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Big Data-Based Landslide Risk Analysis for Buildings and Study on Linking Disaster Risk at the Building Unit

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Summary

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1. Introduction

In recent years, large-scale disasters such as the fire at Coupang's distribution center in Icheon, the flooding at Gangnam Station, and the landslide in Yecheon have occurred frequently, raising concerns about public safety. Disasters that occur in buildings and urban spaces are closely related to people's daily lives, which increases anxiety. In the case of buildings, the cost of damage is high, and physical injuries and deaths of building occupants may occur. Therefore, it is necessary to analyze the risk of disasters and catastrophes in buildings and prepare measures to ensure safety.

Landslides are particularly common during extreme rainfall events, causing physical damage to the building itself, as well as property damage and loss of life in the exterior of the building. In particular, landslides such as the one that occurred in Yecheon in July 2023 have caused large-scale loss of life and property damage to buildings and residents near forests, raising public concern about landslides. In response, various measures have been proposed in laws and institutions, and overseas countries are also seeking ways to minimize damage in various ways.

The characteristics and location of buildings have an important impact on the likelihood of disasters and the extent of damage. For example, buildings with large floor areas are relatively more likely to be affected by fires, low-lying buildings are more likely to be affected by floods, and the extent of damage is likely to increase if there is a basement. By using the disaster damage characteristics of buildings, it will be possible to identify buildings with high disaster risk and prioritize their inspection and management to ensure effective building safety.

Disaster risk at the building level is determined by a variety of factors, making it difficult to accurately predict or estimate. Recently, advanced technologies such as IoT, machine learning, deep learning, and big data have made it possible to analyze the disaster risk of buildings and urban spaces with greater accuracy than previous studies. By processing large amounts of data, it is possible to analyze the complex characteristics of buildings in an integrated manner and build risk analysis models for different types of disasters. Based on the disaster risk analysis of buildings, it is possible to prepare measures to ensure the safety of buildings.

This study aims to derive a method for analyzing various disaster risks that can damage buildings, and to establish a method for linking disaster risks. This study is the third year of a three–year research project, and the first and second years of the study focused on fire and flood risks in buildings. In the third year, we will develop an analysis method for building landslide risk as an additional disaster element, and develop and apply a method for linking multiple disaster risks.

Building disaster risk analysis model

	Building fire risk analysis model	Building flood risk analysis model	Building landslide risk analysis model	Model Integration
Year 1	Model Development Verification of Building Administrative Information Risk Analysis at the Building Unit Level			
Year 2	Improvement of Model Accuracy Introduction of Risk Concepts	Model Development		Integration of Results at the Building Unit Level
Year 3	Utilization of Existing Models	Utilization of Existing Models	Model Development	Risk Integration and Result Interpretation Based on Multi–Dimensional Matrix

