Exhaustive Insights Towards Social-Media Driven Disaster Management Approaches

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***Abstract*—The manuscript presents discussion about the disaster management approaches using social media. It is noted that rising popularity of social media has been witnessed to significantly contribute towards information propagation and community participation to deal with the event of disaster. Different from conventional disaster management policies, the scope of inclusion of social media-based approaches are quite novel and yet promising. However, the problem is towards unclear information about the effectivity of such schemes. Hence, this manuscript contributes towards bridging this information gap by carrying out an exhaustive and systematic review of existing methodology frequently adopted towards disaster management using social media viz. early warning methods, information dissemination methods, crisis mapping method, and predictive approach, where Artificial Intelligence was noted to be quite dominant scheme. The contributory findings of this review study contribute towards clear visualization of updated research trends, critical learning outcomes associated with identified research gap with illustrated discussion of the reviewed articles. A clear and informative study findings contributes towards future researchers. The result of review has also answered the formed research question to give potential insight towards existing system. The result of the review finds that existing approaches has both beneficial aspect and limitation associated with complex learning approaches, higher infrastructural cost, model complexities, security threats, higher resource dependencies.**

***Keywords*—Artificial intelligence; disaster management; information propagation; social media; community**

I. Introduction

Disaster management is a mechanism adopted towards formulating and organizing the resources to facilitate reliefs to the victim and coordinating with the various levels of an organization to gain control over the affected region [1]. The prime agenda of disaster management is manifold. The primary agenda of disaster management is mitigating the event by identifying and evaluating the potential vulnerabilities and risk followed by developing and enforcing constructing codes and regulations to plan the land use [2]. It also implements various countermeasures to control and eliminate the impact of disaster. The secondary agenda of disaster management is preparedness where emergency plans are developed along with conducting drills and various exercises to ensure readiness [3]. It also involves saving resources and supplies in times of emergency, followed by offering proper training to response time and the general public. The disaster management's third agenda is to offer an appropriate response to the situation by deploying or mobilizing the emergency services [4]. The response also involves carrying out a search and rescue process and offering medical care, food, and shelter while communicating information to the public. The fourth agenda of disaster management is towards a recovery system where the degree of damage is assessed, and identification is carried out for the recovery requirement [5]. It also implements a plan for a long-term recovery system focusing on restoring everyday life, essential services, and infrastructure of varied forms. The fifth agenda is facilitating communication and coordination systems for effective emergency control [6] by collaborating with international partners, community groups, and non-governmental organizations. The idea is also towards establishing a uniform structure of command that consists of organization and multiple agencies thereby coordinating efforts at national, regional, and local levels. The sixth agenda is to perform a technological integration for multiple purposes, i.e., early warning system, analysis and mapping using Geographic Information System (GIS), and leveraging multiple communication platforms and social media for sharing real-time information [7]. The final agenda is towards community engagements involving the local community in decision-making and planning [8]. It also fosters a culture of resilience and preparedness within the local communities.

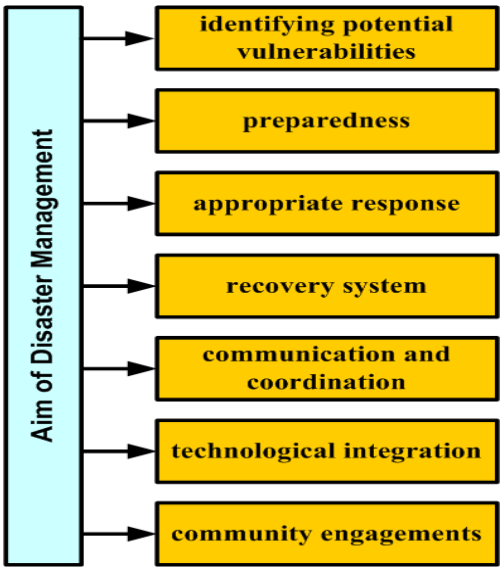

Fig. 1. Standardized aim of disaster management.

Fig. 1 highlights the pictorial representation of all the essential characteristic which every research-based modelling should possess in order to adhere to standards. All the agenda mentioned above of disaster management is fulfilled using various technologies viz. GIS [9], remote sensing [10], early warning system [11], unmanned aerial vehicles (drones) [12], big data analytics [13], Artificial Intelligence [14], Mobile applications [15], robotics [16], blockchain technology [17], satellite communications [18]. It was also noted that the involvement of machine learning and artificial intelligence is slowly increasing in its pace, contributing towards optimizing the strategies of responses by predicting disasters and identifying patterns. Such approaches are also reported to analyze text and image-based information to assess the extent of damage, thereby offering faster processing of information. Further, satellite-based communication is also proven to offer a pervasive beneficial perspective compared to all other technologies. This is because satellite-based communication is highly functional when all the conventional ground-based communication is disrupted during emergencies in affected areas. Another interesting technology observed in disaster management is blockchain, which is used for securing the data ensuring integrity of information connected to the disaster response, relief efforts, and financial transactions. It was also noted that social media plays an effective tool towards disaster management by facilitating information dissemination, coordination, and communication. Therefore, the prime contribution of the proposed study is to highlight the effectiveness of existing research-based solutions, contributing towards exploring pitfalls that can assist in framing an effective solution. The proposed manuscript introduces compact yet resourceful information as an extension of existing review studies and focuses on understanding social media's influence on disaster management. The value-added contribution of this manuscript are as follows:

1) Compact and yet highly resourceful information on prominent taxonomy of methodologies where social media is used for disaster management has been reviewed.

2) An updated research trend is furnished to offer more clarity towards the progressive status of existing research works.

3) A specific set of learning outcomes that assists in better decision-making for future researchers to know the method's effectiveness.

4) A crisp highlight of the research gap that will assist in carving problem solutions for addressing the missing links in existing research methodologies.

The organization of the manuscript is as follows: Section II presents study background, Section III discusses about the research methodology adopted planning of selection of an appropriate information for crafting this review work followed by highlights of the extensive results obtained from the presented review study in Section IV. Critical discussion of the accomplished results in the form of identified research gap as learning outcome and solution of research questions is carried out in Section V, while Section VI presents conclusive summary and future work of the paper.

