DEVELOPMENT OF RISK ANALYSIS TECHNIQUE AND ITS APPLICATION TO GEO-DISASTER MANAGEMENT IN INDONESIA

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論 文 名　：　DEVELOPMENT OF RISK ANALYSIS TECHNIQUE AND ITS APPLICATION TO GEO-DISASTER MANAGEMENT IN INDONESIA
(土砂災害リスクの評価手法の開発およびインドネシアの災害マネジメントへの適用)

区　　分　：　甲

論　文　内　容　の　要　旨

Even though not always as spectacular as earthquakes and tsunami, landslide is of the serious natural hazards since rainfall-induced landslides frequently occur during rainy season in Indonesia. There are 3307 fatalities caused by landslides from 1998 to 2013 with annual average of 207 fatalities per year. Indonesia is also listed as the top three countries with the highest percentage of landslide fatalities in 2003, 2007 and 2008. Therefore, landslide risk management is an important issue to mitigate disaster and there is an increasing awareness toward the need of landslide prediction and risk assessment tools due to the high number of annual fatalities in Indonesia.

The shift from focusing on disaster response to enhancing risk reduction of disasters has been started for disaster mitigation paradigm since 2007 when a law called *Undang-Undang* 24/2007 was enacted, which was driven by scientific society and government awareness after post-tsunami 2004 emergency response and subsequent rehabilitation and reconstruction phase. Risk analysis, as a basis for risk management, is an important issue in the Law. However, comparing with developed countries, the developing country like Indonesia has no adequate landslide inventory available, which is essential for hazard and risk analysis. Also, the technology and know-how of quantitative landslide risk analysis are not well established in Indonesia. For this reason, this study aims at (1) proposing an approach for field investigation to obtain the landslide data and generating a landslide inventory database which is necessary in risk analysis; (2) developing a technique of landslide susceptibility zoning based on the inventory map; (3) proposing a technique to infer rockfall source from rockfall inventory (4) developing rockfall risk zoning based on the distribution of rock boulders from the past rockfall events and the landform classification.

The thesis comprises the following chapters.

Chapter 1 introduces (1) disaster in Indonesia, (2) the shifting disaster mitigation policy in Indonesia, (3) the problems in landslide risk zoning in Indonesia, (4) the scope and objectives of this study, and (5) the organization of the thesis.

Chapter 2 reviews terminologies used in landslide risk analysis and risk management. Although some terminologies are often used interchangeably, the terminology misconception can generate confusion for the decision maker, urban planner, stakeholders and even young engineer. Thus, this chapter attempts to overview the difference between susceptibility, hazard and risk in landslide studies.

Chapter 3 proposes an approach for landslide inventory mapping considering conditions in Indonesia. It includes (1) a plan of items and parameters to be investigated which are necessary in risk analysis; (2) a field investigation procedure which combines the traditional geomorphological field survey method involving active participation from communities with the use of an innovative technology; (3) inventory mapping methods for both landslide and rockfall, which provide information related to location, landslide typology, landslide extents and elements at risk information; (4) statistical analysis to obtain necessary relationships between factors. The so-called *participatory landslide inventory mapping* method is expected to solve the problem of insufficiency of landslide inventory in Indonesia.

Chapter 4 develops a technique of data driven landslide susceptibility zoning based on the inventory map. The key issues in susceptibility zoning are (1) what susceptibility analysis method should be used and (2) what landslide causative factors should be considered. This chapter, at first, makes a comparison between the three widely used methods: a bivariate method called weight of evidence, a multivariate method called logistic regression and a soft computing called artificial neural network by using landslide data obtained from the participatory landslide inventory mapping. The merits and demerits of each method are summarized so that the most suitable method may be taken and necessary landslide causative factors may be considered in Indonesia, which is important in particular to the data availability and the characteristic of the study area. And then, a technique is proposed by combining the bivariate method of *weight of evidence* and the *logistic regression* based on the comparison analysis. Finally, landslide susceptibility maps are made using different method. It is shown that landslide susceptibility map using the proposed technique is of the highest accuracy by means of the success rate.

Chapter 5 proposes a rockfall susceptibility analysis method based on rockfall boulder inventory. The rockfall susceptibility analysis is generally carried based on potential rockfall source which is identified by field investigation. However, field investigation of rockfall source is not always possible for some areas in Indonesia. Thus, how to analyze rockfall susceptibility without the data of potential rockfall source is a great challenge. In this study, at first, a back analysis technique of GIS rockfall simulation is proposed for identifying potential rockfall source based on the distribution of boulders from the past rockfall events. Sensitivity analysis is conducted to discuss the effect of restitution coefficient, a major parameter related to the rebounding characteristic of a falling boulder in the simulation. And then, reliable trajectories, frequency and energy of rockfall are estimated once the potential rockfall sources are identified. Both frequency and energy map obtained from trajectory simulation represent the physical characteristic of rockfall movement and rockfall susceptibility degree.

Chapter 6 develops a technique of quantitative rockfall risk analysis by combining statistical and physical models based on landform classification. Since the movement behaviors of a falling boulder such as flying, rolling, sliding and bouncing are related to landform, firstly, an automated landform classification is proposed by applying unsupervised fuzzy k means based on a modified 9-unit model. And then, a practical formula of rockfall risk is presented based on landform classes. The trajectories and dynamic behavior of boulder when travel along the slope, and its interaction where elements are at risk are calculated based on the landform classes and they are used to evaluate the occurrence probability with particular boulder size in space and time. Finally, the risk to building and the risk to person inside the building are calculated based on the chance of loss (in monetary term) during specified time. The results show that landform class significantly influences the calculated risk and the chance of loss is the highest in the landform of transportational middle slope. Since the result from rockfall risk analysis indicates the chance of loss during specified time, it is very useful and helpful in landuse planning and in cost-benefit analysis of disaster mitigation countermeasure.

Chapter 7 summarizes and concludes the results and achievements of the study. Problems are also highlighted for future studies.