Decision Support Tools for Allocating Economic Resources in Seismic Retrofitting of Residential Buildings

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The pressing need for effective seismic risk mitigation in Italy is driven by the fact that a large proportion of its residential building stock, composed primarily of masonry and reinforced concrete structures, lies within regions exposed to moderate-to-high seismic hazard. While urgent structural reinforcement is necessary, the reality of limited economic resources and the impracticality of retrofitting the entire building inventory necessitate a highly efficient approach to budget allocation. Current resource prioritization frameworks are overwhelmingly deterministic, a major shortcoming when dealing with the inherent, complex uncertainties of earthquake occurrence and damage propagation. Our research directly addresses this gap. The central scientific contribution is the development and application of a Two-Stage Stochastic Model with Recourse, representing a novel tool aiding decision-making for budget allocation in this uncertain environment. The model's core objective is to determine the most effective split of a cumulative budget between Proactive Strengthening (PS) measures, implemented before an event, and Reactive Repairs (RR), required post-earthquake, with the ultimate goal of minimizing the resulting social impact, specifically the number of displaced persons or uninhabitable buildings. This methodology introduces sophistication by enabling the application of different strengthening levels to a single structure, each yielding distinct costs and quantifiable vulnerability reductions. Crucially, the Second Stage repair costs are directly conditional upon the preventive action taken in the First Stage. The model is empirically grounded using building vulnerability data assessed via CARTIS and Macroseismic/Heuristic methods, alongside structural intervention and reconstruction costs calibrated to Italian standards and real-world data from the 2009 L'Aquila earthquake. Applying this model to a Sicilian case study reveals that the optimal PS-to-RR ratio is highly sensitive to the total budget. The analysis indicates that for lower and intermediate budget constraints, the most strategic allocation involves dedicating nearly all available funds to proactive strengthening actions. Conversely, as the available budget increases, the model suggests a more balanced strategy, distributing funds between strengthening and reactive repair. Analysis of the intervention types demonstrates that for smaller budgets, only the less costly local reinforcement measures are implemented; as the available budget increases, the model gradually includes more comprehensive and expensive interventions, such as seismic improvement and adaptation. In conclusion, the Two-Stage Stochastic Model offers a robust, quantitative tool aiding decision-making regarding resource allocation, demonstrating that a preventive strategy, formally guided by the explicit modeling of uncertainty, is the superior and most socially responsible path to managing seismic risk.

Keywords: Seismic hazard, Residential buildings, Resources allocation optimization, Stochastic model