Building Information Modelling for Post-Disaster Reconstruction

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Disasters can be defined as “an action that causes a threat to life, well-being, material goods, and the environment from the extremes of natural processes or technology” . Natural and human-made disasters affect the built environment. The large-scale damages caused by infrastructures and houses are accompanied by injuries and fatalities, reversal or stagnation of the local economy, and mislaying of livelihood sources. Post-disaster reconstruction (PDR) has been gaining more attention in the world because of frequent natural environment disasters, such as earthquakes tsunamis, and other activities, caused by human-made factors, such as conflicts and wars, which have raised the importance of PDR.

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1. Introduction

Disasters can be defined as “an action that causes a threat to life, well-being, material goods, and the environment from the extremes of natural processes or technology” [1]. Natural and human-made disasters affect the built environment. The large-scale damages caused by infrastructures and houses are accompanied by injuries and fatalities, reversal or stagnation of the local economy, and mislaying of livelihood sources [2]. Post-disaster reconstruction (PDR) has been gaining more attention in the world because of frequent natural environment disasters, such as earthquakes tsunamis, and other activities, caused by human-made factors, such as conflicts and wars, which have raised the importance of PDR [3][4]. Following the increasing occurrence of major disasters, stakeholders are increasingly initiating reconstruction to reduce the effects of those disasters on the built environment; however, reconstruction projects are considered challenging to implement in terms of capacity and resources [5][6]. Nevertheless, PDR is categorized as unpredictable, chaotic, complex, and dynamic; this indicates several difficulties due to its differences when compared to traditional construction [7]. Conventional construction has been used in reconstruction projects, whereas some features, such as a single lifecycle of project and inflexibility in aspects of creating a specified project duration, have proven unsatisfactory for the complications encountered in the aftermath of the disaster [8][9]. Reconstruction projects face immense challenges, such as time and cost overrun, and low quality, due to several factors during the implementation [10][11].

The main target of any PDR project is to attain high levels of beneficiary satisfaction. Nonetheless, PDR projects frequently fail in their pre-planned objectives; for example, only 20% of building requirements are fulfilled, with most buildings being constructed on a temporary instead of permanent basis [12]. Moreover, the efforts of reconstruction projects have lacked any suitable coordination mechanism and monitoring framework [13]. If not properly handled, those challenges can result in ineffective PDR project delivery and often a failure of the project [3][14]. Successful delivery of PDR projects is important to restore essential services and return to normalcy after disasters [15][16]. Controlling the cost, time, and delivery of the projects are the most significant factors in evaluating successful PDR projects, which will be heightened by utilizing one of the emerging technologies or processes that aim to enhance productivity and sustainability in PDR projects.

Building information modelling (BIM) is considered one of these technologies, and has altered the ways of the practices of architecture, engineering, and construction industries during recent years. It brings stakeholders in construction to a single productive platform [17]. Additionally, BIM is not only a technical facility but also an activity concept for efficient project delivery linked to advanced technology [18]. It utilizes information and communication technologies to enhance growth monitoring, increase performance, and boost productivity [19]. Consequently, numerous studies have been conducted on BIM within the construction industry from the perspective of the industry, organizations, and users [20][21]. Other studies have focused on BIM in terms of adoption, implementation, challenges, and benefits, as well as strategies and application [22][23].

In this regard, BIM is an intelligence tool that has a wide range of benefits, such as collaboration among parties, visualization of project execution, enhanced productivity and efficiency, enhanced communications, improved design quality, cost estimation, positive return on investment, enhanced sustainability, faster development while reducing the cost and rework, on-time delivery capabilities, clash detection, better contract documentation, life-cycle cost data management, and competitive edge [24][25][26]. These and other advantages have prompted governments, institutions, and organizations to implement BIM in their construction industries [27][28][29].

With the increasing significant challenges in PDR, it is necessary to apply BIM in reconstruction projects after disasters to overcome these challenges [30][31][32][33]. Despite some reported evidence on the benefits of BIM within the construction industry, the adoption of BIM for the PDR field has not received adequate attention. Moreover, there is a lack of adoption of modern methods for managing PDR that is a cause of low boost. However, a few studies have focused on utilizing BIM for PDR. For example, Dakhil and Alshawi [31] explored the BIM applications that supported building disaster management, including disaster planning, site planning, and existing condition modelling, and its advantages; they suggested that future research should empirically study all applications of BIM during the project life cycle and identify the advantages of those applications. Nawari and Ravindran [32] listed the potential advantages of BIM in conjunction with blockchain for post-disaster rebuilding. The authors presented a framework for an automated reconstruction permitting process by using Hyperledger Fabric; however, no evidence of actual implementation has been found. Messaoudi and Nawari [33] proposed a virtual framework based on BIM and a generalized adaptive framework for speeding up the permitting process of reconstruction in the aftermath of the disaster in Florida; however, this framework was limited to the time of the permitting process for rebuilding.

