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TECHNOLOGY INTEGRATION FOR FLOOD MANAGEMENT AND RESILIENCE: A SYSTEMATIC LITERATURE REVIEW & LESSONS FOR PAKISTAN

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ABSTRACT

Floods are recurrent natural disasters that require effective management strategies for post-disaster recovery. This systematic literature review aims to comprehensively analyze the existing body of research on flood management and post-disaster recovery. For this purpose, the researcher assessed 39 articles from 2012 to 2022 regarding the use of technology such as unmanned aerial vehicles (UAV) and business information modelling (BIM) in disaster management. These two technologies were reviewed for their role in flood management and post-disaster recovery and reconstruction separately. The researcher highlighted the challenges of flood management in developing countries such as lack of technological capacity and funds. The study identified the techniques and technologies utilized in disaster management and provided a holistic approach to integrate the use of technologies for post-disaster recovery. The findings suggest that a BIM-based information system must be established that takes images and videos of the flood-prone regions as inputs within a country and uses these images to predict and alarm against possible floods. Moreover, in the post-disaster phase, the UAVs can capture images of flooded areas and compare them to non-flooded images in the database to determine the level of destruction, cost of recovery, and the best possible strategy that can be adopted for recovery.

Keywords: Disaster Management, Flood management, Resilience, UAVs, BIM

1. INTRODUCTION

Natural hazards have increased rapidly due to climate changes worldwide. These natural disasters such as fire, floods, cyclones, drought and others largely impact developing economies, even though developed countries are also not spared by their impacts [1, 2]. Research has focused on creating effective early warning systems and enhancing disaster management methods [2, 3]. Due to low resources and poor infrastructure, natural hazards have a greater negative impact on developing countries compared to developed economies [4, 5]. While natural hazards cannot be prevented, implementing effective disaster management strategies can help mitigate their impact, minimize damage, and reduce tragic incidents. Various disaster management methods are implemented in these three phases which include phase I: which is the pre-disaster phase in which the authorities are alerted about the incoming event; phase II: which focuses on controlling the damage during the event and phase III: which is the post-disaster recovery stage for normalizing the life and routine [6]. The Millennium Development Goals (MDGs) for 2015 focused on enhancing disaster management. As per the MDGS, disaster management can be accomplished through the integration of technology for development [7]. Hence, in order to enhance relief efforts and quick recover, technology can play a significant role.

In this regard, various new technologies and models have emerged. Building information modelling (BIM) is stated as one of the most effective technologies in this context [8]. BIM provides a framework for the management of urban development as highlighted by Nikologianni, Mayouf [9]. The technological shift has moved to a more advanced 3D analysis from the traditional two-dimensional methods which has led to visualization for applications including sustainable development, land administration, and disaster management [10]. Additionally, it is effective in producing productive outcomes by bringing associated stakeholders to a single platform for [11]. The adoption of BIM along with other technologies such as unmanned aerial vehicle (UAV), artificial intelligence and digital technologies for post-flood management is largely being encouraged considering its positive outcomes [10, 12]. Scholars are of the view that various challenges are faced during post-disaster management, so the adoption of BIM and UAV would be opportunistic during this period [13]. Therefore, to improve post-disaster flood management, developing countries such as Pakistan have to adopt and implement various new and advanced technologies.

With the increase in natural disasters due to climate change, various countries are committed to focus on their built environment which requires utilizing resources, advancing technologies and enhancing resilience through strategies [14]. Technologies such as BIM and blockchain and are considered to be effective for improving post-disaster management and capable enough to build a resilient infrastructure [15]. Emerging countries such as China have adopted advanced technologies to mitigate the negative impact of natural hazards [16, 17]. While existing studies have evaluated the adoption of advanced technologies in disaster management [18], the usage and integration of technologies in the particular context of floods is limited. In previous studies, post-disaster management was highly focused in the context of other disasters such as earthquakes [19, 20]; hence, the present study is beneficial in filling this gap. Additionally, previous studies did not focus on BIM and UAV in the context of post-flood management; therefore, the present study has also intended to overcome this observed limitation.

Therefore, the present study intends to evaluate various advanced technologies in the context of post-flood management via a systematic literature review and also offers a holistic understanding in this regard that could be effective for post-disaster flood management, providing lessons for Pakistan. The main aim of this study is to conduct a systematic literature review of the past ten years to review various recent and most high technology techniques in the context of post-disaster flood management. For this purpose, the following objectives are proposed:

- To examine the current state of literature concerning flood management strategies for post-disaster recovery.
- To highlight the challenges in flood management and post-disaster recovery, particularly in developing countries.
- To identify the latest techniques and technologies proposed in the literature for flood management and their potential benefits for post-disaster recovery efforts.
- To provide a lessons for Pakistan to enhance flood management strategies by integrating innovative technologies.

The current review contributes to a comprehensive understanding of post disaster management, particularly flood management strategies, and highlights the potential benefits of technology integration in the context of post-disaster recovery. The study further aids in providing knowledge regarding advanced technologies such as BIM and UAV which can be beneficial for architects, construction professionals, disaster risk reduction experts and policymakers. Hence, with the synthesis of articles, the insights gained from this review provide substantial and valuable lessons and offer recommendations for enhancing flood management practices in Pakistan, where floods pose a recurrent and significant threat. In addition, this study emphasizes the importance of utilizing technology to develop effective flood management strategies and promote more resilient post-disaster recovery efforts.

2. FLOOD MANAGEMENT IN PAKISTAN

In South Asia, issues such as the unregulated urban expansion, socioeconomic and climatic factors, have resulted in a rise in the occurrences of flood-related tragedies [21]. Consequently, this issue has emerged as a significant obstacle in flood risk management and reduction in these developing countries. Pakistan is one of the developing nations that stands as one of the countries profoundly impacted by climate change which primarily attributed to glacier melting. The recurrent climate shifts trigger natural hazards such as floods, cyclones, elevated temperatures, droughts, and intense rainfall [22]. These environmental disruptions have resulted in substantial losses for the nation. For instance, the floods of 2022 in Pakistan were devastating as they not only impacted the lives of the people but also caused severe damage to the country’s agriculture, infrastructure as well as economy. The post-flood recovery of Pakistan has also not been so easy due to poor post-disaster flood management [23]. This has resulted in great attention towards post-disaster flood management for improving the reconstruction projects of the country to prevent future such damages.

