Article

Conceptualizing Smart Disaster Governance: An Integrative Conceptual Framework

Ehab Shahat 1, Chang T. Hyun 1 and Chunho Yeom 2,*

1 Department of Architectural Engineering, University of Seoul, Seoul 02504, Korea; ehab.shahat@gmail.com (E.S.); cthyun@uos.ac.kr (C.T.H.)
2 International School of Urban Sciences, University of Seoul, Seoul 02504, Korea
* Correspondence: chunhoy7@uos.ac.kr

Received: 26 September 2020; Accepted: 13 November 2020; Published: 16 November 2020

Abstract: The discourse of disaster governance is focused on the arrangements, relationships, and roles of the various actors involved in disaster governance. However, due to the lack of research on utilizing emerging technologies in disaster governance systems, this paper addresses the prospective benefits of utilizing Internet of Things (IoT) technologies in smart disaster governance systems. The authors employed a conceptual analysis of the previous research on disaster governance and utilizing IoT in disaster management. The basic concepts and constructs were abstracted from the literature to conceptualize a smart disaster governance system and its processes. As a result, six spheres were portrayed to form the characteristics of the smart disaster governance system, and an integrative conceptual framework for smart disaster governance was developed. The conceptual framework encompasses IoT technologies’ capabilities and disaster governance functions, in addition to the foreseen enhancements in disaster coping capacities and an overall rise in disaster resilience. A hypothetical case study was conducted to investigate the conceptual framework’s plausibility, and it showed a probable enhancement of the disaster governance of the 2018 Kerala floods if the smart disaster governance framework was utilized. This research provides a novel conceptualization of smart disaster governance. It can deepen the understanding of prospective benefits of integrating IoT technologies with disaster governance functions, contribute to disaster governance policy formulations, and construct a basis for future research on smart disaster governance for a sustainable society.

Keywords: smart disaster governance; internet of things; disaster management; disaster resilience; disaster coping capacities; sustainable society

1. Introduction

The abrupt, complex, and destructive nature of natural or man-made disasters makes the disaster governance process very difficult to handle. Although many efforts have been made to reduce the impacts of disasters, and a lot of research has addressed prevention, mitigation, response, and recovery with respect to disasters, still, there is a call for more efforts and research. For instance, for the ten years from 2008 to 2017, an annual average of more than 10,000 people were counted dead and two million people were negatively impacted due to natural disasters worldwide; in addition, around half of the world’s population were vulnerable to natural disasters in 2018 [1].

In the context of the fourth industrial revolution, many technologies have emerged that are able to contribute to confronting disasters, such as the Internet of Things (IoT), which has been gaining high industrial and research momentum [2]. IoT refers to the ability to provide information through mutual interaction between different devices and the environment, and to collaboratively use this information among platforms to produce useful applications [3]. The IoT concept can be grasped through identification, communication, and interaction qualities [4]. That is, the things—or the smart
For devices—need to be identifiable, for example, according to their location and condition in order to be able to emit and receive information and to interact with users, entities, or other devices in the same network. These capabilities empower the intelligence and connectivity of things, and, in general, they amplify the potentials of IoT technology, especially with the recent advancements in wireless and sensory technologies [5]. Since the early beginning of research on IoT, it was perceived as an enabling technology with high potential in the domains of transportation, healthcare, and smart environments, as well as in the personal and social domains [6]. Recently, research conducted on IoT has expanded to provide more applications in commercial, industrial, and other miscellaneous domains [7].

The authors suggest that the optimal utilization of IoT technology may serve as a vital enabler for shifting disaster governance practices into a smart disaster governance process. Since poor governance can be perceived as the root cause of society’s vulnerability to disasters [8], more research on disaster governance is required. However, a considerable amount of research has been conducted to introduce IoT technologies into disaster management. Still, hardly any research has been observed that linked the utilization of IoT to disaster governance to produce what the authors call smart disaster governance. Due to the absence of research about smart disaster governance, it is essential to investigate the potential to enhance disaster governance practices and arrangements by utilizing IoT technologies to expedite the efforts to raise our societies’ disaster resilience.