On the other hand, scientometric analysis is being used by a growing number of scholars to address subjective problems in literature reviews [34][35][36][37]. In contrast, there is a paucity of scientometric analysis in the current studies that explore trends of BIM applications in the PDR projects field. It is worth noting that the PDR in question is still in its early stages for BIM adoption. One of the challenges is determining the need to start setting the foundations for best frameworks and guidelines for promoting the BIM applications in PDR projects. Experience has shown that it is never too early to start preparing for reconstruction in the aftermath of the disaster. Accordingly, it is crucial to map the related literature in order to address this research gap. This study is unique because it explores trends of BIM applications in PDR from an objective standpoint.

2. Post-Disaster Reconstruction

The present study found various expectations for research regarding PDR, with the majority focusing mainly on short-term recovery and ignoring long-term reconstruction. Lyons [38] reported that PDR is primarily unsuccessful in achieving its pre-planned goals, where the failure rate of the reconstruction project is beyond 50% [39]. Delays in the process of reconstruction projects might reduce the effectiveness of the reconstruction and make achieving the goals more challenging [40][41]. Based on the work that needs to be carried out post-disaster, several other challenges can influence the timeframe of the work [8]. PDR mainly relies on economic, cultural, social, environmental, and political elements [42]. Various problems emanate because of inadequate supports from poor governance, local government, poor infrastructure, and insufficient knowledge and preparedness. Moreover, other elements that positively influence the reconstruction processes include addressing technical problems, integrated information, short and long-term approaches, and public participation in dealing with technical problems [43]. PDR is influenced by the locations of the destroyed areas because this influences the assigned funds, technical resources, and labors [5]. Despite the value of community contribution in PDR, it is important to ascertain timely information during the reconstruction period [44]. Moreover, although PDR offers chances to lower vulnerability and enhance sustainability in disaster-affected communities, most reconstruction projects have failed to meet these objectives [45]. Hence, PDR is highly demanding and complex, and needs several well-coordinated and diverse actions.

Moreover, during the past few years, several studies have been conducted in this area to investigate various variables exerting either negative or positive impacts on a PDR project [3][4][5][9][10][44][46][47][48]. The unsuccessful outcomes of PDR projects are due to the following: inadequate availability of resources, delays in project implementations, inadequate coordination amidst participation organizations, corruptions, substandard quality of the reconstructed building, inadequate community participation, inadequate road access, inadequate government support, problems with land availability and acquisition, ineffective design, conventional 2D documentation, manual schedule and cost estimation, and inadequate extensive resource database. Meanwhile, available evidence shows that PDR has a discouraging record of performance in recent decades due to ineffective reconstruction strategies that do not consider the concept of collaboration among parties, have coordination procedures, and adopt modern communication technology.

Some examples of good reconstruction practices include the establishment of construction guidelines and permitting processes, as well as the certification of reconstructed housing to ensure safe building construction [33]. However, these practices have taken a long time to obtain approval. Since acting quickly is the priority in a post-disaster situation, the traditional manual cost estimation methods are not feasible. Based on previous studies, there is a need for a tool to calculate the construction cost of the proposed alternatives quickly and automatically [49]. Reconstruction requires avoiding disintegration between stakeholders, such as governments, emergency agencies, builders, relief organizations, designers, and disaster victims [7], and also demands the enhancement of delivery practices in order to provide higher value to stakeholders [6][16]. Moreover, non-participatory reconstruction practices by donors have caused conflicts and resentment among the local people [13]. This study found that the existing practices of reconstruction projects must be compiled and evaluated to determine whether the proposed conceptual designs satisfy construction codes. Accordingly, it is susceptible to personal mistakes, and any updates need to be performed manually, which causes budget overruns and schedule delays in reconstruction projects.