The primary factor contributing to challenges in assessing the impacts of floods and similar disasters is the absence of advanced data management technologies in Pakistan [24]. Numerous researchers have taken the responsibility of collecting and analyzing data through various techniques to address this issue; however, the data collected from different regions of the country has often been incomplete. Thus, this has resulted in a failure to provide a comprehensive understanding of the extent of damage and losses caused by floods [24]. With the deficiency in data management and advanced technology, Pakistan lags behind in predictive system, flood analysis and management [24]; therefore, the holistic approach of the present study provides lessons to learn for Pakistan from other countries.

3. METHODOLOGY

The present study aimed to provide a holistic approach for effective post-flood management. Thus, the study assessed the progress in research and determined the adoption of various advanced technologies for improving post-disaster management. These goals were achieved by searching reputable databases.

For the present study, the PRISMA guidelines were taken into account for reviewing the literature review [25]. The PRISMA protocol is used in the study as a comprehensive guidance for conducting a systematic review. It provides guidance for the research process, from initial planning and screening of articles to data extraction and analysis. The researcher followed PRISMA as it enhances the transparency and replicability of the review process, ensuring that the results are unbiased and well-balanced [26]. It is crucial to accurately define the research criteria and select appropriate keywords aligned with the study's objective to minimize potential biases that could impact the analysis outcomes. As the PRISMA checklist includes various components of the manuscript, relevant information is gathered to construct the PRISMA flow diagram as illustrated in Figure 1. No meta-analysis approaches were considered while following the PRISMA guidelines. The main focus was to extract most related conference and journal papers on post-flood management and advanced technologies used in this regard [27].

3.1 Database, Criteria and Search Outcomes

During the article identification and selection stage, the researcher utilized Scopus, IEEE, Google Scholar, Science Direct, Elsevier and Springer databases to conduct the literature search. The search was restricted to articles that met the following criteria: (1) published in peer-reviewed journals, (2) written in English, (3) journals and conference proceedings (4) relevant to technology and (5) related to flood management and post-disaster recovery. In order to satisfy the fourth and fifth criteria, the researcher employed the search terms (“smart technology” OR “technology” OR “BIM” or “UAV”) AND (“floods” OR “flood management” OR “post-disaster management” OR “disaster” OR “reconstruction”) across the title, abstract, and keywords of articles. This initial search yielded 713 articles. Additionally, the time period for the selection of paper was set from 2012 to 2022. The time frame was specified as flood management and disaster response are evolving fields that require latest knowledge to address current challenges and implement effective strategies. By focusing on recent literature, researchers can gather insights that are applicable to current and future scenarios.

The removal of duplicates resulted in 321 documents which underwent screening of their titles and abstracts. Out of the 321 articles, 247 were removed as they did not satisfy the inclusion criteria based on title and abstract screening. Complete text for 74 papers was obtained and screened. Full-text screening led to a removal of 35 articles. Therefore, a final number of 39 papers were selected for further analysis.

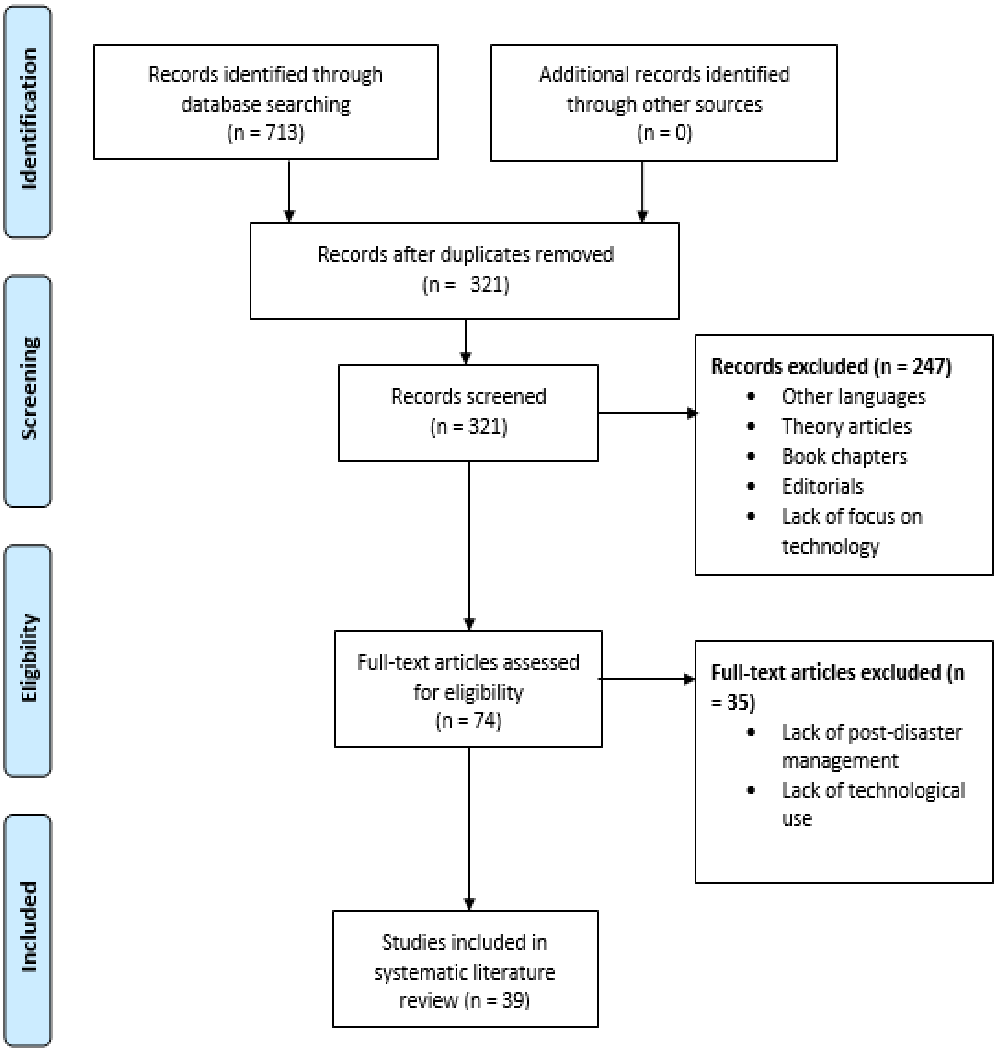

Figure 1: Screening Process

3.2 Data Analysis

In the present study, the researcher employed two approaches to provide a detailed analysis of the articles. Firstly, the researcher relied on bibliometric techniques in order to provide an overview of the articles by using VOS viewer because it is considered to be effective in dealing with networks that are usually large, and it also possesses remarkable capabilities of text mining. Keywords analysis was utilized to shed light on the technologies. Secondly, the researcher utilized content analysis. Content analysis has been utilized by scholars for categorizing and summarizing trends and patterns in the existing literature [28]. Several advantages of this approach are described such as the modesty of the technique which implies that content analysis is free from researchers' demand and recall biases. Additionally, it is regarded as appropriate for both inductive and deductive research.