II. BACKGROUND

There is relevant literature where social media has been actively used in connection with various technological contributions to disaster management. The work by Abdulhamid et al. [19] has presented a discussion about social media's contribution to dealing with emergencies. Deng et al. [20] have discussed assessing the effectiveness of community disaster resilience. Morelli et al. [21] have illustrated different forms of framework where a social media-based communication system is used for gaining control over disaster risk attributes. The adoption of Phengsuwan et al. [22] has presented a discussion of a comprehensive taxonomy of data management using social media for investigating disaster management. Investigation towards varied attributes that have a potential impact on social media towards effective disaster management is discussed by Ramakrishnan et al. [23]. Seddighi et al. [24] have explicitly discussed Twitter disaster data based on disaster management for a better understanding of the severity of damage. A computational framework for disaster management using Internet-of-Things (IoT) is designed by Sharma et al. [25], while an exclusive report discussing response and recovery systems involving social media has been presented. Although there is a comprehensive discussion of existing social media-based studies towards disaster management, there is still an overload of information and pin-pointed discussion towards adopting preferred solutions, with highlights of the research gap potentially missing. There is a need fora specific set of information highlighting prominent gaps so that existing technological problems can be narrowed down to find an effective solution. Irrespective of the availability of various technological contribution towards disaster management, various challenges are associated with the practical implementation of them. The primary problem associated is ensuring seamless communication and data exchange among different included technologies towards disaster management. Such a lack of interoperability is the primary hindrance towards effective implementation. Availability of advanced technologies cannot always be expected in various remote regions which doesn't have proper power, transportation, and communication. Including different technologies in disaster management also involves a lack of standardization, inaccuracies, and inconsistencies, often leading to misinformation and hindering effective decision-making. Resource constraint is another essential problem in many disaster management cases, mainly due to the affected areas' geographical location. Infrastructure vulnerabilities and human factors are other essential problems where people lose control of the situation demanded for effective rescue planning and execution. Apart from this, adopting social media also involves significant problems, e.g., misinformation and rumors, information overload, limited connectivity and access, privacy concerns, security issues, coordination challenges, barriers in culture and language, technological dependence, public panic and fear.

Hence, the problem statement is, "Identifying and controlling the severe situation of disaster demands the acquisition of multiple technological attributes where there is a large gap between the practical impediments and technological execution plans."

III. Methodology Description

The presented review work has been carried out adhering to the standard of PRIMA methodology in order to address any form of biased findings and to offer granular evidential-based conclusive remarks. This section presents vivid discussion of the research method adopted towards presenting this review work as follows:

A. Research Question

The framing of the research question is carried out using standard PICOC methodology, where five research questions were formulated corresponding to essential elements of the adopted methodology i.e., population, intervention, comparison, objective, and context. Table I highlights the framed research question for presented review work.

TABLE I. Framed Research Question

Code	Research Question
P	**R_1**: Which is the most frequently addressed research problems towards disaster management?
I	**R_2**: What is the currently dominant research-based approaches towards analyzing an event of disasters?
C	**R_3**: What are the prominent attributes that has potential influence towards disaster management using social media?
O	**R_4**: What are the complexities associated with adoption of social media towards evaluating the criticality of natural disaster?
C	**R_5**: What are possible means to improvise the efficiency of determination of disaster event using social media?

B. Strategy of Search

The adopted method has used Boolean operator in order to frameup strings to be used for searching the primary information associated with proposed topic. Fig. 2 highlights the primary search methodology constructed in adherence with the standard PICOC methodology. It should be noted that there are approximately 10 permutation and combination of the search terms as well as approximately 20 respective synonymies deployed linked with parent search terms used for this purpose during pilot study. However, after iterative observation being carried out, they were further filtered to obtain much better outcome. Hence, Fig. 1 showcase a single search term which is further deployed with three classes of synonymies. The combination stated in Fig. 1 is witnessed to showcase high quality research article necessary to carry out this review work.

C. Criteria of Eligible Information

The proposed review work has been subjected to certain criteria in order to ensure proper selection of the research papers. It should be noted that the core aim of this review work is to understand the current situation of different methodologies exercised towards disaster management. Table II and Table III presents adopted inclusion and exclusion criteria.

TABLE II. Inclusion Criteria

Code	Description
I_a	Article published between 2018-2024 in high impact factor journals
I_b	Manuscript must include quantitative technique of disaster management
I_c	Implementation papers where social network has been deployed towards disaster management
I_d	Technical papers with validated research outcomes with clear discussion of dataset used

TABLE III. Exclusion Criteria

Code	Description
E_a	All articles published before 2018
E_b	Conceptual discussion manuscript
E_c	Articles from low-impact factor journals
E_d	Articles without any evidence of result/data analysis

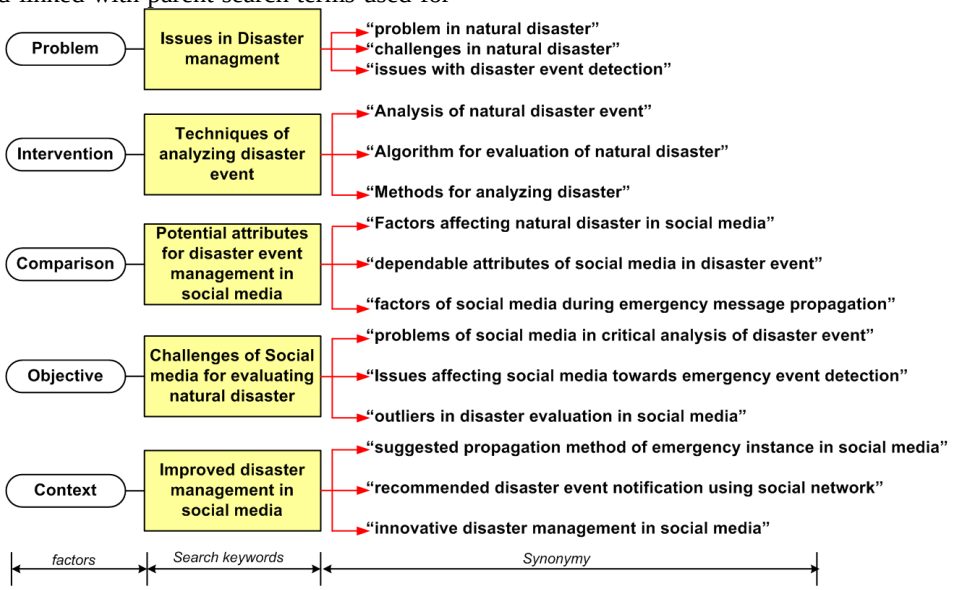

Fig. 2. Primary Search Strategy Formulation using PICOC methodology.

