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Impact of an Integrated Approach in Disaster Management

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ABSTRACT

In recent times, there have been several natural disasters, negatively affecting communities ranging from loss of lives, businesses, homes and economic disruption. Such serious effects on a community can be traced to poor disaster management arrangements. Several project management concepts as well as technologies have been researched and proven to improve disaster management. This article reviews existing literatures to make evident the concepts of project management such as project planning, execution, team collaboration and governance as well as technologies with a focus on the Internet of Things (IoT) through provision of early warning signs for mitigation and preparedness, big data analytics (BDA) for information gathering and unmanned aerial vehicles (UAVs) for emergency relief scenarios in disaster management. Findings of this article reveals the great impact and benefit of an integrated approach for effective disaster management. Hence, this paper recommends an integrated approach to disaster management from a project management and Internet of Things perspective.

KEYWORDS

Big Data Analytics, Disaster Management, Internet of Things, Mitigation, Preparedness, Project Management, Recovery, Response

1. INTRODUCTION

According to the International Federation of Red Cross and Red Crescent (IFRC) a disaster is defined as a "sudden, calamitous event that seriously disrupts the functioning of a community or society causing losses that affects humans lives, infrastructure, economy and environment, resulting in the inability of the society to cope using its own available resources" (IFRC, 2019a). Disasters are either of a natural or man-made origin (Verma, Verma, & Banerjee, 2019). Disasters of natural origins occur as a result of natural processes, for example; Nepal severe local storm, Iran & Afghanistan flash floods, Tropical Cyclone Idai, Peru landslides and flood (IFRC, 2019), Indonesia's Tsunami, India and Paraguay floods, Haiti earthquake, Armenia Hail storm (IFRC, 2018), Tropical Cyclone Luban & Cyclone Mekunu, Sudan, Nigeria, Mongolia, Georgia, Cote d'Ivoire, Myanmar, Philippines & Cambodia floods (OCHA, 2019) to mention a few. On the other hand, man-made originated disasters are caused by human errors and intents this includes chemical spillage and terrorist attacks.

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Regardless of the origins of these disasters, they all result in thousands of casualties and displaced people. The 2018 World Disasters Report by the IFRC reveals that in recent times the intensity of disasters has shown an increase with 3,751 identified cases of natural disaster with about 84.2% of these disasters having weather-related triggers and leaving about 134,000,000 of the world population affected in dire need of assistance (IFRC, 2019b). Evidence from available statistics shows the need to implement several strategies, technologies and management skills to effectively reduce the negative impact of disaster on the human population and society in general.

This paper seeks to make evident the impact of an integrated approach to disaster management from a Project Management and Internet of Things perspective by reviewing existing literature. The Section 2 of this paper will review detailed literature around the nature and phases of disaster management with an aim to establishing project management concepts required for the successful planning and execution of disaster management projects. Section 3 reviews literature around technologies available to enhance efficiency in managing projects on disaster with a core focus on the Internet of Things technology. Finally, Section 4 will conclude the paper.