4. RESULTS

The first objective of the study was to review the current state of literature on flood management and post-disaster recovery. Using bibliometric techniques, the results are presented below.

4.1 Publication Trend

Analysis of the 39 included articles in terms of the published years revealed that the reviewed literature lies between 2013 to 2022, given the specified time period of ten years. Out of 39 articles, 16 articles included in the study were published in the years 2018 and 2019. Two relevant papers were included from 2013. One paper each from 2014 and 2022 was included in the study. Four papers were included from 2015 whereas two papers were included from 2016. Three articles from 2017 were part of the review. Three papers published in 2020 and seven in 2021 were included in the review. These statistics are shown in Figure 2.

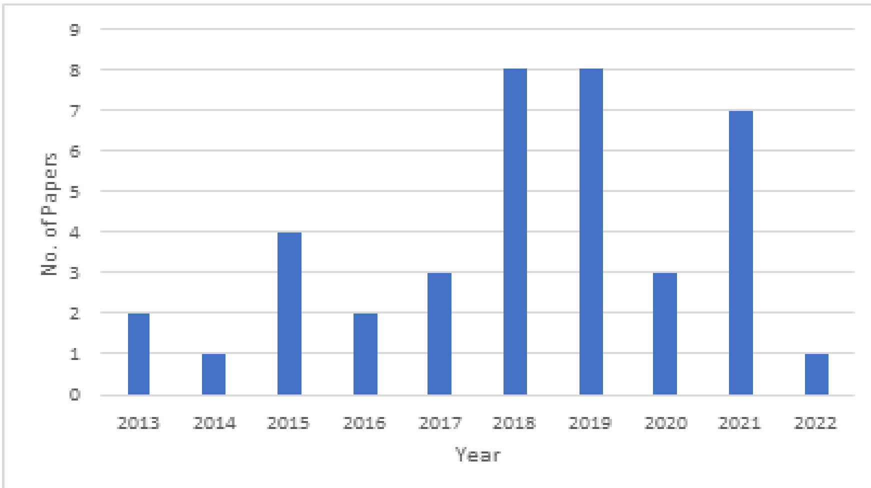

Figure 2: Distribution of Papers Per year

4.2 Analysis of Type of Papers and Sources

In this study, the researcher has included conference proceedings and journal articles. Most of the research included in the study are journal articles. A total of 34 papers in the study are journal articles, accounting for 87% of the total sample, whereas only 13% included in this review are taken from conference proceedings. The reason for including conference proceedings in this study in addition to journal articles lies in the fact that it is a review of a scientific and technical field.

The following table lists the journals and conferences that have acted as sources for the literature in the current review. Moreover, the number of papers extracted from each journal or conference is also listed in the table. Three papers are taken from sustainability and Sensors, while two papers each are published in journals such as "Automation in Construction," "Environmental Modelling and Software" and "Remote Sensing."

Table 1: List of Journals/Conferences and Number of Papers

Journal Name	No. of Papers
Sensors	3
Sustainability	3
Automation in Construction	2
Environmental modelling & software	2
Remote Sensing	2
2013 International conference on unmanned aircraft systems (ICUAS)	1
AASRI International Conference on Industrial Electronics and Applications (IEA 2015)	1
Building information modelling (BIM) in design, construction and operations	1

Buildings	1
Economies	1
IEEE Access	1
IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing	1
Indonesian Journal of Electrical Engineering and Computer Science	1
International Journal of Digital Earth	1
International Journal of Disaster Risk Reduction	1
International Journal of Project Management	1
J. Eng. Res. Reports	1
Journal of Legal Affairs and Dispute Resolution in Engineering and Construction	1
Journal of spatial science	1
Journal of the Korea Academia-Industrial cooperation Society	1
Journal of the National Science Foundation of Sri Lanka	1
Natural Hazards Review	1
Nature communications	1
Proceeding of CSCE 6th International Disaster Mitigation Specialty Conference, Montreal: Canadian Society of Civil Engineering	1
Proceedings of the 2nd International Conference on Sustainable Development in Civil Engineering (ICSDC 2019), Jamshoro, Pakistan	1
Remote Sensing for Agriculture, Ecosystems, and Hydrology XX	1
Risk-Informed Disaster Management: Planning for Response, Recovery and Resilience	1
Safety Engineering	1
Smart Cities	1
Structural Health Monitoring	1
TELKOMNIKA (Telecommunication Computing Electronics and Control)	1
Water	1
Water	1

4.3 Co-Occurrence Analysis

Figure 3 below shows the word co-occurrence network graph for the go cadence of words in the titles of all the references that have been reviewed in this study. The word cooccurrence graph indicates that the most commonly used words include flood detection, flood extent, UAV, BIM, etc. Individual topic-wise word co-occurrence graphs are presented in the sections below.

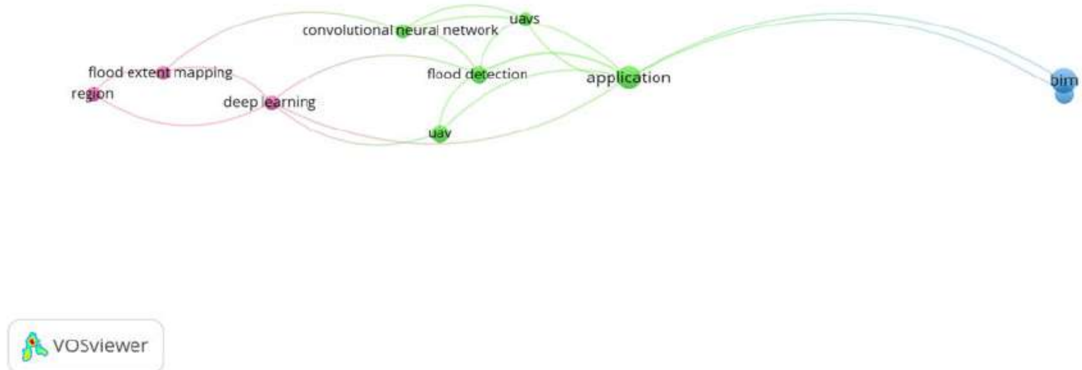

Figure 3: Co-Occurrence of Words (Titles of All papers)

Figure 5 below depicts the biggest cluster when all the references are taken. This cluster consists of 28 links and 12 authors. As can be seen clearly in the cluster, three sub-clusters are forming in this network graph.