The current status of managing PDR mostly seeks to avert factors causing failures in the PDR projects. However, information about post-disaster management is ongoing, and most desire to learn from past failures. To overcome these challenges, PDR must integrate short and long-term reconstruction to guarantee that housing and infrastructure requirements are fulfilled throughout the short-term recovery phase, while lowering vulnerability and enhancing sustainability and resilience in the long-term reconstruction phase. As a result, the goal of efficient PDR may be attained by integrating the requirements of stakeholders with modern management practices and information technology. Therefore, to accomplish the PDR project on schedule, within the allocated cost and with a high standard of quality, there is a need for more objective studies to boost productivity and sustainability in PDR projects. Besides, it is necessary to adopt new developments in modern management practices and information technologies, such as building information modelling, that can enhance the competitive environment of PDR projects based on the improvement of product quality, on-time project delivery, and cost reduction.

3. Building Information Modelling (BIM)

BIM is a powerful tool adopted in construction projects to control project information and building design in digital form throughout the life cycle of buildings. This approach allows for information interchange and interoperability between parties [50]. BIM has been widely promoted as an nD modelling platform to improve collaboration and communication, and its scope has expanded from “geometric models (3D) to include time (4D), costs (5D), sustainability of the environment (6D), and facility management (7D)” [51]. Its significant advantages in terms of cost and time savings, as well as increased performance and boosting of productivity, have compelled construction players to adopt and rapidly implement it within several fields [52]. A 3D building model that identifies the clash detection, improves the schedules of construction, and prepares construction site activities was shown to be useful in everyday operations [53]. Additionally, the utilization of BIM has provided significant benefits to the construction industry over the project’s life cycle, from conceptualization to demolition [54]. Significant advantages found in the design phase of the project include improved visualization, efficiency, and productivity, whereas, during the construction phase, BIM can consist of cost analysis and auto-scheduling, allowing for improved project coordination and on-time delivery capabilities [55]. Accordingly, BIM encourages all professionals and stakeholders to contribute and collaborate to produce a high-quality output throughout the project.

Diffusion and implementation are two steps in the BIM adoption process. With effective BIM adoption and implementation, complexities and challenges in project management will be greatly minimized as and partnerships between stakeholders will be enhanced over the project life cycle [28][56][57][58]. The implementation of BIM is expanding rapidly in the international context [57]. The implementation of BIM has reached a significant level in several developed world countries, such as the UK, USA, Australia, and Canada [23][59]. However, there is a low rate of BIM adoption not only in developing nations but also in certain developed world nations. While BIM implementation in developing nations has fulfilled the criteria during the design stage, it is substandard during the construction stage, as highlighted by Memon et al. [60]. Due to the fragmentation in implementation, BIM applications are delayed, and the construction industry remains at a low level of BIM adoption. Numerous factors contribute to this fragmented activity, including a lack of understanding about BIM implementation activity, a lack of coordination and collaboration between different disciplines, a lack of practice standards and guidelines, resistance to changing current working practices, and a lack of skill in preparing BIM plans and the ability to use them with stakeholders effectively [61]. It can be noted that the studies centering on BIM in developing world nations have highlighted the dynamics of BIM adoption and are working to improve BIM maturity in these countries. The barriers to BIM adoption must be addressed, and the benefits must be explained adequately to achieve comprehensive adoption of BIM and avail its benefits. Thus, future studies concentrating on this research field should perform case studies in which real-life adoption of BIM is validated.

Moreover, the utilization of BIM applications has progressively appeared as an essential topic in the PDR field [31][33]. Despite some reported evidence on its benefits within the construction industry, the adoption of BIM for PDR has been limited, and stakeholders and decision-makers in the aftermath of the disasters are not excited to adopt and implement BIM into its reconstruction practices. Therefore, there is a need to transfer from traditional reconstruction practices to BIM-based practices. Using BIM applications in reconstruction projects for planning, design, and construction will create and manage support key data and reports. The application of BIM in reconstruction projects will result in more cost-effective design and enhance communications and collaboration among parties.

It can be concluded that several studies address BIM adoption in general; however, few researchers concentrate on BIM adoption challenges and factors that influence adoption without providing a comprehensive perspective and an in-depth understanding of issues for the adoption of BIM. Nevertheless, there is a lack of studies on factors influencing BIM adoption in various dimensions of BIM research.