To this end, this paper seeks to formulate a conceptual framework that integrates the qualities of IoT into disaster governance systems and, thus, to contribute to reducing disaster vulnerabilities and minimizing human and economic losses. A conceptual analysis was performed on disaster governance and utilization of IoT in disaster management literature, which resulted in the development of an integrative conceptual framework of smart disaster governance. In addition, a hypothetical application of the conceptual framework was created to explore its potential if adopted. This conceptual framework can provide governing bodies with a new analytical tool that enables better disaster-related policy formulation, and it constructs a basis for future research about smart disaster governance.

The paper’s structure is as follows: In the second section, an overview of disaster governance and utilization of IoT in disaster management will be presented. Then, in the third section, the research method and conceptualization of the smart disaster governance system will be demonstrated. Section 4 will be dedicated to presenting the integrative smart disaster governance conceptual framework and to discussing its applicability to a case study. Finally, in the fifth and sixth sections, there is an overall discussion and conclusion highlighting recommendations for future research.

2. Disaster Governance and Utilizing IoT

2.1. Disaster Governance: Concept, Role, and Characteristics

Generally, governance is about how to run a society. Kaufmann et al. (1999) recognized governance as how a country a is run by utilizing practices, processes, and the establishments in that country [9]. Corporate governance is recognized as the set of mechanisms that safeguard the interests of stakeholders, especially minority investors, in addition to regulating the relationship between ownership and control [10,11], whereas environmental governance is perceived as the influences on the environment-related policies, arrangements, actions, and institutions brought about by state actors and other stakeholders [12]. However, another noticeably integrated concept that has evolved in the public administration literature is collaborative governance, which looks at governance with specificity regarding the public purpose, and it emphasizes collaboration between all stakeholders, such as the public, private, and civic spheres, in addition to citizens’ engagement [13]. Deriving from the collaborative governance approach, Tierney (2012), in her review paper about exploring disaster governance regimes and mechanisms, perceived disasters as among the specific things that need to be governed, and proposed this definition: “... disaster governance consists of the interrelated sets of norms, organizational and institutional actors, and practices (spanning pre-disaster, trans-disaster, and post-disaster periods) that are designed to reduce the impacts and losses associated with disasters.
arising from natural and technological agents and from intentional acts of terrorism” [14] (p. 344). In addition, she differentiated disaster governance from risk governance in that risk governance is a broader context in which the full range of risks encountered in society is addressed, including all kinds of risks, such as health, safety, and environmental risks. While in opposition to disaster management, disaster governance concerns more relationships and constructs from broader societal frameworks, including a diverse set of actors, social, economic, and political forces, and multiscale arrangements [14].

A disaster strike is dependent on the concurrent occurrence of hazard, vulnerability, and lack of coping capacity [8]. While the vulnerability is about the likelihood of being harmed due to the hazard, coping capacity is related to the abilities to avoid or respond properly to the hazard [15]. Consequently, raising the question of how disaster governance can reduce the susceptibility of societies to the impacts of disasters is relevant. For instance, Ahrens and Rudolph (2006) suggested that the root cause for the vulnerability of societies is an institutional failure and that underdevelopment is a critical factor in the increasing vulnerability of societies to disasters [8]. In addition, good governance is indicated to be directly related to improved economic outcomes and development [9]. Good governance is anticipated to be binding to laws, accountable, effective, politically dynamic, and well connected [9,13]. Similarly, disaster governance is seen as transparent and participatory, polycentric, and accountable, as well as a system that can predict, learn, and innovate [8,16]. However, it was pointed out that in the field of disasters, more research addresses disaster management, risk reduction, and governmental activities rather than disaster governance [14].

Recently, further research on disaster governance has been conducted that discusses the success factors and challenges of disaster governance. For instance, Melo Zurita et al. (2015) discussed the merits of the subsidiarity principle for informing disaster management actors [17]. In contrast, others explored the role of decentralization in the effectiveness of disaster governance [18,19]. More recently, as characteristics of disaster governance, timely response to disasters, capacity building, and efficient coordination were found to be challenging in disaster response operations [20]. Lam and Kuipers (2019) argued that participation and collaboration are the most influential characteristics of disaster governance in building resilience [21]. In addition, Song et al. (2020) signalized the role of crowdsourcing in promoting communication, coordination, decision-making, and adaptability in the disaster governance system [22]. In contrast, Albris et al. (2020) explored the role of disaster governance in disaster risk management. They suggested that knowledge sharing, coordination, engaging stakeholders, and developing communication can enhance risk management capabilities [23]. In fact, research on disaster governance is gaining more attention, but still, exploring the potential of utilizing new and emerging technologies in the disaster governance system is lacking, and more research is required.