2. NATURE OF DISASTER MANAGEMENT

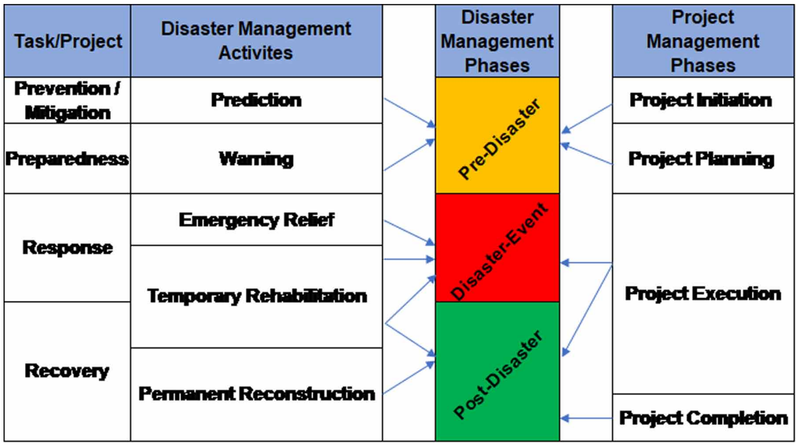
Over the years, there has been indications that the occurrence of various disastrous events have been one of the major concerns of humanity (Jalil Arab-Kheradmand, Ahmadi, Baniasadi, & Khankeh, 2016; Ronchi, 2015). Consequently, driving individuals and organisations to constantly develop innovative approaches to decrease the negative effect of the immediate and post-disaster impact (Williams, Gruber, Sutcliffe, Shepherd, & Zhao, 2017), however, irrespective of what approach is adopted, the main aim and intent is to effectively manage disaster. Disaster management therefore can be viewed as the administrative approaches (Raikes, Smith, Jacobson, & Baldwin, 2019), decisions, operations and technologies that apply to the effective management of different stages and levels of disaster (Ripoll Gallardo et al., 2015). One of the major aims or goals of disaster management is to prevent, reduce the negative impact and build resilience of the affected system or environment (Chroust & Aumayr, 2017; Iizuka, 2018; Oloruntoba, Sridharan, & Davison, 2018). More so, for effective implementation of disaster management approaches, several researches and academic literatures have identified the existence of multi-phases in managing disaster (Abbasi Dolatabadi, Seyedin, & Aryankhesal, 2016; Gupta, 2015; Meduri, 2016; Misra, Goswami, Mondal, & Jana, 2017; Shafiai & Khalid, 2016; Singh, L., Srivastava, & Singh, 2017). In a similar view, to mitigate risk and enhance disaster recovery planning, a global model using PESTLE framework can be applied to different types of disaster-prone systems (Sarwar, Ramachandran, & Hosseinian-Far, 2017). In addition, analysis by Raikes et al., (2019) identifies risk management and crisis management as two conceptual frameworks with both exhibiting different intervention and capacity levels depending on the type of disaster.

2.1. Phases of Disaster Management

Interestingly, there have been relationships between project management and disaster management phases evident in academic literature and researches (Chang-Richards, Rapp, Wilkinson, Von Meding, & Haigh, 2017; Enshassi, Adnan, Shakalaih, & Arain, 2017; Gacasan & Wiggins, 2017; Netek & Panek, 2016). Similarly, a research on the application of project management in building disaster resilience by Prasad, Woldt, Tata, & Altay, (2017) identifies that the internal characteristics of project management (uncertainty and information demand) influences the external elements of disaster management process (imminence, scale and goal intricacy). It is believed that there are similarities between the nature and phases of disaster management and project management (Crawford, Langston, & Bajracharya, 2013; Gaudenzi & Christopher, 2016; Lin Moe & Pathranarakul, 2006). These similarities are evident in their defined interconnected phases as seen in figure 1.

According to Hoque, Phinn, Roelfsema, and Childs, (2017) cycles of a typical disaster management can be conceptualized into two phases connected by activities. These phases are the

Figure 1. A comparison of the interconnected life-cycle phases between disaster management and project management; Adapted from: (Lin Moe & Pathranarakul, 2006).



pre-disaster phase which involves mitigation and preparedness activities and the post-disaster phase which involves response and recovery activities (Enshassi, Shakalaih, & Mohamed, 2019).

2.2. Pre-Disaster Phase

The pre-disaster phase is the initiating or primary stage of the disaster management process (Verma et al., 2019). At this phase, if all tasks and activities are effectively carried out, the expected loss from the foreseen disaster can be determined (He & Zhuang, 2016). This phase includes the strategy and calculation of the probable disaster (Tabata, Zhang, Yamanaka, & Tsai, 2016). The phase includes carrying out mitigating and preparatory tasks that provide activities which aims at reducing the impact to be caused by the potential disaster (Verma et al., 2019), it is therefore believed that to be more effective in managing disaster, it is mandatory to have pre-disaster plans (Crowley, 2017). In a similar view, Guyette, (2017) confirms that pre-disaster planning positively reduces damages and helps organizations maintain a certain level of stability during and after a disastrous event.

The risk management framework in the pre-disaster phase is mainly driven by the prevention-preparedness-response-recovery (PPRR) tasks (Raikes et al., 2019), consequently, the main tasks in the pre-disaster management phase are the prevention or mitigation and preparedness tasks (Ali Torabi, Shokr, Tofighi, & Heydari, 2018), as seen in figure 1.

2.3. Prevention/Mitigation Tasks

In contemporary times, there has been a considerable research attention around disaster mitigation planning (Huang & Shen, 2019; Mika, 2016; Osaragi, 2015; Sarmah & Das, 2018; Schwab, Sandler, & Brower, 2016; van Delden et al., 2016). Just like project management processes require several planning factors such as human, management, organizational and technical factors (Tesfaye, Lemma, Berhan, & Beshah, 2017), disaster mitigation planning also requires human (Aerts et al., 2018), technical (Sinha, Kumar, Rana, Islam, & Dwivedi, 2017), leadership and organizational inputs (Al Shobaki, Abu Amuna, & Abu-Naser, 2016; Valdivieso Fernandez, 2017) to successfully carry out the project of managing of disaster.