4. Disaster Management and Building Information Modelling

The role of BIM applications in disaster management is evident through all phases, from pre- to post-disaster. For instance, Drogemuller [62] conducted a study on the benefits of BIM in disaster response. This study looked at a variety of scenarios in which BIM was used during several disaster stages, including prevention, preparation, reaction, and recovery. By employing augmented reality to simulate multiple disaster scenarios and the best method to cope with them, the BIM can aid disaster preparation. Facility managers can utilize BIM to track key building data to undertake maintenance and prevent the failure of the building in the event of a disaster. Additionally, BIM can create 3D visualizations to assist stakeholders and decision-makers in comprehending the larger picture of a disaster’s effect and speed up assessments of building damage. This could result in more effective planning and cooperation between stakeholders [62]. Dakhil and Alshawi [31] explored the BIM applications that support building disaster management, including disaster planning, site planning, and existing condition modelling, and their advantages; they suggested that future research should empirically study all applications of BIM during the project life cycle and identify the advantages of those applications. Based on the study by Kim and Hong [63], BIM information is a helpful tool for the response of disaster management. They presented a “BIM-based disaster integration information system” that allowed first responders to locate the event occurrence rapidly. In addition, Wang et al., [64] debated using a BIM-based virtual environment to assist the residents’ building management during disasters. This suggested system employed BIM data and the game engine to design a real-time evacuation path for building occupants via a mobile device [64]. Moreover, Boguslawski et al., [65] proposed an algorithm for calculating evacuation routes during disasters. This method used a combination of BIM and geographic information system (GIS) to display the fastest egress route. According to Lyu et al. [66], BIM and GIS integration might be a valuable tool for city managers to identify flooding disasters.

Additionally, Sertyesilisik [67] emphasized the contribution of BIM to the resiliency of disaster from the pre- to the post-disaster stage, particularly by impacting the performance of the rescue operations, rebuild activity, and supply chain. Academic researchers and decision-makers play a vital role in encouraging and educating the public regarding the significance of BIM as a tool for improving the robustness of built environments throughout the disaster management process [67]. Moreover, Kermanshachi and Rouhanizadeh [49] developed a BIM-based automatic cost estimation methodology to aid in reconstruction by providing a precise estimate of the required budget. This tool is limited in that it can only estimate the cost of repairing a damaged structure. The tool has had one upgrade that allows it to reflect changes in estimated costs, although it still has limitations [49]. Furthermore, it was shown that very few studies on BIM integration with blockchain have been undertaken for PDR permits [32]. Nawari and Ravindran [32] listed the potential advantages of BIM in conjunction with blockchain for post-disaster rebuilding. The authors presented a framework for automated reconstruction permitting in any transaction by using Hyperledger Fabric. As a result, paperwork, additional processing fees, and the time it takes to obtain building permits, can all be reduced; however, no evidence of actual implementation has been found. Hence, more time is required to investigate blockchain in PDR. Thus, greater research into BIM and PDR combined with blockchain will provide a major boost in the PDR field.

Furthermore, Biagini et al. [68] recommended using BIM for historic building rehabilitation. The fundamental concern for historical building repair is on-site management. A detailed information plan for executing the restoration plan should be provided in order to provide effective on-site management. While conventional restoration techniques produce 2D maps with inadequate data, BIM allows users to create a 3D model of historic buildings and link it to a range of data. In the case of “Basilica di Collemaggio”, which was harshly damaged because of a seismic event, BIM was used for a variety of purposes, including various scenario simulations for making decisions regarding the collapsed dome, structural analyses, and construction site management through various stages of the rebuild [69]. Xu et al. [70] established a BIM-based seismic damage evaluation based on FEMA P-58. Stakeholders can proceed through a virtual walkthrough to see how damage and loss are distributed, given that FEMA P-58 necessitates thorough information in order to forecast building damage. Furthermore, the BIM model for building components may be at various levels of development. Messaoudi and Nawari [33] proposed a virtual framework according to

BIM and a generalized adaptive framework for speeding up the permitting process of reconstruction in the aftermath of the disaster in Florida. The fundamental procedure of the framework was to determine the type of construction permission, apply the newly established permitting framework, and decide on the permit result. The framework was able to save around 18 h for each permit, though this framework only considered the time of the permitting process of reconstruction. Finally, Rad et al. [71] provided an integration of BIM and life cycle cost (LCC) to assess building resiliency following an earthquake all through the building service life. The proposed BIM-LCC approach mainly was employed during the conceptual stage. The suggested BIM-LCC approach has limitations in that it only addresses earthquakes as one of the potential events that can occur through a building's life cycle. Nevertheless, in order to completely assess the building resiliency, numerous events of a disaster may need to be examined, and the consequences of each on the structure explored, which might be a topic for future research.