D. Process of Selection of Articles

The proposed study has been carried out considering a typical desk research methodology, as exhibited in Fig. 2. It consists of three stages of filtering the information associated with the existing domain of review work. It should be noted that Fig. 3 is obtained after deeper insight of adopted pilot strategy exhibited in Fig. 2. It is noted that existing studies towards disaster management using social media is basically of four types viz. i) studies related to early warning of disaster management, ii) studies emphasizing on information dissemination of disaster event, iii) studies related to development and improvement towards crisis mapping, and iv) studies with predictive modelling towards event of disaster. The core notion of this methodology was to shortlist the recently published research papers that have not been discussed in prior review work to study the degree of effectiveness. After collecting all the data, it was found that there are various ranges of topic of disaster management that can be broadly classified into i) natural disaster, ii) technological / industrial disaster, iii) environmental disaster and iv) complex humanitarian emergencies. The complex humanitarian emergencies basically deal with food crisis, terrorism, and armed conflicts while the environmental disaster deals with pollution, soil erosion, and deforestation. The technological disaster deals with industrial explosion, nuclear accidents, and chemical spills while natural disaster deals with wildfires, floods and earthquakes. A closer look at all the types of disaster management-based studies showcases that natural disaster is the most challenging one which has not yet met with any robust and full-proof solution. It was also noted that the most frequently adopted technologies in studying natural disaster are based on cloud computing, big data, Internet-of-Things (IoT), model-driven engineering, geographic information system, data analytics, and machine learning.

According to Fig. 3, the first stage was to perform a keyword-based search, which yielded 38441 manuscripts related to early warnings, 20082 manuscripts for information dissemination, 2493 manuscripts for crisis maps, and 3274 papers for predictive-based approaches. The second stage consists of reviewing the manuscript based on title and abstract to find 521 papers discussing early warning systems and information dissemination, 1621 papers discussing information dissemination and crisis maps, and 276 papers where all predictive approaches are combined and investigated with information dissemination and early warnings. Finally, when the complete papers have been reviewed, 70 papers have been reviewed whose discussion is presented within this paper. The study has aggregated articles from IEEE, Springer, and MDPI.

Particular emphasis is given towards understanding the methodologies involved and the results being accomplished to narrow down the final findings of the proposed review work. The following section presents the result of the proposed review work.

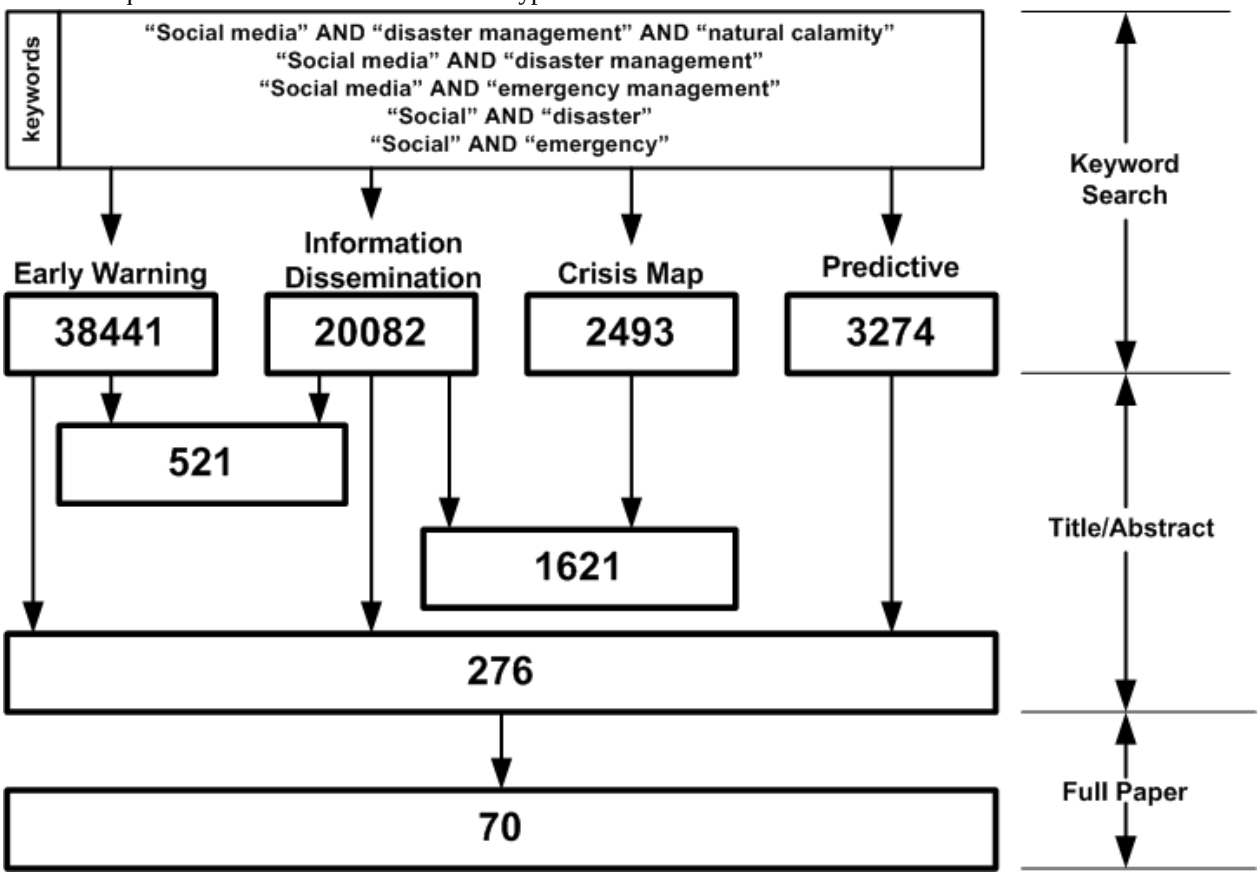

Fig. 3. Finalized Methodology of proposed review work.

