The Role of Building Information Modeling (BIM) in the Construction of Disaster Resilient Infrastructure

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Presentation Outline

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Introduction

- Infrastructure plays a crucial role in a country's economic and social development (Mitchell, 2014)
- In Malawi, infrastructure has been affected by a variety of natural disasters
- Since 1980, more than 50 disasters caused by hydrometeorological events, such as floods, have affected millions of people and infrastructure (NPC, 2021)
- In the last decade alone, there have been over 25 disasters associated with heavy rainfall events
- The most recent, being Tropical Cyclone Freddy, which caused fatalities, injuries, and significant damage to agriculture, homes, and infrastructure in Southern Malawi

Introduction…

- These frequent disasters incur substantial infrastructure repair and reconstruction costs
- To mitigate the adverse effects, the government has implemented several models, policies, and strategies to manage risks associated with disasters and lay groundwork for the construction of disaster resilient infrastructure (Kamanga et al., 2020)
- Disaster resilient infrastructure is one that has the physical capacity to withstand hazards and disasters, minimizing loss of functionality, recovery time, and costs
- This involves the analysis of various hazard data to enable architectural improvement and establish a budget and schedule
- However, incorporating hazard data (such as flood maps, seismic information, and climate forecasts) into infrastructure design phase is a challenge

Introduction…

- Building information modeling (BIM) has emerged as a tool capable of addressing this challenge
- BIM facilitate the integration of different categories of hazard data into design models, which enables designers to subject infrastructure models to adverse environmental conditions, including risks encountered over infrastructure lifecycle (Zhang et al., 2013)
- This paper is a literature review focusing on illuminating the integration of BIM systems throughout the construction lifecycle of disaster resilient infrastructure

Methodology

- This study was done using a comprehensive systematic literature review which is a foundation for building an understanding for a study field
- Global publications of BIM role/benefits and adoption were used
- The literature considered was limited to publications between 2010 and 2023
- Google scholar was selected as the primary tool for locating scholarly articles
- The keywords and phrases used to locate relevant articles included:

"BIM; Disaster resilient infrastructure; BIM role or benefits or adoption; Developing countries; BIM challenges or barriers; Malawi; Disaster"

- A total of 55 relevant publications were reviewed

Findings

Stage	BIM Role/Benefits	Citation
Conceptual Stage	Visualisation for stakeholders	Mahamood & Fathi, 2022; Goyal et al., 2020
	Cost estimation and feasibility studies	Messaoudi & Nawari, 2020; Vieira et al., 2017; Vignali et al., 2021
	Sustainability analysis	Rad et al., 2021; Kang et al., 2022
	Collaborative decision making	Costin et al., 2018; Ghaffarianhoseini et al., 2017; Yang et al., 2021
	Regulatory compliance checks	Messaoudi & Nawari, 2020; Zou et al., 2017
	Visualising design alternatives	Bennett & LS, 2012; Kang et al., 2022; Caldera et al., 2021
	Risk Assessment	TohidiFar et al., 2021; Dao et al., 2021; Mamo et., 2023; Argyroudis et al., 2022

Findings…

Stage	BIM Role/Benefits	Citation
Design Stage	3D visualisation and coordination	Mahamood & Fathi, 2022; Boddupalli et al., 2019; Khanmohammadi et al., 2020
	Clash detection and resolution	Mahamood & Fathi, 2022; Costin et al., 2018; Rajendran et al., 2014
	Sustainability optimisation	Rad et al., 2021; Wang et al., 2019
	Design documentation and drawings	Costin et al., 2018; Eastman, 2011; Sacks et al., 2018
	Communication with stakeholders	Mahamood & Fathi, 2022; Yang et al., 2021; Ghaffarianhoseini et al., 2017
	Disaster impact simulation	Alibrandi, 2022; Lozi, 2022
	Material choice for disaster resilience	Yang et al., 2023; Kaewunruen et al., 2020; Rad et al., 2021

Findings…

Stage	BIM Role/Benefits	Citation
Construction Stage	3D model as a reference for construction	Eastman, 2011; Arayici et al., 2012; Costin et al., 2018
	Clash detection and coordination during construction	Costin et al., 2018; Ghaffarianhoseini et al., 2017; Charehzehi et al., 2017
	Real-time progress monitoring	Ershadi et al., 2021; Hardin, 2015; Kaewunruen et al., 2021
	Documentation management	Nawari & Ravindran, 2019; Arayici et al., 2012; Becerik-Gerber et al., 2012
	Commissioning and handover	Caldera et al., 2021; Hardin & McCool, 2015; Saldanha, 2019; Ershadi et al., 2021
	Disaster risk reduction measures	Argyroudis et al., 2022; Zou et al., 2017; Liu et al., 2019; Chiroli et al., 2023