According to the literature, the available evidence shows that utilizing BIM for PDR is still nascent. Even though BIM has a great deal of potential within the construction industry, the challenges of adopting BIM in PDR have not been extensively studied. Moreover, BIM applications in PDR, such as scheduling, communication and collaboration, project delivery, demolition process, and deconstruction have been neglected in past studies. The majority of previous studies on BIM for PDR have been conducted using a qualitative approach. As a result, further primary investigations should be undertaken to adopt BIM for PDR projects fully. Researchers recommend setting the foundations for a better framework and guidelines for BIM adoption through the planning, design, and construction phases of PDR projects. Researchers also suggest that the barriers to adopting BIM for PDR projects within the construction industry be identified. In addition, studies concentrating on this research field in the future should perform quantitative research approaches in which real-life adoption of BIM is validated, which will be helpful for decision-makers. Finally, researchers recommend the integration of BIM for PDR with blockchain and/or other technology, such as the Internet of Things (IoT), which will provide a significant boost in the PDR field.

References

1. Gunes, A.E.; Kovel, J.P. Using GIS in Emergency Management Operations. J. Urban Plan. Dev. 2000, 126, 136–149.
2. Barakat, S. Housing Reconstruction after Conflict and Disaster. Humanit. Policy Group Netw. Pap. 2003, 43, 1–40.
3. Bilau, A.; Witt, E.; Lill, I. Practice Framework for the Management of Post-Disaster Housing Reconstruction Programmes. Sustainability 2018, 10, 3929.
4. Anilkumar, S.; Banerji, H. An Inquiry into Success Factors for Post-Disaster Housing Reconstruction Projects: A Case of Kerala, South India. Int. J. Disaster Risk Sci. 2021, 12, 24–39.
5. Ismail, D.; Majid, T.; Roosli, R. Analysis of Variance of the Effects of a Project's Location on Key Issues and Challenges in Post-Disaster Reconstruction Projects. Economies 2017, 5, 46.

6. Bilau, A.; Witt, E.; Lill, I. Analysis of Measures for Managing Issues in Post-Disaster Housing Reconstruction. Buildings 2017, 7, 29.
7. Ismail, D.; Majid, T.A.; Roosli, R.; Samah, N.A. Project Management Success for Post-Disaster Reconstruction Projects: International NGOs Perspectives. Procedia Econ. Financ. 2014, 18, 120–127.
8. Dias, N.T.; Keraminiyage, K.; DeSilva, K.K. Long-Term Satisfaction of Post Disaster Resettled Communities. Disaster Prev. Manag. Int. J. 2016, 25, 581–594.
9. Enshassi, A.; Chatat, T.; von Meding, J.; Forino, G. Factors Influencing Post-Disaster Reconstruction Project Management for Housing Provision in the Gaza Strip, Occupied Palestinian Territories. Int. J. Disaster Risk Sci. 2017, 8, 402–414.
10. Alaloul, W.S.; Alfaseeh, A.S.; Tayeh, B.A.; Zawawi, N.A.W.A.; Liew, M.S. Reconstruction of Residential Buildings Post-Disaster: A Comparison of Influencing Factors. AIP Conf. Proc. 2019, 2157, 020035.
11. Charles, S.H.; Chang-Richards, A.; Yiu, T.W. What Do Post-Disaster Reconstruction Project Success Indicators Look like? End-User’s Perspectives. Int. J. Disaster Resil. Built Environ. 2021.
12. Islam, M.Z.; Kolade, O.; Kibreab, G. Post-Disaster Housing Reconstruction: The Impact of Resourcing in Post-Cyclones Sidr and Aila in Bangladesh. J. Int. Dev. 2018, 30, 934–960.
13. Bilau, A.; Witt, E. An Analysis of Issues for the Management of Post-Disaster Housing Reconstruction. Int. J. Strateg. Prop. Manag. 2016, 20, 265–276.
14. Capell, T.; Ahmed, I. Improving Post-Disaster Housing Reconstruction Outcomes in the Global South: A Framework for Achieving Greater Beneficiary Satisfaction through Effective Community Consultation. Buildings 2021, 11, 145.
15. Sospeter, N.G.; Rwelamila, P.M.D.; Gimbi, J. Project Management Challenges for Post-Disaster Reconstruction Projects in Angola: A Public Sector Perspective. Int. J. Manag. Proj. Bus. 2020, 14, 767–787.
16. Aliakbarlou, S.; Wilkinson, S.; Costello, S.B.; Jang, H. Client Values within Post-Disaster Reconstruction Contracting Services. Disaster Prev. Manag. 2017, 26, 348–360.
17. Yaakob, M.; Ali, W.N.A.W.; Radzuan, K. Identifying Critical Success Factors (CSFs) of Implementing Building Information Modeling (BIM) in Malaysian Construction Industry. AIP Conf. Proc. 2016, 1761, 020105.
18. Abdirad, H. Metric-Based BIM Implementation Assessment: A Review of Research and Practice. Archit. Eng. Des. Manag. 2017, 13, 52–78.
19. Abd Hamid, A.B.; Mohd Taib, M.Z.; Abdul Razak, A.H.N.; Embi, M.R. Building Information Modelling: Challenges and Barriers in Implement of BIM for Interior Design Industry in Malaysia.

