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Exploring The Need for Developing Impact-based Forecasting for Extreme Wind Events in the US

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SUMMARY:
Extreme wind events occur more often in the US than in any other country. Regardless of the good meteorological forecasts, wind events keep having significant effects on infrastructure due to the gap of knowledge between a hazard and its impact. For this reason, disaster managers are increasingly interested in knowing the impacts of natural hazards, which can help increase the resilience of the communities. In this paper, the use of Impact Based Forecasting (IBF) for extreme wind events in the US is explored in detail using a paradigm of Hazard – Exposure – Vulnerability – Impact. This paradigm reflects the integrated nature of impacts and the dependence of the outcome on the interaction of the three components. A recent wind event of significance in the US is used to illustrate the paradigm. The wind event is decomposed into different primary hazards. Each primary hazard and building characteristic is then used to obtain exposure and vulnerability. Machine learning (Text Mining) is used to obtain impact quantities from past events and fragility functions are implemented to quantify the descriptive impacts. Associated risk levels are then determined from the risk matrix. The results provide a detailed prediction of the damage and losses associated with extreme wind events.

Keywords: wind disaster, impact-based forecasting, infrastructure resilience, text mining

1. INTRODUCTION

Severe storms have caused the highest number of billion-dollar disaster events since 1980 and tropical cyclones are responsible for the highest number of deaths (NCEI 2018). Since 2018, $2B has been provided to recover North Carolina, followed by $542.6M from the action plan carried out by the N.C. Office of Recovery and Resiliency. In addition to $2.4B from individual and public assistance (FEMA, 2022) for Hurricane Ida in Louisiana, $1.27B was provided by the Louisiana Office of Community Development to strengthen the initial action plan for Hurricane Ida and the May 2021 severe storm.

The similarities between the action plans of North Carolina and Louisiana are that the plans took more than a year to complete and have been implemented simultaneously with the action plans of the previous Hurricanes. Specifically, Hurricane Florence's action plan has been launched parallel with Hurricane Matthew's (2016) action plan. Hurricane Ida's action plan will be initiated simultaneously with Hurricane Laura – Delta's (2020) action plan. For infrastructure to normally function before encountering other hazards, the action plan's life cycle should be minimized while maintaining an adequate level of resilience. To that end, it is pivotal to understand the impacts of imminent wind hazards on infrastructure.

The concept of using Hazard - Exposure - Vulnerability was used by Mileti (1999) to assess natural hazards in the United States. In the UK, the Met Office has implemented an identical idea, called Impact-based forecast and warning services (IBFWS) since 2011. Specifically, the likelihood of hazard is combined with the potential impacts obtained from Exposure and Vulnerability to form the risk matrix as shown in Fig. 1. It is then used to determine the corresponding risk level, followed by the dissemination to the audiences to minimize the damage and losses. Based on the foundation of IBFWS, Hemingway and Robbins (2020) developed the probabilistic Hazard-impact models to reduce subjectivity when determining the risk level from the risk matrix. The model was first used to predict real-time vehicle overturning rates under strong wind events in Great Britain. World Meteorological Organization (WMO) also published two guidelines for implementing multi-hazard impact-based forecast and warning services (WMO 2015, WMO 2021).

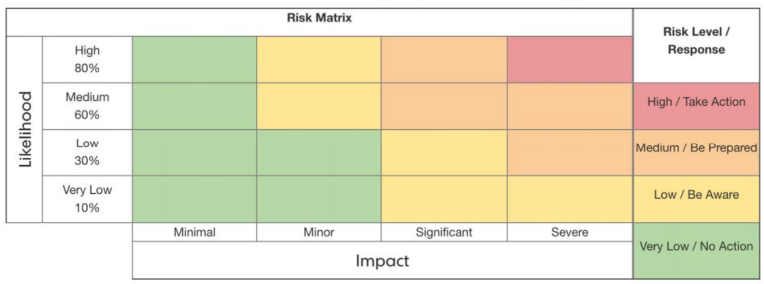

Figure 1. Risk Matrix

As for the development of the paradigm in the United States, it was first applied to flood damages and loss quantification. Nofal and Lindt (2020) used the model to propose a shift from a deterministic to a probabilistic approach to quantify different resilience scales of flood communities. An application to multi-hazard hurricane modeling was introduced thereafter (O. M. Nofal et al. 2021). Finally, a high-resolution regional-level hurricane risk analysis model was proposed with an example in North Carolina under the 2018 Hurricane Florence (O. M. Nofal et al. 2021). The results emphasized that quantifying the hurricane's risk in terms of Hazard – Exposure – Vulnerability can provide better resilience evaluation for coastal communities.

This paper investigates the need for developing an Impact-based forecasting model incorporating both the deterministic and probabilistic approaches that will provide more detailed results for risk analysis under extreme wind events. The damage at the building level can be provided descriptively through the impact tables or quantitatively from the fragility curves. It is a worthy attempt to use the data of the combined impact categories obtained from past events and user-defined archetype buildings for the impact-based forecast analysis.