IV. Result of Literature Review

At present, various methodologies are being introduced to investigate the issues of disaster management using social media. It is to be noted that different methods are mainly associated with analyzing the criticality of the information and managing it in a highly structured manner. The core notion of existing methodologies is also associated with acquiring certain intelligent information to make a correct and reliable outcome of the actual status of a disaster event. Following are some of the existing methodologies being reviewed:

- Early Warning Methods
- Such a form of methodology is related to the usage of real-time updates and automated alert systems. Various methodologies reviewed are Forest fire detection (Aramendia et al.[26]), earthquake detection (Beltramone & Gomes [27]), Rating curve method integrated with nomograph (Cheong et al. [28]), Community-based scheme (Al-Mueed et al. [29]), Loosely coupled architecture for risk assessment (Psaroudakis et al.[30]), Flood detection by hybrid method (Rozos et al. [31]), People-centric method (Shah et al. [32]), Joint modelling with machine learning and classification using rule-based methods (Shen et al. [33]), Cyclone detection (Sultan et al. [34]), Community monitoring for hydrological forecast (Tarchiani et al. [35]), Flood mapping with satellite images (Wania et al. [36]). The contribution of social media platforms in all the schemes mentioned above was mainly to facilitate the authorities to offer more immediate updates about disasters with automatic push alerts to the users in affected areas. The core notion of this method is to warn the users of the severity of upcoming disasters.
- Information Dissemination Methods
- This type of method mainly emphasizes channeling the identified events of disaster to an appropriate communication channel to forward the information to emergency services. Some of the existing research frameworks towards information dissemination implemented are as follows Mobile computing-based emergency management (Astarita et al. [37]), Geospatial-information based disaster management (Ghawana et al. [38]), User behavior centric framework for disaster screening (Han & Wang [39]), Hub-framework connecting the critical community with local emergency management team (Mitcham et al. [40]), Micro-Macro level-based disaster alters using social network (Samaddar et al. [41]), Edge computing-based named data network for disaster response system (Tran & Kim [42]), Acquisition framework for disaster location analysis (Yang et al. [43]), Multimodal framework for disaster data evaluation (Zhang et al. [44]), Model for Dynamic theme propagation for rainstorm detection (Zhang et al. [45]), Integrated machine learning and spatiotemporal analytical framework (Zhang et al. [46]). A closer look into these study models shows that they are mainly meant for the authorities to use social media to propagate safety guidelines, evacuation routes, and emergency information to the affected population. Further, these models are also used by authorities and emergency services by harnessing social media to facilitate officials and precise information thereby having more control over effective information dissemination.
- Crisis Mapping Method
- This is a form of a digital map that offers real-time information associated with emergency stages during a disaster. Such a crisis map is developed to show available resources, evacuation routes, affected locations, etc. A study towards the effectiveness of crisis maps is carried out by Divjak and Lapaine [47] and Divjak et al. [48], which highlights the effectiveness as well as issues about it, viz. unstructured and non-clear methods during cartography. This issue is found to be addressed by Du et al. [49], where map cognition concerning the time-critical perspective is improvised to offer more elaborated visual information in a crisis map. The adoption of organigraphs is discussed by Durrant et al. [50] where the authors have stated its significance towards preparedness against. However, the authors also suggested that there is still an enormous scope for improvement, and the existing system is not yet ready for large scale and dynamic situations. The work by Maxant et al. [51] has presented a discussion about rapid mapping for detecting fire and flood in a shorter period using a pipeline-based detection system. Further, Vavassori et al. [52] discussed a crisis map development using satellite imagery integrated with geographic information. The study also addresses the reliability of data acquired from social media by acquiring metadata demanded for classifying images. Hence, crisis mapping lets the user share the geotagged information where mapping and social media platform is used to construct the map to understand hazard severity better.
- Predictive Approach
- This approach is meant for performing a predictive analysis on the given data to confirm or classify the degree of severity associated with the target disaster event. The work carried out by Asif et al. [53] used have Convolution Neural Network (CNN) to classify the disaster from the images obtained from social media. Belcastro et al. [54] have also carried out a similar form of implementation where disaster analysis is carried out based on social media posts using supervised machine learning. In contrast, spatial clustering is used for identifying an affected region. The work done by Fan et al. [55] has introduced a framework where multiple modalities, i.e., network performance reticulation, activation, and enactment, have been studied. The study also assesses temporal changes concerning multiple modalities considering Twitter data. Ho et al. [56] have developed a precipitation forecasting model considering weather uncertainty to predict shallow landslides. Hong and

Martinez [57] have presented a data-driven predictive model to make decisions about the evacuation flow associated with disaster events. Ide and Nomura [58] present a probabilistic predictive model to construct a renewal model towards tectonic tremors. Karmegam et al. [59] have developed a mapping model towards forecasting a flood event from data captured from twitter. The emergence of an Artificial Intelligence-based model towards the prediction of disaster is carried out by Khattar and Quadri [60] using content from microblogs in social networks. Mendoza et al. [61] developed an early prediction model based on the Mercalli scale integrated with locally supported information for estimating real-life earthquake events. Ng et al. [62] have developed a forecasting framework based on social activity where the main emphasis is evaluating the effectiveness of existing baseline models. Sayama et al. [63] have discussed an ensemble forecasting method using hydrographs for analyzing flood events. Modelling towards support system is constructed by Takenouchi and Choh [64], where road network analysis has been presented to construct a disaster prevention map. A closer look into the above-mentioned methodologies showcases that a large dataset is extensively demanded to construct a predictive model to yield highly accurate outcomes.

- Miscellaneous Approaches
- There are various other associated conventional schemes towards analysis the severity of the disaster management. Citizen reporting and crowdsourcing is another mechanism that uses user-generated content and crowdsourced maps that allow users to share multimedia-based information in real time and contribute to navigation and resource allocation [65]. Adoption of social media is also witnessed towards contributing various forms of aid distribution and donation drives towards rescuing the victims from disaster events [66]. Further, social media is reportedly used for awareness campaigns and training to conduct community engagements [67]. It was also noted that monitoring social media can significantly assist the authorities in assessing real-time concerns [68], identifying emerging issues [69], and measuring public sentiments [70] using sentiment analysis and data analytics.