IOP Conf. Ser. Earth Environ. Sci. 2018, 140, 012002.

20. Howard, R.; Restrepo, L.; Chang, C.-Y. Addressing Individual Perceptions: An Application of the Unified Theory of Acceptance and Use of Technology to Building Information Modelling. Int. J. Proj. Manag. 2017, 35, 107–120.
21. Kim, S.; Park, C.H.; Chin, S. Assessment of BIM Acceptance Degree of Korean AEC Participants. KSCE J. Civ. Eng. 2016, 20, 1163–1177.
22. Al-Ashmori, Y.Y.; Othman, I.; Rahmawati, Y.; Amran, Y.H.M.; Sabah, S.H.A.; Rafindadi, A.D.; Mikić, M. BIM Benefits and Its Influence on the BIM Implementation in Malaysia. Ain Shams Eng. J. 2020, 11, 1013–1019.
23. Georgiadou, M.C. An Overview of Benefits and Challenges of Building Information Modelling (BIM) Adoption in UK Residential Projects. Constr. Innov. 2019, 19, 298–320.
24. Wong, J.; Wang, X.; Li, H.; Chan, G. A Review of Cloud-Based BIM Technology in the Construction Sector. J. Inf. Technol. Constr. 2014, 19, 281–291.
25. Shehzad, H.M.F.; Ibrahim, R.B.; Yusof, A.F.; Khaidzir, K.A.M. Building Information Modeling: Factors Affecting the Adoption in the AEC Industry. In Proceedings of the 2019 6th International Conference on Research and Innovation in Information Systems (ICRIIS), Johor Bahru, Malaysia, 2–3 December 2019; pp. 1–6.
26. Haruna, A.; Shafiq, N.; Montasir, O.A. Building Information Modelling Application for Developing Sustainable Building (Multi Criteria Decision Making Approach). Ain Shams Eng. J. 2021, 12, 293–302.
27. Chan, D.W.M.; Olawumi, T.O.; Ho, A.M.L. Perceived Benefits of and Barriers to Building Information Modelling (BIM) Implementation in Construction: The Case of Hong Kong. J. Build. Eng. 2019, 25, 100764.
28. Gamil, Y.; Rahman, I.A.R. Awareness and Challenges of Building Information Modelling (BIM) Implementation in the Yemen Construction Industry. J. Eng. Des. Technol. 2019, 17, 1077–1084.
29. Saka; Chan A Scientometric Review and Metasynthesis of Building Information Modelling (BIM) Research in Africa. Buildings 2019, 9, 85.
30. Gan, L.; Wang, Y.; Lin, Z.; Lev, B. A Loss-Recovery Evaluation Tool for Debris Flow. Int. J. Disaster Risk Reduct. 2019, 37, 101165.
31. Dakhil, A.; Alshawi, M. Client’s Role in Building Disaster Management through Building Information Modelling. Procedia Econ. Financ. 2014, 18, 47–54.
32. Nawari, N.O.; Ravindran, S. Blockchain and Building Information Modeling (BIM): Review and Applications in Post-Disaster Recovery. Buildings 2019, 9, 149.

33. Messaoudi, M.; Nawari, N.O. BIM-Based Virtual Permitting Framework (VPF) for Post-Disaster Recovery and Rebuilding in the State of Florida. Int. J. Disaster Risk Reduct. 2020, 42, 101349.

34. Sepasgozar, S.M.E.; Hui, F.K.P.; Shirowzhan, S.; Foroozanfar, M.; Yang, L.; Aye, L. Lean Practices Using Building Information Modeling (BIM) and Digital Twinning for Sustainable Construction. Sustainability 2020, 13, 161.

35. Adegoriola, M.I.; Lai, J.H.K.; Chan, E.H.; Amos, D. Heritage Building Maintenance Management (HBMM): A Bibliometric-Qualitative Analysis of Literature. J. Build. Eng. 2021, 42, 102416.

