there are 4 types of lightning: cloud to ground (CG), inner cloud (IC), cloud to cloud (CC) and cloud to air. The first type is considered as the most dangerous one, and hence the CG lightning density (CGD) is counted as the first variable. The other two selected variables are Land Surface Temperature (LST) and Annual Precipitation Rate (APR). These two variables play significant role in lightning quantity, as mentioned by Bourscheidt et al (2008) and Poelman (2010). Latitude does, in fact, influence lightning disaster (Jayaratne and Kuleshov, 2006), however is excluded from selected variables since it has been represented by the LST.

From all three variables, the CG density is set as the most important variables. This selection is supported by the fact that 3 Sub-districts in Subulussalam City, where the high death toll occurred, have highest CG density. Furthermore, the lightning is occurred simultaneously with rainfall, and hence, the APR becomes the following important variables. Accordingly, the AHP process is conducted to weigh these variables, and resulted as followed:

Table 1: The Result of AHP Process for Weighing the Selected Variables

Variables	CGD	LST	APR	Total Weight	Rounding in per cent (%)
CGD	1.00	5.00	3.00	9.00	60
LST	0.20	1.00	0.33	1.53	10
APR	0.33	3.00	1.00	4.33	30
Grand total				14.87	100

The Regulation of the Head of Indonesian National Disaster Management Agency Number 2 Year 2012 sets that each variable should be classed into 3 levels: low, medium and high. The CGD class is determined by the modification of classification by Hu et al (2014). Meanwhile, for LST and APR classes are set based on the climate of Indonesia. Hence, the final proposed lightning hazard index with its weight and class is determined as followed:

Table 2: The Proposed Lightning Hazard Index

Variables	Class			Weight
	Low	Medium	High	
CGD	< 0.5 CG/km^2/yr	0.5-2.0 CG/km^2/yr	>2.0 CG/km^2/yr	60 %
LST	<15 ^{0}C	15-24 ^{0}C	>24 ^{0}C	10 %
APR	< 1,000 mm/yr	1,000-3,000 mm/yr	>3,000 mm/yr	30 %

However, this proposed index is only applicable for Indonesia area. For other area with totally different climate, it is recommended to do some modifications, especially for class range. It is also possible that some other variables might be added.

3. Conclusion

Based on analysis of literature review, cloud to ground lightning density, land surface temperature and annual precipitation are set as selected factors for the calculation of lightning hazard. Using AHP process, the calculation gives result of 60%, 10% and 30%, respectively, for the weight of these factors. Complemented with the determined class for each variable, the proposed lightning hazard index has been produced. However, this proposed index should be tested and reviewed by the agency in charge in Indonesia, so that it might be added into the future guideline and regulation in establishing disaster risk map.

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