Chapter 3
Enhancing Seismic Risk Analysis Through Ensemble Learning:
A Case Study in Nepal

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ABSTRACT

This research presents a machine-learning-based framework for classifying earthquake-induced structural damage, addressing issues like class imbalance, noisy data, and lack of labelled samples. Ensemble classifiers like Random Forest, XGBoost, and Multi-Layer Perceptron are used to increase classification accuracy. Shapley Additive explanations (SHAP) are used to identify key damage levels. The model's effectiveness in emergency decision-making is evaluated using actual post-earthquake construction data from Nepal. The method provides evidence-based assistance for focused treatments, focusing on building age, material, anomalies, and soil type. The proposed structural evaluation process enhances conventional methods and offers an automated, scalable way to conduct accurate and quick structural assessments in disaster-risk locations. The focus on explainability of models ensures that outcomes are trustworthy and actionable for stakeholders in disaster management and urban planning agencies.

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1. INTRODUCTION

The initiative focuses on machine learning-based catastrophic risk management and earthquake damage prediction. It develops quick, exact, and simple models to categorize the structural damage that buildings sustain after an earthquake. This domain is essential for efficient emergency response, resource allocation, and recovery planning in seismically active places. Strong methods for predicting complex phenomena, such as the structural damage that structures sustain during an earthquake, have been built thanks to recent developments in machine learning. Accurate damage classification is essential for risk assessment, resource use, and catastrophe mitigation in seismically active areas. Present-day applications use machine learning models trained on actual post-seismic datasets, such as the one from the 2015 Nepal earthquake, such as RF, XGBoost, and MLP. Metrics like ROC-AUC, confusion matrices, and classification reports are commonly used to assess these models. SHAP helps emergency decision-makers by improving feature importance and model interpretability. Even with encouraging outcomes, there are still several issues with the mechanisms in place. Rare damage classes are underrepresented due to a severe class imbalance; noisy and sparse labelled data decrease training efficiency; generalizability is limited across various structural and regional contexts; and class-specific performance is obscured by reliance on macro evaluation metrics. Furthermore, traditional manual evaluation techniques are still laborious and challenging to scale, especially in major disasters.

The effectiveness of classical modelling techniques is often hampered by class imbalance, noisy samples, and the sparsity of labelled data. This article presents an end-to-end methodology that uses ensemble machine learning models, resampling techniques, and data preparation to forecast earthquake damage levels. The goal is to reduce the class imbalance and enhance model performance by combining under-sampling with SMOTE. SHAP is employed to determine the most crucial characteristics. To explain the model's choice. Using a multi-model approach, different models such as RF, XGBoost, and MLP are used, and their performances are evaluated using ROC-AUC scores, classification reports, confusion matrices, and accuracy.

In addition to increasing forecast accuracy, this approach transparently streamlines decision-making, which is crucial for implementation in real-world emergency reaction situations. This study builds on earlier research that demonstrated the effectiveness of machine learning in evaluating structural vulnerability using Nepalese post-earthquake building data, especially in choosing suitable models and identifying the most important building-level characteristics (Abdallah et al., 2020). Although pre-earthquake warnings, including abnormalities in land surface temperature detected by remote sensing, have been studied, their predictive value

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