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Multidimensional Prioritization Of Flood Mitigation Barriers Based On Resilience And Bowtie Modelling

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Urban areas around the world are struggling to adapt their spaces to the adverse impacts of climate change when analyzing the trend of natural disasters on a global scale (Da Silva, Alencar and De Almeida, 2022). Given this context, current challenges for public managers include the improvement of flood mitigation actions towards an efficient urban adaptation against extreme events. Consequently, it plays a fundamental role in the implementation of guidelines to promote urban resilience, thereby recommending reliable decisions to the government (Da Silva, Alencar and De Almeida, 2021).

Considering that flood might impact urban functioning in several ways, such as displacements, economic losses, cascading effects, and spread of infectious diseases, proper flood risk management combines results, information, and recommendations from safety to risk and resilience practices, which are used as essential information for the definition and prioritization of natural disasters mitigation barriers. In addition, the process encourages all actors involved (e.g. designers, operators, authorities, stakeholders, etc.) to promote and achieve an integrated and comprehensive vision of disaster management toward risk reduction-oriented governance taking into account the context of multiple and even conflicting objectives and constraints inherent in the flood risk management process, which implies a multidimensional perspective to tackle these decisions (De Almeida et al., 2015).

Various methods and approaches have been proposed for the management of risks associated with natural disasters. This way, emerging approaches that contribute to risk and resilience modeling employ a combination of scientific, technological, and participatory methods to effectively manage the complex and dynamic risks posed by natural disasters.

Based on this backdrop, this paper seeks to explore a prioritization framework of safety barriers for flood mitigation using a novel hybrid of an extended resilience triangle and bowtie modelling. In this paper, we extend a previous work on modelling the resilience triangle which is conceptualized as an extended 'V' shape of bouncing back over a period of time combined with the bowtie modeling which is also represented across the same time domain. In this modeling both the hazard in the bowtie modeling and the lowest point of the resilience triangle share the same instant of time (Labib, 2021).

The current paper explores three main modeling contributions, in the context of landslides and flood mitigation, that can aid the decision-maker in adapting urban areas against extreme events: resilience modelling, balanced-sensitivity analysis, and bowtie modelling.

First, we improve the resilience triangle by extending the assumption of straight lines and use instead an integral to capture the ‘deterioration’ of performance and the various scenarios of prevention and recovery guided by the characteristic capacities termed as the 4R’s of Robustness, Redundancy, Resourcefulness, and Rapidity.

Resilience as the ability to bounce back has been modelled as a ‘V’ shape and hence the name ‘triangle. This was based on the works of Burneau et al (2003), and Attoch-Okine et al (2009). Such modeling has been extended by the work of Ayuub (2014) where the straight line assumption has been relaxed to be a set of curves of scenarios of deterioration and recovery.

A review of various approaches for various quantitative metrics of resilience has been compiled by Cheng et al (2022). This compilation can be summarized into the following broad approaches for resilience quantification: hazard and recovery time, performance over time period, performance at a time instant, probabilistic indicators, and metrics with multiple indicators. The resilience has been combined with bowtie modeling and applied to the Covid-19 pandemic through the work of Labib (2021).

Second, we proposed a balanced-sensitivity analysis approach to optimize the type of barriers to be employed using a combination of a weighted sensitivity analysis goal programming algorithm, knapsack method for resource allocation (Jones et al, 2021, 2023; Jones and Tamiz, 2010), and the Haddon matrix (Haddon, 1980).

With the aid of Multicriteria Decision-Making approach (De Almeida et al., 2015), improvements can be achieved by considering the time dimension ie upstream and downstream, where more importance should be given to barriers nearer to the knot of the Bowtie (the hazard). Another modification can be realised through optimising the diversification of types of safety barriers.

Third, we improve the Bowtie model by setting a prioritized set of barriers across time on both sides of the bowtie; where prevention-type barriers are prioritized on the left side and response-type barriers are prioritized on the right side of the model.

The bowtie model is named after its shape and represents a visual framework for qualitatively mapping causal factors on the left side and consequences on the right side, and the main hazard as the knot of the bowtie. Although it is useful for communicating risk as a visual representation, it suffers from various limitations especially with respect of safety barriers as identified by Labib (2021). For example, it does not provide quantitative analysis. Also it does not provide any ranking in terms of sequence of safety barriers. Furthermore, safety barriers are not prioritized so no weights are assigned to safety barriers. In this paper we contribute to these limitations.

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