

UNIVERSITI TEKNOLOGI MARA

**DEVELOPMENT OF A
WINDSTORM HAZARD INDEX
USING STRUCTURED DECISION-
MAKING AND DIMENSIONALITY
REDUCTION TECHNIQUES BASED
ON METEOROLOGICAL, BUILT
ENVIRONMENT AND SOCIAL
PARAMETERS**

NUR HID A YAH BINTI ZAKARIA

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ABSTRACT

The intensity of windstorms in Peninsular Malaysia growing in both frequency and severity and they are now becoming a significant threat to the public, infrastructure and the economy. Growing dangers aside, it is unfortunate that there is no comprehensive region-specific index that evaluates and categorizes the windstorm threat which results in ineffective planning and disaster mitigation. This study aims to develop a Windstorm Hazard Index (WHI) for Peninsular Malaysia to assess and categorize windstorm risks across the region. Four key objectives were pursued: (1) to identify the significant that influence windstorm events in Peninsular Malaysia. (2) quantifying the effects of these parameters using windstorm data from 2008-2018, numerical simulations (WRF-ARW), and urban morphology analysis via Envi-MET software, (3) formulating the WHI using Analytic Hierarchy Process (AHP) and Principal Component Analysis (PCA), and (4) validating the WHI with real windstorm cases from 2020-2024. The WHI classifies Peninsular Malaysia's regions into six risk levels: very low (0.1-0.5), low (0.501-0.6), moderate (0.601-0.7), high (0.701-0.8), very high (0.801-0.9), and extreme (0.901-1.0). Southern and central states such as Negeri Sembilan and Pahang exhibited very low risks, while moderate risks were noted in Kelantan and Terengganu. High-risk areas were concentrated in coastal and northern regions, including Penang, Kedah, and Pedis, where climatic and geographical factors intensified windstorm activity. Extreme-risk zones were identified in parts of Perlis and Kedah, necessitating robust disaster preparedness and mitigation strategies. The study revealed that environmental variables such as wind speed, temperature, humidity, and precipitation significantly influenced windstorm hazards. Coastal and high-altitude areas were particularly vulnerable due to stronger wind speeds and atmospheric instability. Land use and urban density further exacerbated windstorm impacts, especially in urban areas like Penang and Johor. Validation of the WHI confirmed its reliability, with extreme-risk events, such as those in Perlis and Kedah, correlating with high wind speeds, significant property damage, and disruptions. The WHFs practical application was demonstrated through accurate classification of past windstorm events across various states, reflecting both physical and environmental factors affecting storm intensity. In conclusion, the WHI provides a comprehensive framework for assessing windstorm risks and offers valuable insights for urban planning and disaster management. It emphasizes the importance of integrating environmental monitoring and resilient infrastructure into mitigation efforts. This study contributes to hazard preparedness by presenting a sensitivity map that highlights vulnerable regions, guiding policymakers toward effective interventions. Future refinement of the WHI is recommended to adapt to evolving environmental conditions and enhance disaster resilience across Peninsular Malaysia.

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CHAPTER 1

INTRODUCTION

1.1 Research Background

Windstorms are among the most destructive and frequent natural hazards worldwide, capable of causing severe damage to infrastructure, ecosystems, and human life (Lee et al.,2017). In Peninsular Malaysia, the occurrence of windstorm events has notably increased in recent years, raising alarms about the vulnerability of both urban and rural regions. These events can cause widespread disruption, including structural collapse, power outages, transportation failures, and even loss of life. The urgency to understand and manage windstorm risks is growing, especially in light of rapid urban development and climate variability.

Despite the increasing frequency and severity of windstorms in the region, there remains a significant knowledge gap in understanding the specific environmental and meteorological factors driving these hazards. Key parameters such as wind speed, atmospheric pressure, temperature, humidity, topography, land cover, and urban infrastructure can influence windstorm formation and intensity (Merz et al., 2020a) However, the interactions and relative importance of these parameters in the Malaysian context remain poorly quantified. Addressing this gap is critical for developing predictive tools that can inform risk mitigation and enhance early warning systems.

The impacts of windstorms are further compounded by their short life cycles many lasting less than 30 minutes leaving little time for response and evacuation (Astray-Caneda III, 2013) . As such, there is an urgent need for proactive planning and preparedness strategies. Current approaches to disaster risk management in Malaysia often fall short due to the lack of localized, data-driven hazard models. This leads to limited spatial understanding of exposure, sensitivity, and vulnerability among stakeholders and decision-makers, particularly when multiple hazards such as floods and landslides occur concurrently with windstorms (Lawrence, 2015).

To address these critical issues, this study proposes the development of a Windstorm Hazard Index (WHI) tailored for Peninsular Malaysia. The WHI will be constructed using a multi-criteria decision-making approach that integrates significant meteorological and environmental parameters. Through analytical methods such as the