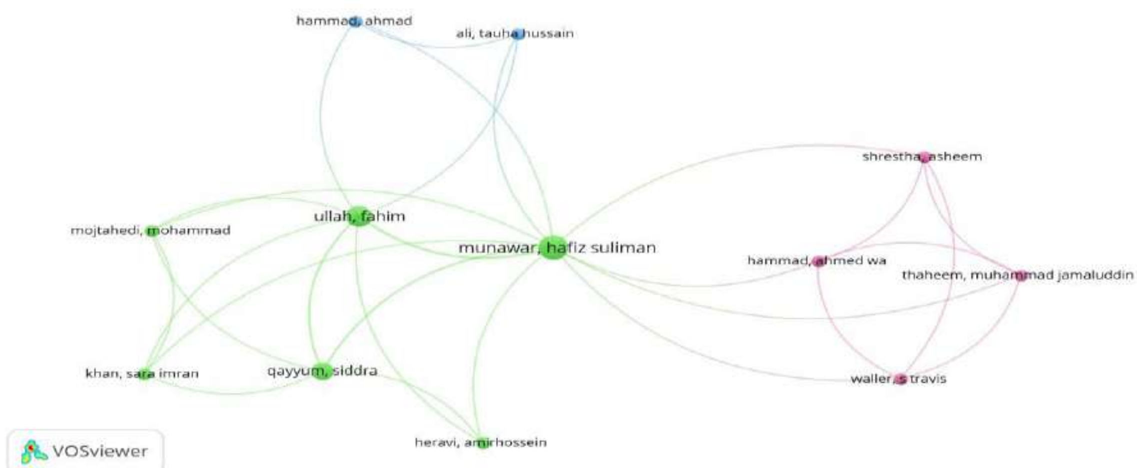

Figure 4: Author Co-Occurrence (Biggest Cluster in All references)

Table 2 presents the technologies discussed in the articles and their associated benefits.

Table 2: Technologies in the Review

Dimension	Benefit	References
UAV:	Increased efficiency	[29, 30]
	Easy transportation	[31]
	Cover large areas quickly	[31]
UAV & Machine learning, Sensors, Deep learning	Cost estimation	[29, 32]
	Improved flood detection outcomes	[30, 33]
BIM	Cost Effectiveness	[34] [35]
	Improves coordination	[11]
	Visualization of Project	[36, 37 , 38]
	Enhanced Productivity	[39-41]
	Increased overall resilience	[42, 43]
	Improved response strategies	[39-41]

5. DISCUSSION

The present study intended to review the current literature of flood management for post-disaster recovery, highlight the challenges and identify the latest techniques and technologies in existing literature in order to provide a holistic approach.

5.1 Challenges in Flood Management and Post-Disaster Recovery in Developing Countries

As per the second objective, the challenges in flood management and post-disaster recovery are discussed. According to Tagliacozzo [19], the effectiveness of post-flood construction projects is largely impacted by the time frame, and it has been observed that delay in these projects negatively influences the efficiencies of such projects. Besides this, various other factors also influence post-disaster reconstruction, including social, cultural, political, environmental and economic factors [44]. Particularly in the case of developing countries, post-disaster reconstruction also depends on the location site as it impacts the accessibility of funds, labor and other essential technical resources [45]. Balica, Popescu [46] revealed that in developing countries the vulnerability to floods is aggravated due to low resilience and the recovery processes are slow.

Moreover, the increasing number of natural disasters has gained the attention of many professionals who have worked over the years to determine better and more effective variables for improving post-disaster reconstruction to prevent future negative impacts of these disasters. Many researchers have also worked in this context to provide better empirical evidence. Past studies have shown that various factors are responsible for ineffective reconstruction projects during post-disaster recovery in developing countries [47, 48]. These factors include the unavailability of required resources, lack of government support, lack of public participation, issues with the availability of land, conventional documentation, lack of advanced technologies, poor designs, cost issues and lack of funds [37]. Ismail, Majid [48] discussed the importance of technical staff and technological resources in order to facilitate post-disaster reconstruction in order to survive future hazards. The adoption of advanced technologies could also be effective in improving the efficiency of post-disaster reconstruction. In this regard, various new models, such BIM, have also been introduced [49]. Therefore, the utilization of new and advanced imaging devices, such as UAVs, has also proved to be effective in better designing reconstruction projects during post-disaster recovery [50].

5.2 Flood Management Using Latest Techniques

The second objective of the study was to identify the latest techniques and technologies utilized in disaster management and post-disaster recovery. The review showed that various modern technologies are being utilized for flood management and other natural disaster management. One of these technologies is edge detection which is used for measuring water levels [51]. This is found to be effective in pre-processing the water levels in the context of any floods. Another important technique in this regard is the flood alarm technique [52] which incorporates digital camera sensors for obtaining images of rising levels of water in real-time. Another technique introduced by Esteban, McRoberts [53], is a random forest-based algorithm which is used for infrastructure monitoring and post-disaster assessment.

Water level can be measured by the use of edge detection techniques in post-flood situations. The steps involved in the measurement of the water level are numerous. First, the Region of Interest (ROI) technique is applied to remove noise from an image and to single out the areas of interest [54]. Next, the image is usually adjusted for its brightness and contrast to improve its quality followed by converting the image to greyscale and threshold information. The Edge Detection algorithm can help in the establishment of a warning system to alert people of upcoming disasters in pre-flood phases or of important flooded areas, such as bridges and roads, in post-flood phases for ensuring quick recovery [55-57].

One of the main techniques which are used for post-disaster management is UAV. This technique is effective in rehabilitation as well as relocation efforts within the location. Ground surveys are also utilized for detecting agriculture damages [58]. UAVs are not only utilized for assessing infrastructure and building damages but it is also used for estimating agriculture industry damages. For this purpose, multispectral and normal RGB cameras are used. The image processing technique is utilized for calculating the vegetation indices while the file experts are considered to be responsible for gathering the knowledge based on the ground [59]. In this regard, facilitation from the government is considered to be essential for making an effective recovery after a natural disaster. In various studies, remote sensing was also applied for computing the volumetric and volume changes in the context of forest areas. This technique was used due to various challenges faced in implementing patch forest's ground-based survey. Another study was conducted by Esteban, McRoberts [53] to determine the changes in biomass and volume of forest cover utilizing the data from remote sensing. For this study, the selected areas were Norway and Spain. The forest volume was predicted by the Random Forest algorithm. Similarly, other techniques such as tracer test analysis, UAV, UAS etc. have also been used for determining changes induced by floods [20].