36. Wu, Z.; Yang, K.; Lai, X.; Antwi-Afari, M.F. A Scientometric Review of System Dynamics Applications in Construction Management Research. Sustainability 2020, 12, 7474.

37. Qureshi, M.I.; Khan, N.; Qayyum, S.; Malik, S.; Hishan, S.S.; Ramayah, T. Classifications of Sustainable Manufacturing Practices in ASEAN Region: A Systematic Review and Bibliometric Analysis of the Past Decade of Research. Sustainability 2020, 12, 8950.

38. Lyons, M. Building Back Better: The Large-Scale Impact of Small-Scale Approaches to Reconstruction. World Dev. 2009, 37, 385–398.

39. Ika, L.A.; Diallo, A.; Thuillier, D. Critical Success Factors for World Bank Projects: An Empirical Investigation. Int. J. Proj. Manag. 2012, 30, 105–116.

40. Tagliacozzo, S. Government Agency Communication during Postdisaster Reconstruction: Insights from the Christchurch Earthquakes Recovery. Nat. Hazards Rev. 2018, 19, 04018001.

41. Rouhanizadeh, B.; Kermanshachi, S.; Dhamangaonkar, V.S. Identification and Categorization of Policy and Legal Barriers to Long-Term Timely Postdisaster Reconstruction. J. Leg. Aff. Disput. Resolut. Eng. Constr. 2019, 11, 1–10.

42. Chang, Y.; Wilkinson, S.; Potangaroa, R.; Seville, E. Identifying Factors Affecting Resource Availability for Post-disaster Reconstruction: A Case Study in China. Constr. Manag. Econ. 2011, 29, 37–48.

43. Sharma, K.; KC, A.; Subedi, M.; Pokharel, B. Post Disaster Reconstruction after 2015 Gorkha Earthquake: Challenges and Influencing Factors. J. Inst. Eng. 2018, 14, 52–63.

44. Sadiqi, Z.; Trigunarsyah, B.; Coffey, V. A Framework for Community Participation in Post-Disaster Housing Reconstruction Projects: A Case of Afghanistan. Int. J. Proj. Manag. 2017, 35, 900–912.

45. Shi, M.; Cao, Q.; Ran, B.; Wei, L. A Conceptual Framework Integrating “Building Back Better” and Post-Earthquake Needs for Recovery and Reconstruction. Sustainability 2021, 13, 5608.

46. Rouhanizadeh, B.; Kermanshachi, S.; Nipa, T.J. Exploratory Analysis of Barriers to Effective Post-Disaster Recovery. Int. J. Disaster Risk Reduct. 2020, 50, 101735.

47. Rouhanizadeh, B.; Kermanshachi, S. Barriers to an Effective Post-Recovery Process: A Comparative Analysis of the Public’s and Experts’ Perspectives. Int. J. Disaster Risk Reduct. 2021, 57, 102181.

48. Baarimah, A.O.; Alaloul, W.S.; Liew, M.S. Post-Disaster Reconstruction Projects in Developing Countries: An Overview. Lect. Notes Electr. Eng. 2022, 758.

49. Kermanshachi, S.; Rouhanizadeh, B. Feasibility Analysis of Post Disaster Reconstruction Alternatives Using Automated BIM-Based Construction Cost Estimation Tool. In Proceedings of the CSCE 6th International Disaster Mitigation Specialty Conference, Montreal: Canadian Society of Civil Engineering, Fredericton, NB, Canada, 13–16 June 2018; pp. 13–16.

50. Ilhan, B.; Yaman, H. Meta-Analysis of Building Information Modeling Literature in Construction. Int. J. Eng. Innov. Technol. 2013, 3, 373–379.

51. Montiel-Santiago, F.J.; Hermoso-Orzáez, M.J.; Terrados-Cepeda, J. Sustainability and Energy Efficiency: BIM 6D. Study of the BIM Methodology Applied to Hospital Buildings. Value of Interior Lighting and Daylight in Energy Simulation. Sustainability 2020, 12, 5731.

52. Bui, N.; Merschbrock, C.; Munkvold, B.E. A Review of Building Information Modelling for Construction in Developing Countries. Procedia Eng. 2016, 164, 487–494.

53. Kim, K.P.; Freda, R.; Nguyen, T.H.D. Building Information Modelling Feasibility Study for Building Surveying. Sustainability 2020, 12, 4791.

54. Obi, L.; Awuzie, B.; Obi, C.; Omotayo, T.S.; Oke, A.; Osobajo, O. BIM for Deconstruction: An Interpretive Structural Model of Factors Influencing Implementation. Buildings 2021, 11, 227.