A. Research Trends

An evaluation of the frequency of the publication associated with the proposed topic will be carried out from 2018 to 2024. The notion is to realize the different evolving solutions fordisaster events. Table IV showcases some of the publication trends towards the varied forms of disasters to find that 147,906 manuscripts have been published to date discussing the solutions towards mitigating disaster events. An in-depth analysis showcases that a good number of resources are available in MDPI Journals (=382) and IEEE Journals (550); however, journals related to Springer, Hindawi, and Elsevier have more theoretical discussion with a smaller number of actual implementation studies. More number of research work has been carried out towards investigating flood (=37738), fire (=33705), earthquake (=22,320) and COVID-19 (=19788).

TABLE IV. TREND OF INVESTIGATION DISASTER EVENTS

Events	MDPI	Springer	IEEE	Hindawi	Elsevier
Multi-hazard	1	18	4	720	874
Eruption	0	2960	4	120	877
COVID-19	15	19021	34	116	602
Cyclone	11	7032	32	0	311
Drought	0	20	0	0	0
Fire	29	33460	114	0	102
Earthquake	107	21539	133	0	541
Hurricane	23	12335	73	7	0
Typhoon	34	4656	15	333	111
Flood	161	37344	134	0	99
Tornado	1	3230	7	133	413

The trend explored from the numerical outcome of Table V showcases that there are 96081 research papers considering social media of varied sources. The outcome shows similar relevancy of papers mainly from MDPI and IEEE journals with extensive consideration of Facebook (=21200), Twitter (=17314), and mobile technologies (=19329). One essential finding is that WhatsApp and Instagram, one of the most widely used mobile social media applications, have been less involved in existing research methodologies.

TABLE V. TREND OF INVESTIGATION ADOPTION OF SOCIAL MEDIA

Media	MDPI	Springer	IEEE	Hindawi	Elsevier
WhatsApp	20	6474	15	2408	39
YouTube	29	12016	7	2144	30
Instagram	20	6306	13	2348	18
WeChat	11	2988	13	3250	89
Mobile Technologies	193	16460	288	2348	40
Facebook	67	17784	45	3264	40
Twitter	102	13884	197	3083	48

The research trend in Table VI shows that 231,955 manuscripts have adopted explicit forms of standard taxonomies associated with investigating warning, impact, response, and relief-based methodologies. The outcomes show that extensive studies have considered addressing disaster tracking-based problems (=51971), event detection (=45388), event prediction (=42840), and early warning systems (=38441). Other associated approaches are significantly less addressed, while the problem mentioned above solution has adopted less computational-based approaches and used more on data-centric analysis.

The outcome shown in Table VII highlights that out of 153780 manuscripts, extensive work is carried out considering a behavior-based approach (=91747) followed by perception-based analysis (=49861). These approaches are seen to be

implemented over varied use-cases of disaster events. The majority of these implementations have been assessed using accuracy as a parameter. They are more linked with offline analysis and less towards online analysis.

TABLE VI. TREND OF INVESTIGATION EXISTING APPROACHES

Approaches	MDPI	Springer	IEEE	Hindawi	Elsevier
WARNING					
Event prediction	204	33430	160	8796	250
Early Warning system	138	36459	313	871	660
Predictive	199	2165	113	476	321
IMPACT	**MDPI**	**Springer**	**IEEE**	**Hindawi**	**Elsevier**
Information Dissemination	34	18498	70	543	937
Event Detection	705	35927	1845	6752	159
RESPONSE	**MDPI**	**Springer**	**IEEE**	**Hindawi**	**Elsevier**
Disaster Tracking	129	48593	477	2651	121
Situational Awareness	44	20	1	703	44
RELIEF	**MDPI**	**Springer**	**IEEE**	**Hindawi**	**Elsevier**
Tools	20	20689	37	766	688
crowdsourcing	22	3685	70	664	13
Crisis Mapping	179	141, 243	162	1990	162

TABLE VII. IDENTIFIED AI-METHODS FOR DISASTER MANAGEMENT

AI Methods	MDPI	Springer	IEEE	Hindawi	Elsevier
Perception	209	47551	132	1923	46
Cognition & Learning	8	10974	10	781	399
Behavior	43	82054	397	9058	195

B. Identified Primary Research Gap

Prior to make a conclusive remark associated with the research gap of proposed review work, it is essential to understand some of the significant findings of proposed review as a contribution and novel findings. These remarks are based on the most frequently adopted approaches associated with an investigation towards disaster management.

- Data Analytics and Machine Learning: The existing studies have been noted to adopt this approach mainly in order to accomplish its increased predictive accuracy [53]-[64]. These approaches are also reported to offer proactive decision making based on trends and data patterns. Further, optimization of evacuation routes and identification of disaster affected area are it's another benefits. However, the problems of adopting these approaches are as following:
  - Adoption of complex machine learning approaches offers significant interpretability challenges [53]-[64]. Practical deployment of such models also demands regular maintenance and continuous updating with higher dependency of voluminous real-time data, which may not be available all the time.
- *Geographic Information System / Spatial Analysis*: This is another frequently adopted approaches that offers effective mapping of affected region for identification [38] [52]. Apart from supporting user-friendly decision making, it also offers effective visualization-based monitoring and supports heterogeneous data sources integration for deeper analysis. However, the problems identified in these approaches are:
  - Higher infrastructural cost of maintenance is the prime issue in these techniques. There is also excessive time involvement towards data collection and initial setup.
- *Model Driven Approaches*: This approach facilitates clear system behavior with better collaborative and interpretability [33] [45] [46], and [56]-[59]. Apart from this, it is also known to optimize its allocation of resources with systemic analytical approaches. The potential challenges associated with this approach are:
  - These approaches [33] [45] [46], and [56]-[59] involve significant degree of complexity towards development and integration of the model. It also consumes resources and extensive time for constructing the framework.
- *Sensor / IoT based Approaches*: These approaches are gaining more momentum at present owing to its capability to collect real-time data and its respective parameters [9]-[18]. It also assists in early assessment and detection. The mechanism is also reported to offer timely information and accurate decision making. However, its inherent challenges are:
  - These approaches suffer from greater deal of security threats as well as reliability issues associated with readings of sensors. Apart from this, setting up large scale network using IoT also demands higher expenses.
- *Cloud and Big Data Approaches*: These approaches are another popularly adopted approaches in current era towards disaster management [13] [53] [54]. It is known for it capability to accomplish enhanced forecasting by leverage historical data. This approach is also known for its data sharing with more collaborative users thereby facilitating analysis and processing in real-time. It is also known for its scalable storage of data. However, its issues are as follows:
  - These approaches [13] [53] [54] have higher consideration of cost towards data storage and maintenance of cloud infrastructure. There is also a higher dependency of seamless and uninterrupted internet connection towards facilitating transmission of data.