The reviewed techniques may not all be used for flood management in the respective papers; however, these techniques are all such that can be used in post-disaster flood management applications to fasten the recovery and restoration. Figure 2 below shows the word frequency graph for the papers in the current subsection and shows that the three main domains were image processing, edge detection, and flood management, which is what the theoretical findings reflect as well. Moreover, in table 2 below, the findings of each of the reviewed papers and the implications for the domain of flood management have been presented.

Table 2: Overview of Reviewed Literature (Post Disaster Management Techniques)

Author and Year	Domain	Results	Implication for Flood management
Esteban, McRoberts [53]	Remote data sensing and image processing	Random forest algorithm to sense biomass changes	Can be used to signal out the flood-affected areas by indicating changes in pre and post-flood images using the tested random forest algorithms.
Jyh-Horng, Chien-Hao [59]	Flood monitoring using image identification mechanisms	Real-time videos and images are used to identify flood events successfully	The study indicates that several algorithms and techniques can be used to determine temporal changes in image sequences to develop a flood alarm system.
Munawar, Hammad [55]	Machine learning-assisted Image Processing	A number of images are used to detect flood-affected areas by using image processing in machine learning algorithms with 90% accuracy.	Since there is high accuracy in detecting affected areas, it can be used in future flood management and detection applications.
Stylianidis, Akca [20]	Satellite-based capturing and image processing	Provided high accuracy in the detection of forest volume and health.	Increase the opportunity for flood detection in areas covered by vegetation.

Supriyanti, Suwitno [58]	Edge Detection	In this study, the edge detection algorithm was improved by modifying brightness and contrast. The results indicate that modification led to improved image quality, reduction in overall noise in the image, and better ability to detect flooded areas from non-flooded areas within an affected region.	The improved imagery and detecting ability of flooded areas from the north flooded yes can lead to better solutions for flood detection and disaster management systems.
Tseng, Chen [56]	Behaving mechanisms for improving flood monitoring in cases where hazy weather conditions led to capturing of efficient images.	The dark channel prior mechanism was used to dehaze images and improve their pixel quality. The proposed method has been proven to improve flood detection and monitoring mechanisms.	The mechanism of dark channel prior used in this study to dehaze low-quality images can prove to be a suitable and viable technique in future flood management systems to improve the quality of captured images and videos.
Utomo, Irawan [57]	A combination of various computer vision and image processing strategies for the development of an early warning flood detector system	Object detection system and water level detection system were designed separately in this solution and they can perform well in integration.	The object detection system and water level detection system designed in this study can contribute to future solutions where it is important to indicate where a particular infrastructure is.
Wing, Pinter [51]	Big data analysis for flood damage reporting and better future management.	Big data allows in-depth damage function calculation. The observed flood losses can be	The proposed solution can be used in future recovery systems for post-disaster management.

		used to develop future recovery strategies more carefully. .	
Yeum, Choi [54]	Classification strategy and automated image localization	By extracting regions of interest using the SfM algorithm, the flooded regions can be detected	The use of structure from motion algorithm is also supported in other previous literature that will be discussed later.

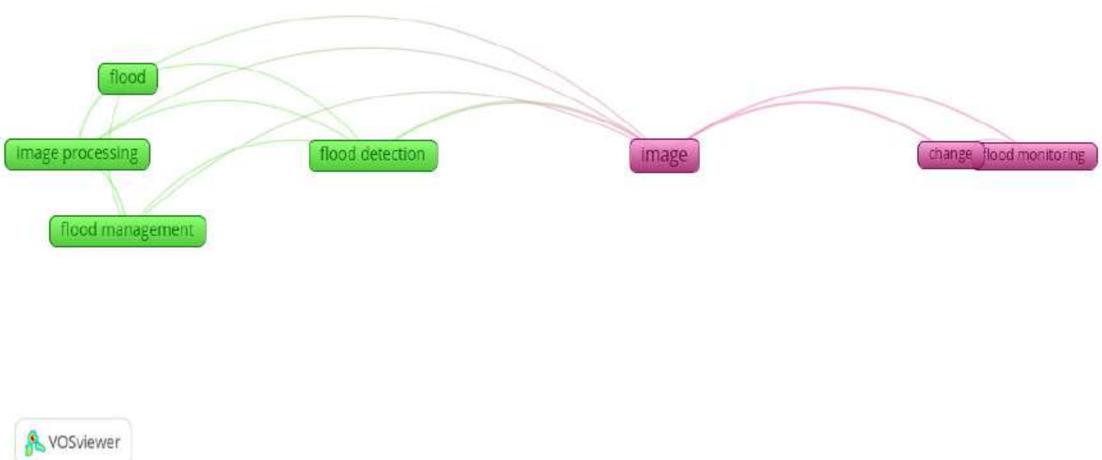

Figure 5: Word Frequency Network (Image Processing Techniques)

5.2.1 Flood Management Using UAVs

Unmanned Aerial Vehicle (UAVs) has emerged in recent years as a low costing technique of capturing data for image processing platforms, especially in the field of disaster recovery and management. According to Govedarica, Jakovljević [60], UAVs not only provide a low-cost mechanism for producing high-quality and frequency data, provides higher levels of accuracy and spatial and temporal resolutions in the captured imagery. Moreover, it is also indicated that the techniques of data collection and monitoring are also much more flexible due to the introduction of UAVs in the field. Govedarica, Jakovljević [60] aimed to compare UAV-based Digital Elevation Models and LiDAR-based Digital Elevation Models. The results indicated that better flood disaster management outcomes were observed by the use of DEMs that was created using high-resolution images captured using UAVs and processed using Structure from Motion (SfM) algorithms. Hashemi-Beni, Jones [29] also established the effectiveness of a UAV-based DEM for the evaluation of flood extent and mapping of spatial flood assessment and had similar results. Rivas Casado, Irvine [32] discussed the use of UAVs in post-disaster assessment by presenting a loss-adjustment framework that presents an estimate of the losses that occurred to residential properties after a flood. The findings showed that the technique gave 84% accuracy in terms of direct tangible losses, compared to the actual manual data collection by experts. In an earlier study, Feng, Liu [16] captured imagery using a UAV for monitoring the urban waterlogging issues in an area of China, Yuyao. The researcher used a Random Forest classifier to determine the flooded area in the captured imagery. The results showed an improved outcome of RFC, with an accuracy of 87.3%, in response to data collected by UAVs showing that UAVs are an ideal platform for flood monitoring.