Prevention and mitigation have been identified as the first task in managing disasters effectively, it comprises of preventive strategies applied and projects undertaken with an aim of reducing the occurrence or fatal consequences resulting from any inevitable disaster (Verma et al., 2019). There have been several research advances around this vital aspect of disaster management as a result of the critical role it plays in estimating, mitigating, reducing the occurrence and impact of a disaster

(Kreibich, Thaler, Glade, & Molinari, 2019). Example of these researches are; in drought disaster mitigation (Bachmair, Svensson, Prosdocimi, Hannaford, & Stahl, 2017; Markantonis et al., 2018), mitigation of extreme disastrous rainfalls (Cortés Simó, Turco, Llasat-Botija, & Llasat Botija, María del Carmen, 2018; Spekkers, Rözer, Thieken, Veldhuis, & Kreibich, 2017), mitigation of earthquakes (Altunışık & Genç, 2017; Yılmaz & Çağlayan, 2018) and in mitigation of several flood types (Bernet, Prasuhn, & Weingartner, 2017; Laudan, Rözer, Sieg, Vogel, & Thieken, 2017; Wagenaar, Jong, & Bouwer, 2017).

Existing literature shows that there are two common strategies used in disaster mitigation (Katanha & Simatele, 2019); the structural and non-structural disaster mitigation strategies (Yoon, Kang, & Brody, 2016). Structural mitigating strategies includes relocating and rebuilding resilient structures while non-structural mitigation strategies includes training, coordinating emergency planning, coastal protection and land use management (Arlikatti, Maghelal, Agnimitra, & Chatterjee, 2018; Hosseinian-Far, Pimenidis, Jahankhani, & Wijeyesekera, 2011; Strusińska-Correia, 2017) see table 1. However, the mitigation task can be conceptualized as disaster risk reduction since it possesses components that aims at reducing risk impact of disasters throughout the society and environment (Mojtahedi & Oo, 2017). A research by Goniewicz & Burkle, (2019), reveals that the potential implementation of early warning systems based on text messages helps mitigate potential disaster as well as reduce vulnerability and risk associated with the event.

2.4. Preparedness Tasks

Disaster preparedness concept can be viewed as a different concept such as disaster readiness (DeYoung & Peters, 2016) and disaster contingency planning (Hashemipour, Stuban, & Dever, 2017). Consequently, the word ‘’preparedness’’ can be identified as a concept of a greater theoretical, multidimensional picture as it cannot be solely measured but rather understood as an umbrella covering tasks involved in preparing for an event of disaster (Staupe-Delgado & Kruke, 2018). Hence, preparedness tasks can be viewed as a cycle of continuous equipping and taking corrective action driven by the aim to attain readiness to respond to a disastrous event (Haddow, Bullock, & Coppola, 2017). In addition, the preparedness tasks can be viewed as being similar to the mitigating tasks because of their proactive nature in combating and minimising the negative impact of a disaster (Boonmee, Arimura, & Asada, 2017). For example, through the use of early warning signs, the proactive nature of preparedness can be seen to create a position of readiness in case of a disaster to reduce the resulting negative impact (Herlianita, 2017; Zhou, Wu, Xu, & Fujita, 2018).

The preparedness tasks are carried out when the mitigating or preventing strategies fall short because not all disasters can be prevented (Staupe-Delgado & Kruke, 2018). The preparedness tasks possess the potential of bridging the response and mitigation task as it recognises the existence of unmitigated risks. In a wider perspective, the task of disaster preparedness covers several activities such as risk and preparedness analysis, training and exercising (Baker & Grant Ludwig, 2018) and evacuation (Medina, 2016) see table 2. Therefore, a disaster preparedness plan should contain an early warning, protective measures against the potential disaster and precautionary measures (Chandramohan, Anu, Vaigaiarasi, & Dharmalingam, 2017). In the case of a drought-related disaster,

Table 1. Disaster mitigation tasks and responsibility

Mitigation Tasks	Responsibility
Relocation	All affected parties
Rebuilding resilient structures	Government
Training & emergency planning	Disaster managers and planners, NGOs
Coastal protection and land use management	Environmental professionals and Government

Nhamo, Mabhaudhi, & Modi, (2019) emphasises on the importance of preparedness through forecasting and monitoring as being fundamental to an early warning system and resilience building to such disaster (Hosseinian-Far & Jahankhani, 2015; Farsi *et.al. 2017*).