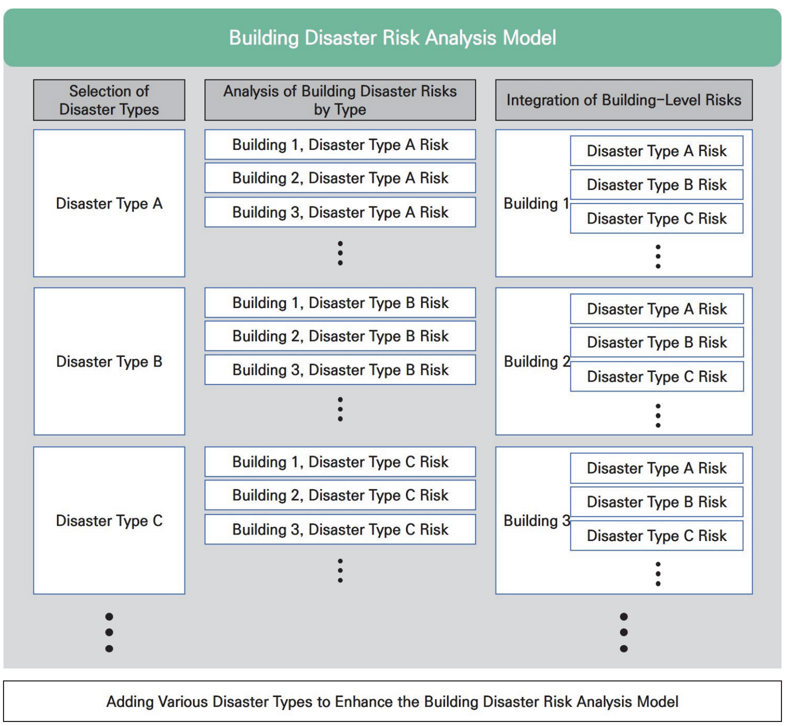
Development Status of Models by Year

This study is divided into four phases. First, the development of a building risk analysis model. The existing models are reviewed and the development framework of the model to be developed in this study is presented. Second, the development of a building landslide risk analysis model. This study aims to develop a method for analyzing the risk of building landslides, a type of hazard that was not included in the first and second studies. Third, the developed model will be used to analyze the risk of building landslides. In doing so, we aim to establish building risk data in the landslide sector for linking building disaster risk. Finally, we aim to link building landslide, flood and fire risks at the building level. In this way, we will verify the effectiveness of the building disaster linkage model and suggest policy improvements to enhance the disaster safety of buildings by synthesizing the implications derived from the entire research process.

Concept of Landslide Risk Analysis Model for Buildings

2. Development Direction of Disaster Risk Analysis Models for Buildings

The building risk analysis model developed in this study aims to fulfill three criteria. First, it should be able to respond to a variety of disaster types and be able to freely add or remove disaster types. Second, it should be able to represent disaster risk at the building level. Third, the results should be easy to understand so that countermeasures can be developed based on building disaster risk. To this end, a building disaster risk analysis model will be developed to analyze the risk of buildings for individual disaster types and to link the disaster risks analyzed at the building level.

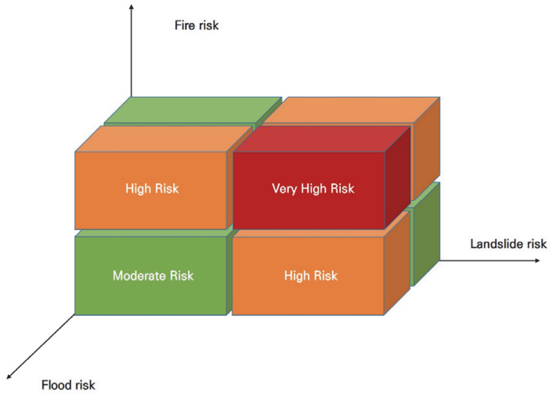


Concept of Developing Disaster Risk Analysis Models for Buildings

The analytical process of a building disaster risk analysis model can be divided into three steps. First, the type of disaster to be considered is selected. However, since the building disaster risk analysis model in this study aims to link the risks of building units, it is necessary to select the types of disasters that can cause damage to buildings. Second, the disaster risk of each building is derived by disaster type. For this purpose, it is necessary to develop a risk analysis method for each type of disaster, and this study aims to develop a building landslide risk analysis method following the building fire and flood risk analysis method in previous studies. Third, it is the step of linking disaster risks to building units. In order to link different disaster risks in the same building unit, this study applies the multidimensional matrix technique.

Multidimensional matrix is a tool that can organize and analyze data from multiple dimensions simultaneously, and is effective in systematically identifying interactions among risks and formulating comprehensive response strategies. It enables prioritization, scenario analysis, and the systematic management of complex data, taking into account the correlation between risks. However, the complexity and data requirements of a multidimensional matrix increase dramatically as the number of dimensions increases. Lack of sufficient data or difficulty in quantifying risks can reduce the reliability of the analysis, and the cost and time required to build and maintain them can be prohibitive for small organizations.

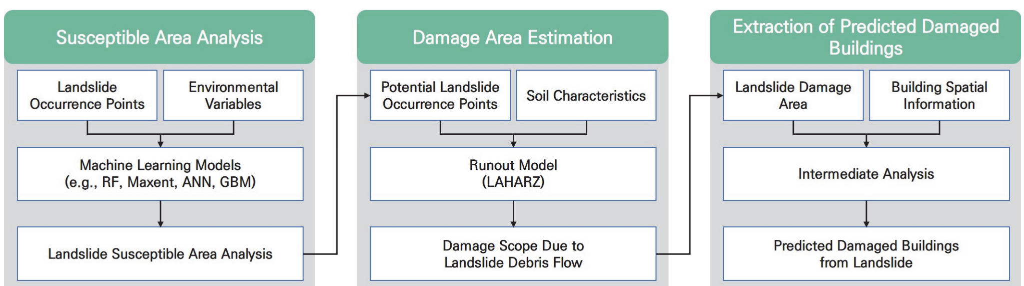
In this study, a multidimensional matrix is used to comprehensively analyze the fire, flood, and landslide risks of buildings at the building level. The risk level for each type of hazard can be determined for each building and the combined risk level for all three hazards can be analyzed. This allows you to assess a building's exposure to a combination of hazard types and develop strategies for specific situations.