Munawar, Ullah [61], in line with the older reviewed studies above, indicated that satellite images do not provide accurate results and cannot be used for real-time flood management and response systems due to their delayed response. Thus, the researchers in Munawar, Ullah [61] developed an automated imaging system supported by UAVs to identify flooded areas by taking aerial images. 91% accuracy is reported in the study to differentiate flooded from non-flooded regions [61]. Gebrehiwot, Hashemi-Beni [62] also discussed a machine learning technique for extraction of affected areas on images captured using UAVs but instead focussed on flood extent mapping. FCNs were found to be the most accurate and effective in creating flood extent maps. The use of a convolutional network for an early detection system in case of floods was also presented in a more recent study by Munawar, Ullah [33]. The results indicated that the designed strategy is effective in terms of assessing the damage that has been made to local buildings and infrastructure within the impacted areas. The findings also show a 91% accuracy in the results of positive flood detection. Hashemi-Beni and Gebrehiwot [30] also use machine learning algorithms and integrated a CNN-behaved classifier to extract flooded areas from UAV-captured optical images. At the same time, region-growing mechanisms have been used to estimate the extent of floods that are not visible from imagery by using a digital evaluation model. The results show that data augmentation and deep learning techniques are capable of enhancing the accuracy of flood classification in images by detecting floods in both visible as well as covered areas.

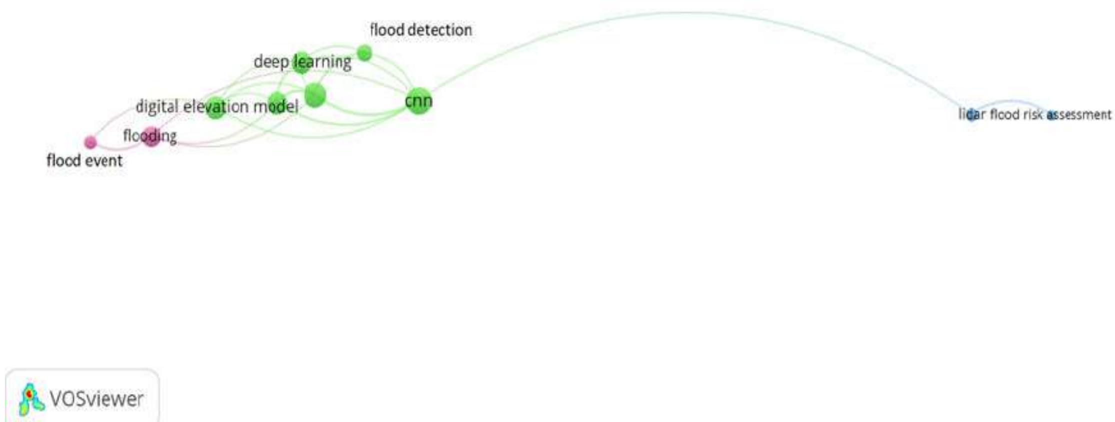

Figure 6: Word Frequency Network (UAV)

Table 3: Overview of Reviewed Literature (UAVs)

Techniques/Technologies involved	Method	Outcomes	Implications	Reference
UAV and Microsensors	UAV equipped with microsensors is sent to required area	Multiple flights with the sensor delivery system for UAV dynamic model were carried out.	UAVs are more reliable than satellite-based images	[31]
DEM, UAV	Comparison of various techniques with	DEM is well developed by taking inputs	UAVs can replace satellite	[29]

	DEM supported by UAV data	from UAVs	imagery-based platforms altogether due to increased efficiency and lower costs.	
DEM, LiDAR, SfM, UAV	Comparison of LiDAR and UAV-based data collection for DEM formation	UAVs and SfM work better in Lay lowing areas and smaller study areas	In future flood disaster assessment applications, SfM-based DEMs can be used to indicate the most affected areas by the collection of data using UAVs	[60]
UAVs	Estimation of loss to residential properties post-flood event.	84% accuracy of results	The study indicates that the tested approach is capable of cost estimation in response to urban as well as rural flooding events	[32]
UAVs, Remote Sensing, Random Forest Classifier	Flood disaster monitoring in post-flood regions	The imagery captured using UAVs allows better identification and accuracy of random forest classifier algorithms.	UAVs can serve to be ideal for flood monitoring in urban regions and can allow an improved segmentation to extract flooded areas from normal ones.	Feng, Liu [16]
UAV, deep learning	Develop and examine the effectiveness of UAV-based	91% accuracy in results.	Such quick response systems can enable early	[61]

	data capturing and processing for classifying flooded and non-flooded areas		flood relief and rescue of stranded people, transforming the future of disaster management.	
UAV, Deep Convolutional Neural Network	Flood extent mapping by comparing the effectiveness of classification of flooded and non-flooded regions using UAV imagery input to CNNs and other classifiers	97.52% accuracy by using a fully convoluted neural network (FCN-16)	In the future, machine learning and AI algorithms can be exploited to improve outcomes of flood management platforms that take inputs in form of UAV-based imagery.	[62]
UAV, Convolutional Neural Network	development of an early detection system for flood management and post-disaster response and recovery.	91% accuracy in detecting flooded areas	Smart governance of urban areas can be enabled by the use of such strategies to manage and monitor disasters to maximize disaster response and minimize disaster damage.	[33]
Deep learning, UAV, DEM	digital evaluation model for estimation of flood extent and classification of	the results indicate that the data augmentation technique allows for the detection of flooded areas	The results are promising in terms of the usage of machine learning techniques for	[30]

	flooded areas from non-flooded areas	which are visible as well as not visible due to being covered by vegetation.	enhancing the outcomes of flood detection and disaster estimation systems	

5.2.2 BIM for Recovery and Reconstruction

Building information modelling can contribute to resilient build-back in post-disaster phases and is important in all phases of disaster management, from pre- to post-disaster. Studies such as Drogemuller [39] have explored the benefits of BIM in terms of disaster response. The study found that BIM was productive in terms of prevention, preparation, recovery, and response or reaction to a disaster. additionally, by employing augmented reality strategies, BIM can aid in disaster preparation by predicting the possibility of future disasters, therefore, contributing to effective planning and disaster management [39]. Kim and Hong [40] concluded that building information modelling helps plan responses in the various stages of disaster management. The study presented a BIM-based disaster integration system that facilitated the first responders in terms of locating the region of an event to the fasten response mechanisms. Similarly, an older study used a combination of GIS and BIM to present an algorithm that can predict the fastest and easiest evacuation route during a disaster situation, therefore enabling better recovery and response [41].