In addition, a study by Girons Lopez, Di Baldassarre, & Seibert, (2017) reveals that a high social preparedness contributes to effectively mitigating losses from flood-related disasters. Furthermore, creating emergency procedures in advance and stakeholder institutional capacity in order to enhance the possibility of an effective response to impact from a potential disaster is a vital in disaster preparedness (Mojtahedi & Oo, 2017).

2.5. Disaster and Post-Disaster Phases

This phase which is a latter to the pre-disaster phase is often known to deal with uncertainties and complexity (Sabouhi, Tavakoli, Bozorgi-Amiri, & Sheu, 2019; Song, Chen, & Lei, 2018). This phase is considered as one of the most challenging aspect of the disaster management phase (Granville, Mehta, & Pike, 2016; Mejri, Menoni, Matias, & Aminoltaheri, 2017; Noham & Tzur, 2018). However, to solve the issue of complexity, a heuristic algorithm based on Tabu-search is recommended (Noham & Tzur, 2018).

The disaster and post disaster phase can be termed ''dynamic'' as it encompasses several periods and tasks; the immediate response task in the face of disaster and the long-term recovery task (Çağlar & Murat Ermiş, 2017). Interestingly, just like projects, this phase should be well-defined, planned and implemented in stages or tasks (Ismail, Majid, & Roosli, 2014b). Therefore, for effective management and evaluation of this phase the adoption of existing tools or the development of new tools are required (Banerjee, Basak, Roy, & Bandyopadhyay, 2019; Kermanshachi & Rouhanizadeh, 2018; Lorca, Çelik, Ergun, & Keskinocak, 2017; Yi & Yang, 2014).

There are several issues that affect the successful execution of the disaster and post disaster phase, ranging from relocation issues (Sangasumana, 2018), technical issues (Erdelj, Król, & Natalizio, 2017), financial issues (Dückers & Thormar, 2015; Moon et al., 2017) and human resource issues (Aliakbarlou, Wilkinson, Costello, & Jang, 2017). Furthermore, using the risk management framework driven by the PPRR tasks (Raikes et al., 2019), the response and recovery tasks are considered as key during a disaster and post-disaster management (Hoque, Phinn, Roelfsema, & Childs, 2017). These tasks will be discussed in sections below.

2.6. Response Task

The response tasks comprise of series of reactive activities carried out when a disaster is imminent and after the disaster (Rabbani, Manavizadeh, Samavati, & Jalali, 2015; Rebeeh, Pokharel, Abdella, & Hammuda, 2019). It is basically the first stage of disaster management in the occurrence of a disaster. Classically, the response in disaster management is observed when the plans in the preparation stage are implemented with the sole aim of reducing the impact during and after the disaster (Verma et al., 2019). The response tasks are carried out at all levels impacted by the disaster; community level (Rehman, Sohaib, Asif, & Pradhan, 2019), local, state and federal government levels (Farber, 2018;

Table 2. Disaster preparedness tasks and responsibility

Preparedness Tasks	Responsibility
Risk and preparedness analysis	UNISDR, Disaster risk analyst
Training & Exercising	Disaster managers and planners, NGOs
Evacuation planning and evacuation	Disaster managers and planners, NGOs and affected parties
Information dissemination	Government, NGOs and ICT

Melo Zurita, Maria de Lourdes et al., 2018). Thus, the success of this phase is defined by how well prepared all actors and levels of impact are (Fagel, 2016) as well as the efforts made by several actors at different collaboration and cooperation levels (Tatham & Christopher, 2018).

In addition, to enhance the efficiency in the response phase, the utilization of attacker-defender games using games theory for the modelling of both the mitigation and response in a disaster is recommended (Seaberg, Devine, & Zhuang, 2017). This phase encompasses activities such as an emergency relief during the event of disaster (Cao, Li, Yang, Liu, & Qu, 2018; Maharjan & Hanaoka, 2018; Ni, Shu, & Song, 2018) and temporary rehabilitation during and immediately after the disaster (Dixit et al., 2018; Maharjan & Hanaoka, 2019; Mousavi et al., 2019) see table 3. In order to minimize the negative effect of disaster on lives and the economy, disaster response has to be effectively and efficiently implemented within 72 hours of the occurrence of the disaster (Erdelj, Natalizio, Chowdhury, & Akyildiz, 2017).