Concept of Multi-Dimensional Matrix-Based Integrated Disaster Risk

3. Developing Landslide Risk Analysis Models for Buildings

The Building Landslide Risk Analysis Model consists of a three-step process: 1) identification of landslide-prone areas, 2) identification of landslide-prone areas, and 3) identification of buildings at risk of landslide damage.



Concept of Landslide Risk Analysis Model for Buildings

To identify landslide-prone areas, historical landslide occurrence data and environmental variables related to topography, soil, vegetation, and climate that affect landslide occurrence were used. To increase the reliability of the data used as the dependent variable, Pearson's correlation coefficient was used to exclude variables with high correlation. Machine learning based ensemble models such as ANN, XGBoost and GLM were used as models to analyze landslide prone areas. The AUC value for the accuracy analysis of the final model was 0.934, indicating that the model is highly accurate.

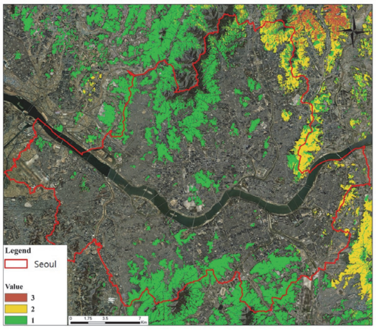
To derive the landslide hazard area, different runout models were considered and finally LAHARZ was used. LAHARZ is a software developed by the United States Geological Survey (USGS) for debris flow analysis and is widely used for landslide extent analysis. For the analysis, the possible landslide points were extracted from the results of the landslide-prone area, and information such as weather conditions, topography, geology, soil, and vegetation were used to analyze the extent of damage caused by debris flows in the event of a landslide.

Finally, we extracted the buildings that were within the damage area of the debris flows. For this purpose, the information from the building register was geocoded and converted into spatial data. The geocoding was performed using the geocoding tool of BIZ-GIS, and the analysis was performed on 596,244 buildings in Seoul.

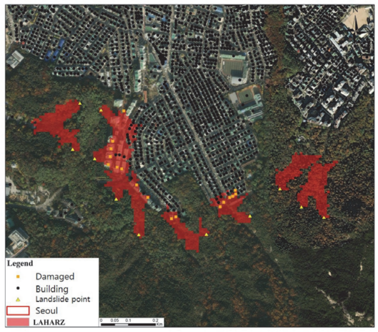
4. Integrated Analysis of Landslide, Flood, and Fire Risks for Buildings

Seoul was selected as the target city for the analysis of building landslide-flood-fire risk nexus. The flood and fire risks of buildings in Seoul were derived from the results of the second year of the study, and the landslide risk of buildings was analyzed in this study. The percentage of landslide occurrence points in the landslide-prone areas identified by the model analysis is 88.4%, which shows a relatively high accuracy.

To derive the landslide risk for each building, a landslide damage area analysis was conducted for Gwanak-gu, Seoul. The landslide-prone areas were extracted from areas where the landslide sensitivity analysis showed a sensitivity of more than 80%. A total of 19 possible landslide sites were identified in Gwanak-gu, and the LAHARZ model was run on these sites.