Research has also emphasized that BIM contributes to increasing resiliency in the pre as well as post-disaster stages [42]. This is because BIM impacts the performance of the rebuilding activities, overall supply chain during and post-disaster, and rescue and recovery operations. Cost estimation methodologies are also proposed in studies like Kermanshachi and Rouhanizadeh [34] which utilize BIM-based tools to estimate the cost of recovery and rebuilding. Such solutions contribute effectively to better building back of the infrastructure [34]. Rad, Jalaei [35] also discussed a cost evaluation solution focused on increasing resiliency in the reconstruction. Nawari and Ravindran [43] conducted a study on the benefits of incorporating blockchain and BIM-based solutions in post-disaster phases, especially rebuilding, to ensure that the reconstruction is done to enhance resilience in the structures.

Xu, Zhang [36] developed a system based on BIM for damage evaluation by using a FEMA P-58, enabling users to take a virtual overview of the damages. Messaoudi and Nawari [37] also developed a virtual framework for the process of speeding up permitting process of reconstruction in post-disaster stages based on BIM. The basic aim of the framework was to establish which type of permit was required, apply the various requirements of the permit to the current framework and decide what the result of the format would be. timely reconstruction will be enabled by investing in similar frameworks and solutions

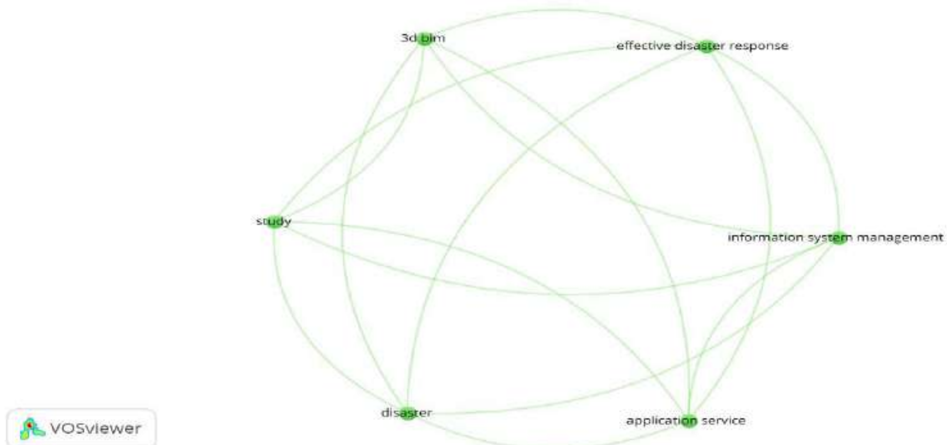

Figure 7: Word Frequency Network (BIM)

Table 5: Summary of Literature on BIM

Author	Objective	Implications
Amirebrahimi, Rajabifard [38]	Offers a framework of technology integration, using BIM and GIS	Allows detailed representation of building information, enhanced in-depth results to assess the damage, overcomes limitations of current damage assessment, facilitates better decision-making
Boguslawski, Mahdjoubi [41]	Development of an innovative approach for reconstruction	Utilization of BIM supports emergency responses and 3D model reconstruction
Del Duca, Rocha [11]	Detected exposed areas and defined possible hazards and risk assessments	BIM provides enhanced visualization, accuracy and flexibility
Drogemuller [39]	Analyzes use of BIM for resilient buildings and assesses case studies to discuss how BIM can aid disaster recovery	Supports rapid assessment of buildings, 3D visualization, location-based planning
Kim and Hong [40]	Analyzes post disaster management and BIM technology disaster system	BIM has the ability to manage building data with 3D visualization; hence, it can be utilized by management for different purposes. These include designing and maintenance. Additionally, proposes the use of BIM for monitoring and response services.
Kermanshachi and Rouhanizadeh [34]	Proposed BIM tool for decision-making and cost estimation methodology for post-disaster reconstruction	The tool based on BIM can be utilized for quick rehabilitation and supports coordination among decision-making. Another implication for post-disaster reconstruction is precise economic estimation.
Messaoudi and Nawari [37]	Addresses the issues of post-disaster reconstruction	Innovative frameworks can aid in obtaining data for damage assessment, facilitates the

	with the introduction of a framework for permits that utilizes innovative methods, such as BIM in order to improve the efficiency of obtaining construction permits during the recovery process.	process of permitting by reducing time and cost.
Nawari and Ravindran [43]	Analyzes the usage of BIM and other smart technology such as blockchain (BCT) for recovery efforts in post-disaster management	Multiple benefits of utilizing BIM along with BCT as it can provide open governance and improved transparency. In addition, integration of BIM and BCT can result in cost saving in post-disaster rebuilding.
Rad, Jalaei [35]	Explores how to enhance resilience of buildings with the incorporation of life cycle cost into a BIM.	A framework for designing more resilient infrastructure and early-stage estimation can assist designers make informed decisions.
Sertyesilisik [42]	Assesses the use of BIM to enhance disaster resilience and strength of infrastructure	In the rescue phase of disaster management and, BIM can enable evacuation and enhance safety management. In terms of recovery and reconstruction phases, BIM enhances quality and construction.
Xu, Zhang [36]	Proposed a model that is based on the integration of BIM and FEMA guidelines.	The FEMA P-58 guidelines were integrated with BIM data which allowed damage assessment and mapping of damage. The integration resulted in reduction in manual work, obtain precise information about the damage and predict repair costs. Additionally, the technology allowed visualization of damage.