Findings…

Stage	BIM Role/Benefits	Citation
Operation and Maintenance	As built documentation for ongoing maintenance and upgrades	Klein et al., 2012; Woo et al., 2010; Kassen et al., 2015; Ensafi et al., 2022
	Maintenance planning and scheduling	Wanigarathna et al., 2019; Kaewunruen et al., 2022; Salzano, 2023
	Asset management and tracking	Kivits & Furneaux, 2013; Lu et al., 2020; Wijeratne et al., 2023
	Emergency response planning and training	Colker, 2020; Drogemuller, 2015; Dakhil & Alshawi, 2014
	Lifecycle cost analysis and financial planning	Becerik-Gerber et al., 2012; Rad et., 2021; Sanchez et al., 2014
	Collaboration and communication for facility management	Siriwardena et al., 2013; Eastman, 2011; Sepasgozar et al., 2020
	Disaster preparedness and recovery	Cao et al., 2023; Sertyesilisik, 2017; Lei et al., 2020; Cheung et al., 2018

Discussions

- The escalating impact of climate-induced natural disasters poses a growing threat globally, demanding effective measures and international collaboration to enhance resilience
- The construction industry, a pivotal player, can significantly mitigate disaster effects and contribute to recovery by fortifying its resilience through efficient project management and robust built environments
- BIM and advanced technologies significantly boost the construction industry's resilience to natural disasters, with pre-disaster applications enhancing resilience in conceptualization, design, and construction, and post-disaster implementations strengthening operations and maintenance

Discussions…

Pre-disaster

- BIM for project management and design, support tasks such as 3D modeling and scheduling for better project understanding
- BIM aids in initial cost estimation, budget planning, and feasibility studies, fostering collaboration among stakeholders and enhancing decision-making during the design phase
- BIM tools also play a role in evaluating environmental impact for sustainable practices and automate regulatory compliance checks, ensuring adherence to construction codes and standards
- BIM is instrumental in exploring design alternatives, visualizing concepts, and assessing disaster risks
- BIM models facilitate precise design and construction execution, offering real-time progress monitoring, and serving as a centralized repository for project documentation

Discussions…

- BIM also plays a crucial role in streamlining commissioning procedures, ensuring a smooth transition from construction to operation

Post-disaster

- BIM models streamline asset management and boost maintenance productivity for infrastructure
- BIM enhance emergency response preparedness by offering real-time information on existing infrastructure
- Shifting to BIM-based approach and integrating facilities management is crucial for boosting disaster resilience in the construction industry
- However, true resilience demands a comprehensive strategy, encompassing policy, collaboration, education, community engagement, and government-media involvement

Discussions…

- Policies and regulations should also promote collaboration among various stakeholders, including professional organizations, construction firms, public entities, and universities, emphasizing international cooperation
- Educational institutions and construction-related entities must integrate comprehensive disaster management education, incorporating innovative tools like BIM, and emphasize the interdisciplinary aspects to enhance global disaster resilience training for built environment professionals and diverse stakeholders

Conclusions

- This study raises BIM awareness in the Malawian construction industry
- It highlights that BIM can contribute to resilience at various construction stages, including conceptualization, design, construction, operation and maintenance, and reconstruction
- To fully harness the benefits of BIM, the study suggests the importance of promoting its adoption among policymakers and stakeholders, integrating it into education and training programs for built environment professionals who play a crucial role in managing technical and managerial aspects before and after disasters

References

- Mitchell, T. (2014). Introduction: life of infrastructure. Comparative Studies of South Asia, Africa and the Middle East, 34(3), 437-439. https://doi.org/10.1215/1089201X-2826013
- NPC. (2021). Malawi Priorities: Disaster Risk Reduction. Copenhagen Consensus Center. https://copenhagenconsensus.com/publication/malawi-priorities-disaster-risk-reduction#:~:text=The%20wide%20variety%20of%20natural,by%20these%20extreme%20weather%20events
- Kamanga, T. F., Tantanee, S., Mwale, F. D., & Buranajarukorn, P. (2020). A multi hazard perspective in flood and drought vulnerability: Case study of Malawi. Geogr. Tech, 15, 132-144. http://dx.doi.org/10.21163/GT_2020.151.12
- Zhang, S., Teizer, J., Lee, J., Eastman, C. M., & Venugopal, M. (2013). Building information modeling (BIM) and safety: Automatic safety checking of construction models and schedules. Automation in Construction, 29, 183-195. https://doi.org/10.1016/j.autcon.2012.05.006

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