Furthermore, just as every other phase of disaster management requires an aspect of project management (Al Shobaki et al., 2016; Crawford et al., 2013), for example; the mitigating and preparation tasks in disaster management requires effective project planning to successfully achieve its goal (Hashemipour et al., 2017; Huang & Shen, 2019), in similar manner, the response task requires effective project governance to successfully carry out disaster response and relief activities (Levie, Burke, & Lannon, 2017). Thus, to enhance the success of the disaster response task as well as to realize the strategic objectives of this phase effective project governance is required (Musawir, Serra, Zwikael, & Ali, 2017).

2.7. Recovery Task

Recovery tasks are reactive activities or strategies driven by the sole aim of returning normality after the impact of disaster (Kennedy, Gonick, Meischke, Rios, & Errett, 2019; Rebeeh et al., 2019). In similar way, Oloruntoba et al., (2018) views it as a set of well-coordinated processes that supports disaster affected communities by restoring and reconstructing (short-term or long-term) the affected environment.

The post disaster recovery tasks completes a sequence of identifiable activities: response, emergency relief, temporary rehabilitation, permanent reconstruction (Ismail, Majid, & Roosli, 2014a), hence, the post disaster recovery tasks similar to the successful execution of a project should be defined, planned and implemented in stages (Chen, Das, & Ivanov, 2019; Francis, Wilkinson, Mannakkara, & Chang-Richards, 2018), because without a proper plan, it will be a herculean task to foresee or expect a successful disaster recovery. Disaster recovery projects are extremely demanding and challenging as they require multiple resources and actors (Suri et al., 2018).

Furthermore, for the successful completion of disaster recovery tasks, investment and collaboration from several actors and stakeholders are required (Tang, 2019). Actors such as government investing in resilient infrastructure (Marto, Papageorgiou, & Klyuev, 2018), likewise NGOs creating partnerships and collaboration amongst organizations (Chan, Roy, Lai, & Tan, 2019). However, upon implementation of recovery and reconstruction tasks it is crucial to take into consideration the restoration of cultural landmarks of the affected community (UNESCO, 2018). This is vital as communities are cultural constructs where culture and landmarks are important to the social fabric

Table 3. Disaster preparedness tasks and responsibility

Response Tasks	Responsibility
Emergency search and rescue	Government, NGOs and ICT
Emergency relief	Government, NGOs and ICT
Temporary rehabilitation	Government and NGOs

of its population (McLean, Lonsdale, Hammersley, O'Gorman, & Miller, 2018; Petrovic, 2018). More so, Pyles, Svistova, Ahn, and Birkland, (2018) also suggests that community participation in disaster recovery is key to the success of the recovery projects as the affected communities have a first experience and understanding to accurately identify immediate problems and needs.

3. TECHNOLOGIES FOR DISASTER MANAGEMENT

More interestingly, there have been a remarkable development in information and communication technologies (ICT) which has enabled it to possess a diverse range of applications for the effective management of disaster (Parajuli & Baral, 2017). The scope of ICT applied in the field of Artificial Intelligence- AI (Nunavath & Goodwin, 2018), Internet of Things- IoT (Zahra, Shafique, & Farid, 2018), Geographic Information System- GIS (Ranjan, Vallisree, & Singh, 2019; Thomas, 2018), Global Positioning Systems- GPS (Khaliq, Chughtai, Qayyum, & Pannek, 2018) and Remote Sensing-RS (Schwarz et al., 2018; Singh, Pandey, & Mina, 2019) all contribute and support massively when applied in disaster mitigation, preparedness, response, relief and recovery processes for effective and efficient disaster management (Bhanumurthy & Sharma, 2019).

3.1. Internet of Things (IoT)

Internet of Things technology is experiencing a rapid evolution to what is now known as the Internet of Anything and Everything and is with a defined aim to enhance, improve, collate, analyse and share network data among its nodes and afterwards converting collated data in meaningful information and knowledge (Khamayseh, Mardini, Atwood, & Aldwairi, 2019). IoT can therefore be introduced and applied for an effective management of any type of disaster during any disaster management activity, for example in early warning, preparations or in remote monitoring (Ray, Mukherjee, & Shu, 2017; Wellington & Ramesh, 2017). Applying and integrating IoT with several disaster management systems is evident through the classification-based perspectives (Ray et al., 2017).