5.3LESSONS FOR PAKISTAN FOR A HOLISTIC APPROACH TOWARD FLOOD MANAGEMENT AND DISASTER RECOVERY

As per the fourth objective of the study, the researcher intends to offer a strategies based on the holistic approach using technology for flood management and post-disaster recovery in order to provide applications for Pakistan. The above discussion showed that the use of technology and innovative techniques is imperative for effective disaster management and recovery which have led to the following lessons for Pakistan:

- **Early Detection and Damage Assessment**

As per the findings, the establishment of an automated imaging system which is supported by UAVS can aid in identification of flooded areas quickly and allow for quicker response and mitigation efforts. Secondly, the review also showed that UAVs equipped with sensors can be utilized to assess flood damage and infrastructure impacts. This can provide critical information for post-disaster response and recovery. Additionally, UAV images along with machine learning techniques for flood mapping and damage assessment can enhance decision-making in flood management.

- **Resilient Reconstruction**

The findings emphasize the importance of integration of BIM into flood management and post-disaster reconstruction processes. Therefore, it is recommended that Pakistan should implemented BIM into recovery processes in order to enhance the efficiency and accuracy of rebuilding efforts. Given the challenges faced by

Pakistan, such as lack of funds, cost estimation methodologies based on BIM can also aid in better planning and budgeting for reconstruction projects. Lastly, BIM can also facilitate collaboration among stakeholders involved in rebuilding and ensure that structures are designed and built to be more resilient to future floods.

- **Training and Education: for Integration of UAV and BIM**

In Pakistan, training and education of professionals involved in disaster management and reconstruction processes must be enhanced for successful integration of the use of UAVs and BIM. Relevant training and education can provide professionals the understanding required to use the technologies in flood management.

Using UAV and BIM, the researcher presents an integrative outline for flood management that primarily uses techniques of flood detection and prediction to enhance early recovery and response to flood events.

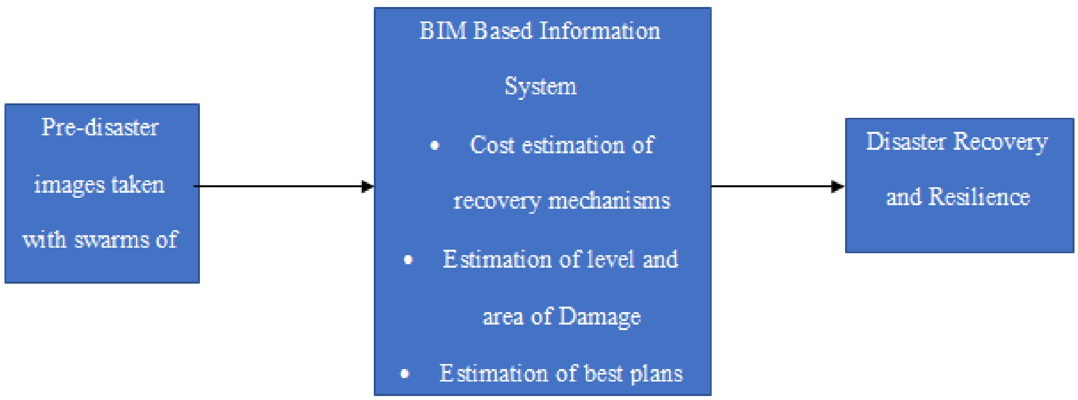

Figure 8: Holistic Approach for Resilience

The framework integrates the studied UAV-related technologies and BIM technology. As per the knowledge of the researcher, there are no previous holistic approaches provided on the integration of UAV and BIM. Developing countries such as Pakistan can utilize the above-presented integrated framework for resilient build-back. The technique that is suggested is to have small UAVs in swarms to keep visiting flood-prone regions regularly and take images and videos of the infrastructure. These images will be stored in databases that will serve as inputs to the BIM-based information systems. The images and videos will be used by the BIM system to predict any issues of infrastructure and any possible floods for time management. Moreover, the boat disaster images will also be collected by the same swarms of UAVs and will be fed into the database so that the BIM information system can compare the before and after flood images of the region to estimate the intensity of damage that has been inflicted upon the affected area, cost estimations for recovery of the infrastructure, and estimation of the best possible plan to carry out instruction and recovery steps. In the case of the floods in Pakistan, this integrated framework can be used to present an estimation of the cost for recovery, distribute the level of damage done, predict the best recovery and reconstruction plan, and ensure resilient build-back so that future floods may be mitigated.

6 CONCLUSION

Post-disaster reconstruction is a complex, dynamic, and challenging phenomenon. In recent years, unmanned vehicles and business information modelling have been individually used for the collection of data regarding flooded areas to assess the level of damage, the cost for recovery, and the best plan possible for recovery and reconstruction. In this review, the researcher assessed 39 papers that discuss flood management, UAVs, or BIM for disaster management and recovery. The papers were analyzed using bibliometric techniques along with the use of content analysis. The content analysis of the study revealed that images collected using UAVs for flood area indication and management provide much more accuracy in comparison to images taken from satellites. Moreover, the importance of BIM as an information management system to enhance resilience in post-disaster reconstruction is also established. Based on these findings, the researcher presented an integrative outline for enhancing resilience in post-disaster reconstruction processes in Pakistan.

6.1 Theoretical and Practical Implications

The present study contributes to the understanding of disaster resilience by discussing the importance of integration of technology in disaster response and recovery. It significantly adds value to the existing research stream by synthesizing articles related to technological use in disaster management. Additionally, by identifying the latest techniques and technologies, the research provided a holistic approach that can be utilized and offered recommendations to enhance flood management strategies for a flood-prone developing country, Pakistan. These findings also hold significant practical implications for professionals involved in disaster management in Pakistan.

The study highlights the use of technology, such as UAVs, for enhanced detection and monitoring of floods. It can serve as a guide for professionals to improve response measures and enhance damage assessment in flood-prone regions in developing countries. The study offers insights into image processing techniques for assessment of floods which can be utilized for effective decision-making. Lastly, the findings are useful for promoting the implementation of BIM in post-disaster reconstruction. Construction professionals, governments and disaster recovery teams can benefit from the findings to improve planning, design, cost and reconstruction processes.

6.2 LIMITATIONS

While the researcher significantly added to existing literature and presented a framework based on the literary findings, there are several limitations of the current study. First of all, the scope of the paper is wide as it covers more than one technology, UAV, BIM, image processing, etc. In the future, studies conducted for enhancing flood management and resilience in reconstruction can focus on a single technology to provide a more focused and in-depth review. Additionally, the present study was limited to English language articles and conference proceedings. Future research can broaden the scope by including other relevant types of paper in different languages. Moreover, future researchers need to validate the presented conceptual framework through statistical and empirical analysis to provide evidence for the usefulness of integrating the usage of technologies like UAVs and BIM.

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