2.2. IoT Utilization in the Disaster Management Realm

IoT technology enhances emergency response operations by providing wireless indoor and outdoor data, real-time information, and dynamic object tracking [24]. Generally, in disaster management, the heterogeneity of data, the proliferation of data sources, and the sensitivity of timely response confirm the exigency of utilizing IoT technologies [25]. In addition, utilizing Big Data analytics (BDA) and IoT technologies has proven their validity and usability for enhancing disaster management practices [26]. However, IoT is currently extensively used in various aspects of disaster management, and much research has been conducted to introduce the utilization of IoT for the enhancement of disaster management practices. For instance, Du and Zhu (2012) demonstrated that early warning systems that are based on IoT technology are capable of realizing efficient monitoring, control, and prediction in emergency management [27]. In addition, Gubbi et al. (2013) suggested the potential of IoT applications in emergency services and disaster scenarios [3]. As for the emergency response, four enhancements can be brought about by IoT for emergency response operations: accountability, situational awareness, localization, and shared information infrastructure [24]. Moreover, Wellington and Ramesh (2017)
proposed an interlinking system using IoT to enhance coordination among disaster management organizations during a disaster [28].

Furthermore, Ray et al. (2017) surveyed the research work of IoT-enabled disaster management systems [2]. They classified the IoT-based applications for disaster management based on the type of disaster management system: service-oriented (e.g., crowdsourcing), natural (e.g., early warnings and detections), man-made (e.g., real-time monitoring, alerts, predictions), and post-disaster (e.g., localization and positioning) management systems. The research that integrated Big Data analytics and IoT technologies for disaster management applications was reviewed [25], and disaster management systems applications were classified based on the phase of disaster management, for example pre-disaster applications, such as disaster prediction, early warnings, simulation exercises, and post-disaster applications, such as evacuation, rescue assistance, monitoring, and logistics management [25]. Moreover, connectivity, data storage, real-time analytics, cost-effectiveness, and multiple data sources were signalized as principal benefits of Big Data analytics and IoT for disaster management environments [21].

3. Smart Disaster Governance

According to the accessible literature and the best of the authors’ knowledge, there has never been any attempt to provide a conceptual framework regarding smart governance systems in the disaster management realm. The authors did not even find the term smart disaster governance in research databases such as Scopus and Google Scholar, except in a few articles, which were all published through a project titled “Enhancing smart disaster governance: Assessing the potential of the net-centric approach” [29]. Anyway, the use of the term is rare and limited to a project title, and no academic discussion about it has been recorded until the time of editing this paper. The authors are introducing a novel conceptualization of smart disaster governance, which can be the inception of a new subfield that, sooner or later, will be an essential part of the disaster management realm.

3.1. Method

The scope of this paper is limited to the IoT as a key enabling technology for shifting the usual disaster governance practices into a smart disaster governance practice. For that purpose, this paper employs a conceptual approach to identifying the appropriate linkages between disaster governance arrangements and enabling IoT solutions to reduce vulnerability to disasters and to facilitate and enhance disaster governance functions.

Following the three main aspects of Stephen Toulmin’s framework of arguments’ assessments, claims, grounds, and warrants [30], the research was designed. The claim is that utilizing IoT technology will promote disaster governance functions and thus enhance coping capacities, which will contribute to raising disaster resilience for a sustainable society, whereas, the grounds are manifested through previous research that has discussed disaster governance approaches and characteristics, in addition to the literature that indicated the ability of IoT technologies in promoting the various functions and arrangements of disaster management. Subsequently, the basic concepts and constructs were abstracted. Finally, the warrant is the logical reasoning and explanation of the link between the grounds and the claim. That is, the building blocks of a smart disaster governance system were identified as six spheres and, considering the disaster management requirements, analogies were drawn to match the appropriate IoT solutions and the governance functions and arrangements. Thus, the authors were able to conceptualize how a disaster governance system can be smarter by portraying the characteristics of a smart disaster governance system. In addition, an integrative conceptual framework was developed. The framework elaborates on the capabilities of IoT technologies that promote disaster governance functions in order to enhance coping capacities and thus raise disaster resilience for a sustainable society. Afterward, a hypothetical application of the developed framework was performed through the case of the 2018 floods that took place in the Indian state of Kerala to validate the applicability of the integrative smart disaster governance framework.
3.2. Six Spheres of Smart Disaster Governance