V. DISCUSSION OF RESULTS

This section presents discussion of the core findings from prior Section III. After reviewing the existing methodologies associated with disaster management, various learning outcomes are associated with the review work. There is no

doubt that extensive assessment-based modelling has been carried out with varied agendas and use cases of disaster management. They act as a beneficial guideline, but there is still a certain set of open-ended challenges. Apart from this, this section also presents illustration of the formulated knowledge towards seeking answers for the research questions.

A. Learning Outcomes

The learning outcomes of the proposed review work have been presented in the form of a significant research gap as follows:

- Most of the existing research work has been carried out considering publicly available disaster datasets, where the models don't focus on dynamic properties. Hence, their applicability towards practical implementation environments has not been proven with reliability or benchmarking.
- A closer look into the population of data shows that the adoption of Artificial intelligence and machine learning-based approaches is relatively less, and their adoption is increasing slower. Extensive studies have been carried out considering data-centric methods and simplified empirical approaches.
- Studies towards early warning systems using predictive approaches are quite innovative. Yet, there are fewer schemes to prove its reliability and interpretability when machine learning approaches are found to be frequently deployed.
- The involvement of the term social media is only limited to dataset origination point and not much research model has involved any form of user or community participation. Adopting a citizen reporting system is one of the critical processes in disaster management using social network, which is technically less reported in the existing scheme.
- There is also lesser involvement of innovative computational-framework-based approaches towards disaster management systems. The adoption of advanced analytics is also much less explored in existing methodologies. Further, there is no report of any benchmarked computational model from this perspective.
- In machine learning, some significant advancements are contributed by deep learning and other associated algorithms. However, there are a smaller number of predictive approaches witnessed in existing methodologies. Available machine learning-based strategies towards disaster management are computationally extensive models with more dependencies on trained data. Their practical execution is still less spoken of in existing learning-based models.

B. Solution to Research Question

The next part of the discussion is associated with exploring the identified solution towards the research questions being highlighted in Section II.

R_1: Which is the most frequently addressed research problems towards disaster management?

Existing research in disaster management are witnessed to addresses a variety of issues, but some of the most frequently addressed problems are i) *risk assessment and prediction* (Psaroudakis et al.[30]), ii) *preparedness and planning* (Aramendia et al.[26], Sultan et al. [34]), iii) *response and recovery* (Tran & Kim [42], Psaroudakis et al.[30], Zhang [46], Asif et al. [53], Malla et al.[70]), iv) *community resilience* (Tran and Kim [42], Dixon et al. [67]), and v) *technology and innovation* (Ghawana et al. [38]). Under risk assessment and prediction, it is related to understanding the factors that contribute to disaster risk, developing models to predict the occurrence and severity of disasters, and identifying vulnerable populations and assets. Under preparedness and planning scheme, the scheme focuses on developing strategies for disaster preparedness, including creating emergency response plans, establishing early warning systems, and conducting drills and exercises. Under response and recovery scheme, such scheme targets towards **i**mproving the effectiveness and efficiency of emergency response efforts, including search and rescue operations, medical care, shelter provision, and infrastructure restoration. Under community resilience methods, the scheme emphasizes on building the resilience of communities to withstand and recover from disasters, including fostering social cohesion, enhancing infrastructure resilience, and promoting sustainable development practices. Under technology and innovation approaches, the methods focus on leveraging technology and innovation to improve disaster management, including the use of remote sensing, GIS (Geographic Information Systems), drones, AI, and communication technologies for early warning, situational awareness, and decision support.

R_2: What is the currently dominant research-based approaches towards analyzing an event of disasters?

Several dominant research-based approaches are used to analyze natural disasters viz. i) *Interdisciplinary Research* (Tavra et al. [65], Khattar & Quadri [60], Ide & Nomura [58]), ii) *Risk-Based Approaches* ((Psaroudakis et al.[30]), iii) *Data-driven Analysis* (Ghawana et al. [38], Vavassori et al. [52], Zhang et al. [45]), iv) *Resilience Frameworks* (Maxant et al. [51], Divjak and Lapaine [47], Du et al. [49]). Under interdisciplinary research scheme, it is considered that natural disasters are complex events involving multiple factors, including physical, social, economic, and environmental dimensions. Interdisciplinary research approaches, which integrate insights from various disciplines such as earth sciences, social sciences, engineering, and public health, are commonly used to analyze the causes, impacts, and responses to natural disasters. Under risk-based approaches, the risk assessment and management are fundamental to understanding and mitigating the impacts of natural disasters. Research-based approaches focus on assessing the likelihood and potential consequences of different types of hazards, identifying vulnerable populations and assets, and developing strategies to reduce risk and enhance resilience. Under data-driven analysis, it is noted that the advances in data collection, processing, and analysis have enabled researchers to use large datasets from sources such as remote sensing, GIS, social media, and sensor

networks to analyze natural disasters. Data-driven approaches allow for the identification of trends, patterns, and correlations that can inform disaster preparedness, response, and recovery efforts. Under resilience frameworks-based approaches, it is noted that resilience is increasingly recognized as a key concept in disaster management, emphasizing the ability of communities, organizations, and systems to absorb and recover from shocks and stresses. Research-based approaches to resilience analysis involve assessing the adaptive capacity, coping mechanisms, and recovery processes of individuals and communities in the face of natural disasters. These approaches are often used in combination to provide comprehensive insights into the causes, impacts, and responses to natural disasters, and to inform evidence-based decision-making and policy development.