From a disaster mitigating perspective, the integration of IoT with spatial big data solutions can also help in mitigating and predicting disaster risks, for example, relating coastal erosions and flood (Boursier et al., 2018; Sharma & Kaur, 2019). More so, Alsamhi, Ma, Ansari, & Gupta, (2019) suggests the collaboration between drones and Internet of public safety things (IoPST) for disaster mitigation and emergency response. Little wonder why Sterbenz, (2016) projected that Unmanned Aerial Vehicles (UAVs) are expected to play vital role in city-wide IoT infrastructures for the creation of situational awareness.

From a service-oriented disaster management system perspective, crowd Sourcing (CS) within this field, is a key enabler that has been examined to be integrated with IoT in order to improve disaster response through the use of important values gotten from the use of RFID technology and social media (Han, Huang, Luo, & Foropon, 2018). Similarly, Poslad et al., (2015) presents a semantic integration approach which provides an IoT Early Warning System (IoTEWS) framework to improve environment disaster risk and management in a more efficient way. In addition, Gautam, Wasaki, & Sharma, (2016) proposes the implementation of a fault alarm system that is supported by a monitoring device (Tensai Gothalo) to guarantee network stability, improve decision making as well as ensure disaster preparedness and readiness. Since it is a better option to stay prepared than to be alleviated after the occurrence of a disastrous event.

An attempt to solve the problem of not being prepared or disaster ready paved the way for the introduction and suggested implementation of an IoT based Safe Community Awareness and Alerting Network (SCALE) by (Benson et al., 2015) and the Environmental Sensing and Community Alert Network (EnviroSCALE) by (Rahman et al., 2019) to provide alarms when a potential disaster is detected, in addition, to improve fault tolerance in disaster management using IoT, a fault tolerance system based on machine-learning, wireless sensor networks and IoT called SENDI (System for Detecting and Forecasting Natural Disasters based of IoT) is used to detect and forecast natural disasters by providing alerts and warnings (Furquim, Jalali, Pessin, Pazzi, & Ueyama, 2018). In like manner, an integrated IoT-Fog-Cloud energy efficient framework was proposed by Kaur & Sood, (2019) to enable forecasting and predicting disasters related to wildfires. In addition, in order to reduce the impact after the event of a disaster, IoT provides a range of technologies that possess the potential to effectively aid activities during post-disaster response, relief and recovery (Zafar, Shah, Wahid, Akhunzada, & Arif, 2019). For example; (Ali, Nguyen, Shah, Vien, & Ever, 2019) proposes edge-based IoT applications that works with device-to-device (D2D) transmissions between IoT enabled devices to provide communication benefits for disaster management systems (DMS) in emergency relief situations. Likewise, in cases of flood related disasters, the integration of IoT, HPC and Big data positively helps in providing solutions for flood analysis, prediction and minimization of flood disaster (Sood, Sandhu, Singla, & Chang, 2018). Furthermore, IoT through information obtained, plays a vital role in enhancing situation awareness during the aftermath of a disaster and recovery processes (Suri et al., 2018), the integration of IoT technologies and Big data Analytics also creates an approach that provides fast and effective situational awareness which in turn reduces the negative impact after a disaster (Hosseinian-Far, Ramachandran, & Sarwar, 2017; Hosseinian-Far, Ramachandran, & Slack, 2018; Shah et al., 2019). In a similar view, for better understanding in managing disasters the use of analytics is recommended for the simulation of natural disaster (Chang, 2018). Also, (Lee, Hong, Jung, & Chang, 2018) suggests the use of CCTV image pattern and big data analysis to increase better comprehension of hazards due to bad weather conditions.

4. CONCLUSION

The adoption and implementation of some concepts of project management such as effective project planning during the pre-disaster period, project governance and team collaboration during the event and post-disaster period plays a vital role in effectively managing disasters. IoT, which enables and facilitates an easy interconnection between diverse devices with diverse operational use, is a practicable solution during the management of disasters. Reviewed literature integrates effective project management concepts with internet of things technology (Big data Analytics and AI) and demonstrates the great impact of an integrated approach in managing disasters effectively through the provision of adequate planning, governance, early warning signs for disaster mitigation and preparedness to UAV relief activities. In summary, this paper's aim is to make evident the impact of some project management concepts and Internet of Things technology in disaster management from past research and literature. However, further research is required to understand better how IoT can be effectively used for disaster recovery and enhance the overall disaster management processes.

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