On one side, suitable governance arrangements contribute to the effectiveness of disaster management practices [8]. On the other side, smart governance was pointed out to improve the overall quality of life [31]. The term “smart” often refers to the advanced utilization of information and communication technologies (ICTs) [32,33], and ICTs are a core element in smart governance [34]. However, since many of the challenges facing disaster governance and management are related to information and communication availability and efficiency [28,35], utilizing ICT advancements is therefore crucial in proposing a smart disaster governance conceptualization for the enhancement of disaster governance practices.

Six spheres that encompass linkages between the IoT solutions and the governance functions regarding disaster management were manifested (Table 1). These spheres are essential for portraying a smart disaster governance system that utilizes IoT technologies in coping with and recovery from disasters.

| Sphere                  | Relevance                                                                 |
|-------------------------|----------------------------------------------------------------------------|
| Information             | Disaster-related data collection and analysis                              |
| Communication           | Data transfer and information sharing among stakeholders                  |
| Timeliness              | Prompt realization and response to a disastrous situation                  |
| Effectiveness and Efficiency | Result-oriented to cope, recover, and rationalize the use of resources |
| Reliability             | System performance, inclusiveness of stakeholders, and transparency in decisions and actions |
| Ubiquity                | Highest possible level of awareness of the disastrous situation and highest level of control over resources |

3.2.1. Information

Information is the ground base for smart governance [36]. Similarly, all the capabilities of governing in a disaster rely on the availability and quality of the information provided. This first sphere can be perceived as the primary and essential requirement for disaster governance. In addition, it is the core element that IoT technologies generate. Indeed, IoT generates data in the sensing layer, and then the data are transferred to the application layer to analyze and produce information [27]. This information created by IoT is fundamental for developing a smart disaster governance setting.

3.2.2. Communication

Due to the several stakeholders involved in disastrous situations, in addition to the remote locations of hazards and disaster management and relief units, communication is vital. That is, to share the information gained about the disaster, it is essential to establish powerful communication platforms. For instance, cloud computing and peer-to-peer (P2P) connectivity facilitate information sharing among stakeholders and between hazardous areas and control units [37].

3.2.3. Timeliness

The time factor is very sensitive when it comes to coping with disasters. That is, disasters can be unpredictable, where an instant response is crucial for saving lives and minimizing economic losses. That is why disaster governance requires a prompt response and punctually obtained information. Indeed, real-time data transfer and analysis are among the main benefits of IoT technologies.
3.2.4. Effectiveness and Efficiency

In the new and emerging public management approaches, effectiveness and efficiency were recognized as key values to improve responsiveness to the public needs [38]. Similarly, a key enabler for governing in a disaster is to have effective and efficient governing systems. So, the disaster governance process ought to be result-oriented with respect to reducing losses, maximizing capabilities to cope and recover, and rationalizing the use of resources. IoT technologies support resource management and distribution [3] and provide accurate accountability of resources and comprehensive situational awareness [24]. In addition, currently, the costs of IoT hardware and software components are declining [25]. These features in IoT are promising for the enhancement of disaster governance efficacy and efficiency.

3.2.5. Reliability

Building confidence in the governing body during the disaster is vital for a smoother and credible relationship between the governing body and the various stakeholders. In managing the disaster, the government is the key stakeholder [39]. Thus, responsiveness and cooperation among stakeholders lean heavily on the reliability of the governing body. However, reliability does not mean relying only on the governing body, but also the other actors and the whole network of relationships [40]. In the case of smart disaster governance, the IoT supports the governing body with highly acute data and provides adequate platforms for data sharing and strengthening communication among stakeholders. Thus, utilizing IoT technologies will promote the performance and inclusiveness of all stakeholders and substantiate the reliability of the whole disaster governance system.