Analysis Results of Landslide Susceptibility in Seoul



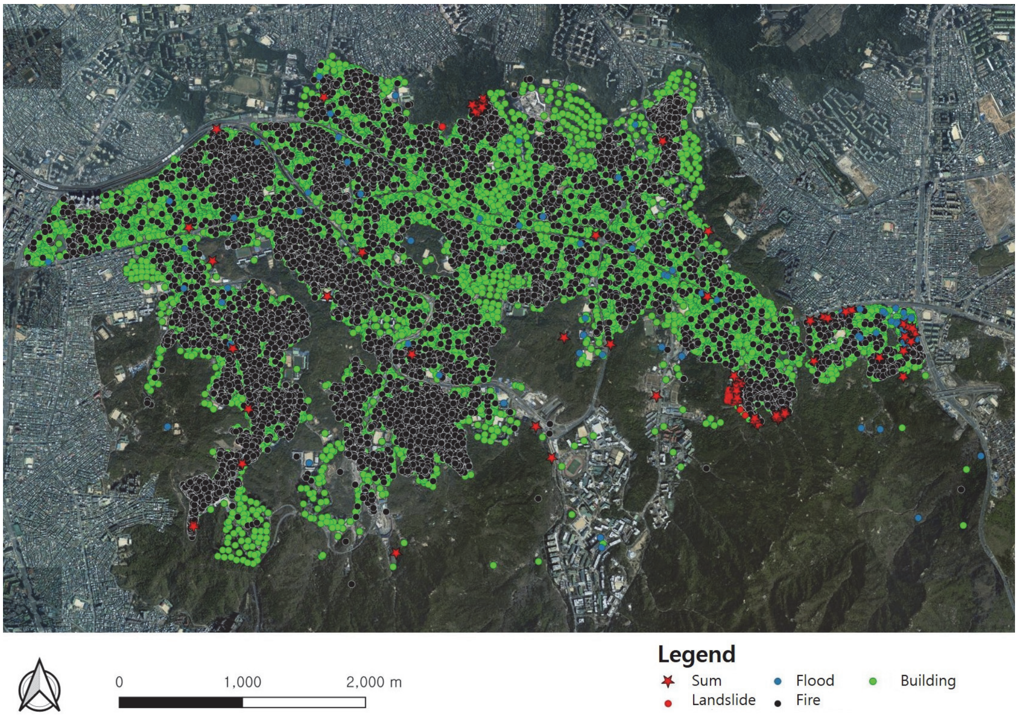
Example of LAHARZ Model Simulation Results

Analysis Results of Landslide Susceptibility and Damage Scope

After deriving the landslide damage area, an overlap analysis was performed with the building spatial information. In 10 of the 19 possible landslide sites, buildings were located within the damage area in the event of a landslide, but in the remaining 9 sites, no buildings were found to be damaged even if a landslide occurred. As a result, a total of 67 buildings in Gwanak-gu, Seoul are likely to be damaged in the event of a landslide.

Finally, we linked the building fire, flood, and landslide risks for Gwanak-gu, Seoul. By linking the three risks through a multidimensional matrix, the risk of buildings is classified into eight categories: "very risky", "risky", "somewhat risky", and "safe", according to the number of high-risk disaster types. Of the 32,079 buildings in Gwanak-gu, 48 buildings (0.15 percent) are at high risk of fire and flood, mainly located along rivers and boulevards. On the other hand, 47 buildings (0.15 percent) are at high risk of fire and landslide, mainly located in forested areas.

There were no buildings at high risk of both flood and landslide, and therefore no buildings at high risk of all three hazard types. A total of 95 buildings (0.3 percent) were at risk of two or more types of hazards, which is consistent with the sum of the number of buildings at risk of fire and flood, and fire and landslide. Based on the risk characteristics of each type of building disaster and the regional distribution of high-risk buildings, it will be possible to establish inspection areas, set inspection items, and prepare countermeasures to ensure the safety of buildings.



Integrated Results of Landslide, Flood, and Fire Risks for Buildings

5. Conclusions

This study aims to identify various disaster risks of buildings in advance by linking them and deriving basic data to propose efficient management measures based on them. In connection with the existing first and second year studies, we have analyzed the landslide, flood, and fire risks of buildings by developing a method for analyzing the landslide risk of buildings and introducing a multidimensional matrix technique that can link various risks. The results of the study show that the disaster risk of buildings can be predicted with high accuracy. The study also provides three policy implications.

First, it is necessary to strengthen data linkage at the building level. Various data have been used to analyze the disaster risk of buildings, but the data are currently managed inefficiently in individual systems. By integrating and distributing disaster-related information such as fire, flood, and landslide into a building life history system, data linkage should be improved and a system should be established to facilitate safety management activities such as statistical analysis of disaster safety, alerting, and emergency inspections.

Second, a building–level disaster risk identification system is needed. Currently, services that provide building–level disaster safety information are limited, and it is difficult for people to check whether their buildings are safe from disasters. By establishing a building–level disaster risk identification service using a building life history management system, residents and users can easily determine whether their buildings are safe and take countermeasures. This will help ensure disaster safety and increase the efficiency of building management.

Third, it is necessary to establish an integrated building safety platform. Currently, disaster information such as fire, flood, and landslide is managed by different organizations and is not integrated at the building level, which reduces efficiency. It is necessary to build an integrated platform where building occupants and users can check various disaster information such as heat wave, typhoon, etc. at a glance, in addition to fire, flood, and landslide. To do this, it is necessary to link data between different organizations and build additional disaster risk data that is missing.

Keywords

Big Data, Building Fire Risk, Building Flood Risk, Building Landslide Risk, Machine Learning