55. Ghaffarianhoseini, A.; Tookey, J.; Ghaffarianhoseini, A.; Naismith, N.; Azhar, S.; Efimova, O.; Raahemifar, K. Building Information Modelling (BIM) Uptake: Clear Benefits, Understanding Its Implementation, Risks and Challenges. Renew. Sustain. Energy Rev. 2017, 75, 1046–1053.

56. He, Q.; Wang, G.; Luo, L.; Shi, Q.; Xie, J.; Meng, X. Mapping the Managerial Areas of Building Information Modeling (BIM) Using Scientometric Analysis. Int. J. Proj. Manag. 2017, 35, 670–685.

57. Adekunle, S.A.; Ejohwomu, O.; Aigbavboa, C.O. Building Information Modelling Diffusion Research in Developing Countries: A User Meta-Model Approach. Buildings 2021, 11, 264.

58. The Business Value of BIM for Construction in Major Global Markets; SmartMarket Report; McGraw Hill Construction: New York, NY, USA, 2014; pp. 1–60.

59. Doan, D.T.; GhaffarianHoseini, A.; Naismith, N.; Ghaffarianhoseini, A.; Zhang, T.; Tookey, J. Examining Critical Perspectives on Building Information Modelling (BIM) Adoption in New Zealand. Smart Sustain. Built Environ. 2020.

60. Hameed Memon, A.; Abdul Rahman, I.; Memon, I.; Iffah Aqilah Azman, N. BIM in Malaysian Construction Industry: Status, Advantages, Barriers and Strategies to Enhance the

Implementation Level. Res. J. Appl. Sci. Eng. Technol. 2014, 8, 606–614.

61. Construction Industry Transformation Programme 2016–2020. CIDB Kuala Lumpur Malays. 2016, 184, 1–71.
62. Drogemuller, R. BIM Support for Disaster Response. In Risk-Informed Disaster Management: Planning for Response, Recovery and Resilience; 2015; pp. 391–405. Available online: https://eprints.qut.edu.au/76145/1/E3.2.pdf (accessed on 5 December 2021).
63. Kim, J.-E.; Hong, C.-H. A Study on the Application Service of 3D BIM-Based Disaster Integrated Information System Management for Effective Disaster Response. J. Korea Acad. Coop. Soc. 2018, 19, 143–150.
64. Wang, B.; Li, H.; Rezgui, Y.; Bradley, A.; Ong, H.N. BIM Based Virtual Environment for Fire Emergency Evacuation. Sci. World J. 2014, 2014, 589016.
65. Boguslawski, P.; Mahdjoubi, L.; Zverovich, V.; Fadli, F.; Barki, H. BIM-GIS Modelling in Support of Emergency Response Applications. Build. Inf. Model. Des. Constr. Oper. 2015, 149, 381.
66. Lyu, H.-M.; Wang, G.-F.; Shen, J.; Lu, L.-H.; Wang, G.-Q. Analysis and GIS Mapping of Flooding Hazards on 10 May 2016, Guangzhou, China. Water 2016, 8, 447.
67. Sertyesilisik, B. Building Information Modeling as a Tool for Enhancing Disaster Resilience of the Construction Industry. Trans. VŠB Tech. Univ. Ostrava Saf. Eng. Ser. 2017, 12, 9–18.
68. Biagini, C.; Capone, P.; Donato, V.; Facchini, N. Towards the BIM Implementation for Historical Building Restoration Sites. Autom. Constr. 2016, 71, 74–86.
69. Brumana, R.; Della Torre, S.; Oreni, D.; Previtali, M.; Cantini, L.; Barazzetti, L.; Franchi, A.; Banfi, F. HBIM Challenge among the Paradigm of Complexity, Tools and Preservation: The Basilica Di Collemaggio 8 Years after the Earthquake (L'Aquila). ISPRS Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci. 2017, 42, 97–104.
70. Xu, Z.; Zhang, H.; Lu, X.; Xu, Y.; Zhang, Z.; Li, Y. A Prediction Method of Building Seismic Loss Based on BIM and FEMA P-58. Autom. Constr. 2019, 102, 245–257.
71. Rad, M.A.H.; Jalaei, F.; Golpour, A.; Varzande, S.S.H.; Guest, G. BIM-Based Approach to Conduct Life Cycle Cost Analysis of Resilient Buildings at the Conceptual Stage. Autom. Constr. 2021, 123, 103480.