2. METHODOLOGY

The building locations and hazard maps are used to determine the building's exposure. If the buildings are exposed to the hazard, the additional exposure inputs, including building characteristics and demographic information are derived from Hazus. Text mining will be used to recognize element and building-level impact data in damage reports. Sentences and numbers in the damage reports will be labeled as containing impact data. The labels are then used to train a machine learning model to recognize impact data.

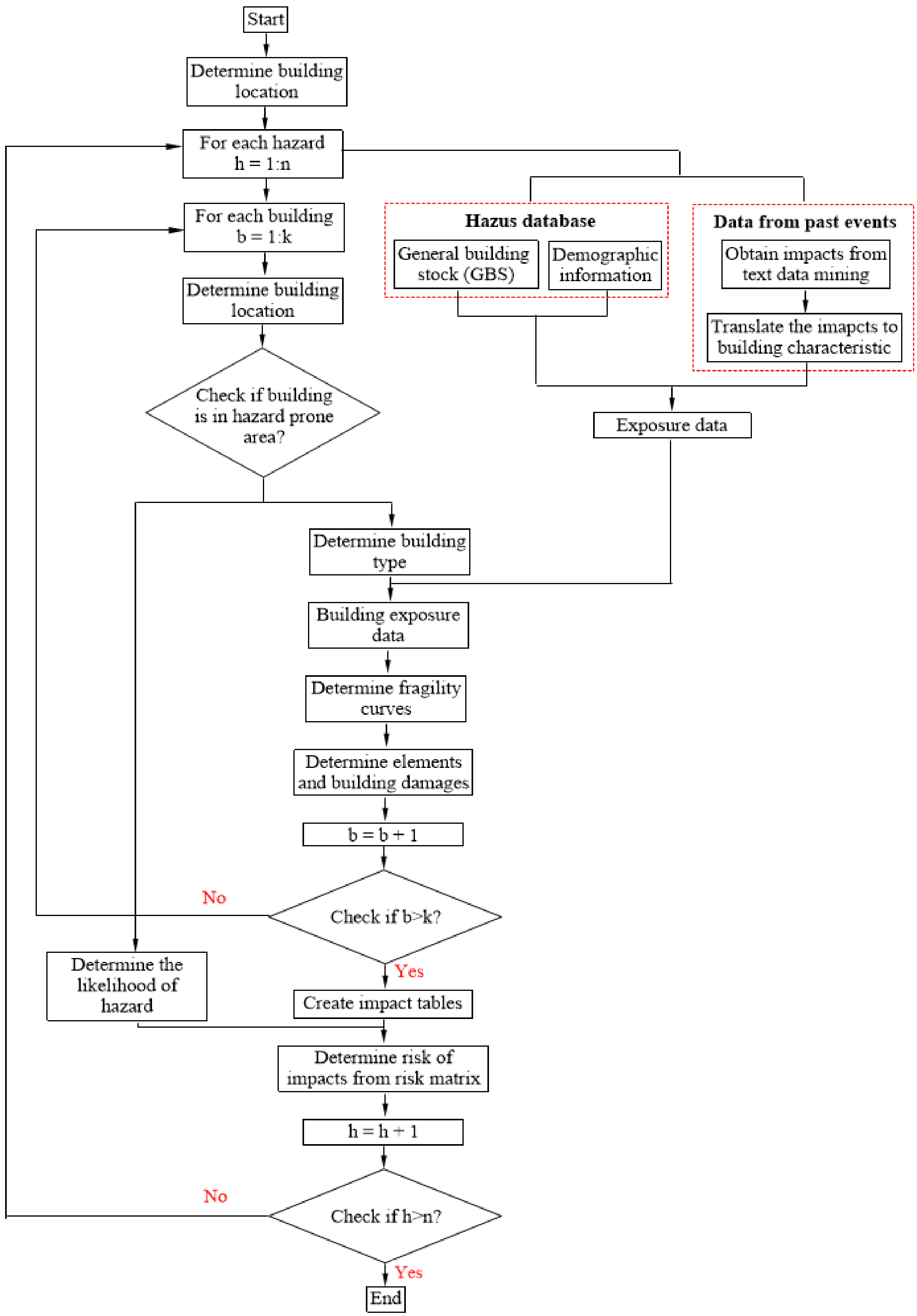

Figure 2. Flow chart for the analysis of each hazard

Hurricane Florence will be used to illustrate the workflow of identifying risk and associated impact for low-rise residential buildings in North Carolina. Overall, the analysis will be operated four times based on four primary hazards resulting from Hurricane Florence: wind, surge, rainfall, and debris. The flowchart for the analysis of each hazard is shown in Fig.2. Impact tables and risk matrixes associated with primary hazards from the extreme wind event are developed. For each primary hazard, graphic maps that visualize the hazard, exposure, vulnerability, critical element damage, building damage, and risk of impact are created. A descriptive response table associated with the predicted risk is also developed.

3. CONCLUSION

The new impact-based forecasting model combining text data mining and fragility functions provides a better understanding of the impact of extreme wind events and helps decision makers to be able to act and execute pre-agreed early actions. By identifying the set of corresponding primary hazards, the extension of the paradigm for other hazards including tornados and downbursts is highly possible.

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