R_3: What are the prominent attributes that has potential influence towards disaster management using social media?

Social media platforms have become increasingly important tools for natural disaster management, with several prominent attributes that have the potential to influence disaster response efforts viz. i) *Real-Time Information Sharing* (Aramendia et al.[26], Beltramone & Gomes [27], Cheong et al. [28], Karmegam et al. [59], Turay and S. Gbetuwa [68], Zhu et al. [66]), ii) *Crowdsourced Data Collection* (Tavra et al. [65], Astarita et al. [37]), iii) *Two-Way Communication* (Tran & Kim [42], Zhang et al. [45]), iv) *Public Engagement and Mobilization* (Malla et al. [70], Tarchiani et al. [35], Al-Mueed et al. [29], Mitcham et al. [40]), v) *Information Aggregation and Analysis* (Malla et al. [70], Han & Wang [39], Tavra et al. [65]), vi) *Crisis Mapping and Visualization* (Divjak and Lapaine [47], Du et al. [49], Durrant et al. [50], Maxant et al. [51], Vavassori et al. [52]). Under attributes of real-time information sharing, it is believed that social media allows for the rapid dissemination of information during disasters, enabling authorities, organizations, and individuals to share updates on hazards, evacuation orders, shelter locations, road closures, and other important developments in real time. For crowdsourced data collection, it is noted that social media users often share firsthand accounts, photos, and videos of disaster impacts, providing valuable situational awareness to emergency responders and decision-makers. Crowdsourced data can help identify affected areas, assess damage, and prioritize response efforts. For two-way communication, it is seen that social media platforms facilitate two-way communication between authorities and the public, allowing for interactive dialogue, feedback, and questions from affected individuals. This enables authorities to address concerns, provide reassurance, and gather information about emerging needs and priorities. For public engagement and mobilization, it is observed that social media can be used to engage and mobilize the public in disaster preparedness, response, and recovery activities. Authorities and organizations can use social media to raise awareness, promote safety messages, recruit volunteers, and coordinate community-based initiatives. For attributes of information aggregation and analysis, it is studied that social media analytics tools enable the aggregation and analysis of large volumes of social media data to identify trends, patterns, and sentiment related to disasters. This can help authorities and researchers gain insights into public perceptions, needs, and behaviors during disasters, and inform decision-making and resource allocation. Under crisis mapping and visualization, the social media data can be integrated with geographic information systems (GIS) and mapping tools to create crisis maps and visualizations of disaster impacts, response activities, and resource distribution. These maps can enhance situational awareness, facilitate coordination among stakeholders, and support decision-making in complex and dynamic environments. Overall, the prominent attributes of social media contribute to more effective and inclusive disaster management by facilitating communication, collaboration, and coordination among stakeholders, and by empowering affected individuals and communities to participate in disaster response efforts. However, it's important to recognize that social media also presents challenges, such as the spread of misinformation, privacy concerns, and digital divides, which need to be addressed to maximize its potential benefits for disaster management.

R_4: What are the complexities associated with adoption of social media towards evaluating the criticality of natural disaster?

The adoption of social media for evaluating the criticality of natural disasters presents several complexities:i) *Data Veracity* (Han et al. [39], Mitcham et al. [40]), ii) *Data Volume and Velocity* (Durrant et al. [50], Takenouchi and Choh [64], Kamiya et al. [68], Karmegam et al. [59], Wania et al. [36], Asif et al. [53], Ghawana et al. [38], Vavassori et al. [52]), iii) *Bias and Algorithmic Fairness* (Fan et al. [55], Khattar and Quadri [60], Mendoza et al. [61], Ng et al. [62], Sayama et al. [63], Takenouchi and Choh [64]). Under data veracity problem, the researchers have developed a model towards ensuring that model reliability without much considering the authenticity of the data from contextual viewpoint. Social media platforms are prone to the spread of misinformation, rumors, and false reports during disasters. Distinguishing between credible information and misinformation can be challenging, requiring careful verification and fact-checking to ensure the accuracy and reliability of data. Such complexities are found few to be addressed in existing studies and hence will impose a bigger challenge towards evaluating criticality of natural disaster. Under data volume and velocity challenge, it is noted that social media generates vast amounts of data in real time, including text, images, videos, and geospatial information. Managing and analyzing this data in a timely manner can be overwhelming, requiring advanced analytics tools and techniques to process and extract actionable insights from large and rapidly changing datasets. Under bias and algorithmic fairness problem, it is seen that social media algorithms may introduce biases in the selection, prioritization, and presentation of content, potentially skewing perceptions, and assessments of disaster criticality. Addressing algorithmic bias and ensuring fairness in the analysis of social media data require transparency, accountability, and continuous monitoring of algorithmic decision-making processes. Addressing these complexities requires a multidisciplinary approach that combines expertise in data science, social science, ethics, and disaster management, as well as close collaboration between researchers, practitioners, policymakers, and affected communities to harness the potential of social

media for evaluating the criticality of natural disasters while mitigating associated risks and challenges.

R_5: What are possible means to improvise the efficiency of determination of disaster event using social media?

Improving the efficiency of determining natural disaster events using social media involves implementing various strategies and leveraging advanced technologies. Here are some possible means to achieve this:

- Real-Time Monitoring Tools: Real-time monitoring tools can be developed that automatically collect, filter, and analyze social media data for indicators of natural disaster events. These tools can use keyword detection, geolocation, and image recognition algorithms to identify relevant posts and prioritize actionable information for further analysis.
- Machine Learning and AI: Machine learning and artificial intelligence algorithms can be implemented to automatically classify and prioritize social media posts related to natural disasters based on their relevance, credibility, and urgency. These algorithms can learn from labeled training data to improve accuracy and efficiency over time and help filter out noise and irrelevant information.
- Geospatial Analysis: Geospatial analysis techniques can be integrated with social media data to map the spatial distribution and temporal evolution of natural disaster events. Geotagged posts and location-based metadata can be used to identify affected areas, assess the severity of impacts, and prioritize response efforts in real time.
- Social Network Analysis: Social network analysis techniques can be designed to identify influential users, key information sources, and emergent communication networks during natural disaster events. Analyzing social media networks can help pinpoint trusted sources of information, detect patterns of information diffusion, and target communication strategies to reach broader audiences.
- Multimodal Data Fusion: The social media data with other sources of information can be used (such as satellite imagery, weather data, sensor networks, and traditional news sources) to enrich situational awareness and improve the accuracy of natural disaster detection and assessment. Multimodal data fusion techniques can integrate diverse data streams to provide a more comprehensive understanding of disaster events.
- Community Engagement and Crowdsourcing: System can be designed to engage with affected communities and leverage crowdsourcing platforms to solicit real-time reports, observations, and needs assessments from social media users on the ground. Empowering local communities to contribute to disaster monitoring efforts can enhance the timeliness and relevance of information and foster a sense of ownership and resilience.
- Cross-Sector Collaboration: It is essential to foster collaboration and data sharing among government agencies, non-governmental organization, academic institutions, technology companies, and social media platforms to leverage their respective expertise, resources, and data assets for improving the efficiency of natural disaster determination using social media. Collaborative initiatives can facilitate data interoperability, standardization, and mutual support in disaster response efforts.
- User Education and Awareness: It is necessary to promote user education and awareness campaigns to enhance digital literacy, encourage responsible social media usage, and disseminate accurate and reliable information during natural disaster events. Providing guidelines, training, and tools for verifying information and reporting emergencies can empower social media users to contribute to disaster response efforts effectively.

By implementing these means and adopting a holistic approach that combines technological innovation, data analytics, community engagement, and collaboration, it is possible to improve the efficiency and effectiveness of determining natural disaster events using social media, ultimately enhancing disaster preparedness, response, and recovery efforts.

Future work in disaster management systems will likely focus on several key areas to address current limitations and emerging challenges:

- Advanced Predictive Analytics: Enhancing predictive modeling capabilities to anticipate the occurrence, severity, and impact of disasters with greater accuracy. This involves integrating machine learning algorithms, remote sensing data, and socio-economic factors to improve early warning systems.
- Real-time Data Integration: Developing robust systems for real-time data collection, aggregation, and analysis from various sources including IoT devices, social media, and satellite imagery. This will enable faster decision-making and response coordination during disasters.
- Resilience Planning and Infrastructure: Researching innovative approaches to enhance the resilience of critical infrastructure, urban systems, and communities against diverse hazards such as climate change-induced events, cyber-attacks, and pandemics.
- Community Engagement and Behavioral Insights: Conducting research on effective communication strategies, community engagement methods, and understanding human behavior during disasters to improve risk communication, evacuation, and response efforts.
- Interdisciplinary Collaboration: Encouraging collaboration between disciplines such as computer science, social sciences, engineering, and public health

to develop holistic and adaptive disaster management strategies.

- Evaluation and Learning: Developing robust evaluation frameworks to assess the effectiveness of disaster management systems, identify lessons learned, and foster continuous improvement through feedback mechanisms.

Despite these potential advancements, it's essential to acknowledge the limitations inherent in disaster management systems, such as:

- Resource Constraints: Limited financial, human, and technological resources can hinder the development and implementation of comprehensive disaster management systems, particularly in low-income and developing regions.
- Data Quality and Availability: Challenges related to data quality, interoperability, and accessibility can impede the effectiveness of decision-making and response efforts, especially in complex and rapidly evolving disaster scenarios.
- Uncertainty and Complexity: Disasters are inherently complex and uncertain phenomena influenced by various interconnected factors, making it challenging to develop deterministic models and strategies for mitigation and response.

Addressing these limitations will require a concerted effort from researchers, practitioners, policymakers, and communities to foster innovation, collaboration, and resilience in disaster management practices.

VI. Conclusion

This paper has discussed the existing approaches towards disaster management using social networks. Some of the core issues in this manuscript that has been investigated and enumerated are as:

- Existing research methods towards disaster management is quite unclear of its effectiveness towards set of practical problems during natural events.
- There are few disclosures about prominent attributes from existing studies that can assists in future modelling perspective towards exploring avenues of disaster management.
- Inclusion of social media and their challenges are less emphasized in existing studies especially towards classifying degree of severity of disaster event.

The prime contribution of the proposed review paper are as follows: i) the novelty of this manuscript is the highlights of some core open-ended issues about existing methodologies concerning its learning outcomes, ii) the paper highlights the latest studies being carried out considering the frequently adopted varied standard methodologies in highly compact, crisp, and yet highly resourceful, iii) the paper also presents updated highlights of current research trend which offers significant insights towards the direction of the degree of adopted methodologies towards disaster management. One of the essential learning outcomes of the study is that there are fewer computational modelling attempts towards early warning systems, which is one of the most critical steps towards disaster management. It is also identified that learning approaches have potential solutions to such challenges and yet their frequency of publications is relatively less in contrast to other non-learning-based methodologies.

Therefore, the future work of this paper is to develop a scheme of social networks where the involvement of data and users will be given equal importance in modelling, unlike existing approaches. The idea will be to generate indexed data from social media. At the same time, the work can be further extended towards adopting a machine learning model for developing an early predictive warning system. The notion will be to accomplish accuracy aligned with the interpretability of the predictive model towards disaster management. The future work will be carried out towards developing an innovative and yet simplified classification models that can not only assists in efficient disaster event data transmission but also offer better computational efficiency. Machine learning can assist in damage assessment, early warning system. ML algorithms can analyze historical data on past disasters, weather patterns, seismic activity, and other relevant factors to develop predictive models for early warning systems. These models can forecast the likelihood and severity of upcoming disasters, enabling authorities to issue timely alerts and evacuation orders. ML algorithms can analyze social media feeds, news articles, and online forums to monitor real-time information about disaster events, including eyewitness reports, requests for help, and emerging trends. This data can complement traditional sources of information and provide valuable insights for decision-makers during crisis situations. ML algorithms can facilitate communication and coordination among different stakeholders involved in disaster response, including emergency responders, government agencies, NGOs, and volunteers. By analyzing communication networks, sentiment analysis, and social network data, ML models can identify key influencers, disseminate critical information, and facilitate collaboration across organizational boundaries.

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