3.2.6. Ubiquity

A ubiquitous environment is the ideal setting for disaster governance. That is, a full awareness of the disastrous situation through massive data generation, transfer, and analysis in real time can be the optimal enabler for enhancing disaster governance. In general, the high capabilities of IoT technologies in utilizing heterogeneous and various types of data, sharing, and communication, as well as informing decision-makers, suggest its appropriateness for developing ubiquitous environments [41].

4. Integrative Smart Disaster Governance Conceptual Framework

An integrative conceptual framework for smart disaster governance was developed, consisting of four modules in which the smart disaster governance approach will function (Table 2). The smart disaster governance framework is intended to function through the utilization of IoT technology’s capabilities by generating information from the disaster scene, as well as analyzing and transferring this information to the governing body. Accordingly, the disaster governing body promotes its functionalities to produce applications that can build and strengthen the disaster coping capacities. Subsequently, the enhanced disaster coping capacities will contribute to reducing vulnerabilities and disaster impacts and building disaster resilience (Figure 1). However, to delineate how a smart disaster governance framework may bring about disaster resilience as an outcome, a logic model (Figure 2) is displayed. The logic model depicts the four modules of the smart disaster governance system as inputs, activities, outputs, and outcomes.
Table 2. Elements of the smart disaster governance conceptual framework.

| Module                        | Elements                        | Description                                                                 |
|-------------------------------|---------------------------------|-----------------------------------------------------------------------------|
| **IoT Technologies’ Capabilities** |                                 |                                                                             |
| Accessibility                  |                                 | Access to data sources for data collection                                  |
| Monitoring                    |                                 | Live tracing and tracking of physical entities                               |
| Connectivity                  |                                 | Linking devices for data transfer                                           |
| Real-Time Analytics           |                                 | Prompt information analysis                                                  |
| Prediction                    |                                 | Predictions and early warnings before the disaster                          |
| **Disaster Governance Functionalities** |                             |                                                                             |
| Informative                   |                                 | Obtaining disaster-related information, such as disaster characteristics     |
|                                |                                 | and dissemination of the knowledge among all stakeholders                  |
| Participatory                 |                                 | Sharing information among stakeholders                                       |
| Supportive                    |                                 | Supporting and building capacities of less privileged actors and stakeholders|
| Pro/Reactive                  |                                 | In addition to responding to disasters, it is required to have a flexible    |
|                                |                                 | system and adaptive institutions for the variations in societal, economic,    |
|                                |                                 | environmental, and technological contexts                                   |
| Flexible                      |                                 | Transparent disaster-related decisions and interventions                    |
| Transparent                   |                                 |                                                                             |
| **Disaster Coping Capacities** |                                 |                                                                             |
| Awareness                     |                                 | High realization of the disastrous situation and dissemination of the       |
|                                |                                 | knowledge among all stakeholders                                            |
| Responsiveness                 |                                 | Efficient and effective response to the disaster                            |
| Control                       |                                 | Controlling operations and physical and technological resources             |
| Preparedness                  |                                 | Readiness to cope and recover                                               |
| **Disaster Resilience**       | Coping and Recovery             | Less vulnerability, higher mitigation capability, and more ready to         |
|                                |                                 | cope and recover                                                            |

Figure 1. Integrative smart disaster governance conceptual framework.
4.1. First Module: IoT Technology Capabilities—Inputs

The IoT technologies are at the forefront of smartening disaster governance systems. The essence of the six previously mentioned spheres of the smart disaster governance system can be realized and enhanced by utilizing IoT technologies. In the logic model, the authors perceive the capabilities of IoT technologies as the inputs of the system, i.e., that these technologies will be the source of information upon which decisions and interventions will depend. The five elements in this module can assist the disaster governance functions with the adequate potential to perform according to the requirements of good disaster governance.

Accessibility of data sources is the groundwork for smart disaster governance. Other capabilities of IoT technology and all the functions of disaster governance rely heavily on the availability of data. In order to collect data, the IoT uses devices and technologies such as sensors, radio frequency identification (RFID), wireless sensor networks (WSN), etc. [20, 23]. These devices can be deployed in any location, covering vast areas to generate data and thus inform disaster governance actors.

Monitoring is very linked to accessibility, where, in addition to merely gathering the data, the IoT provides further functions, such as surveillance, detection, and tracking [3]. All these functions can enhance disaster governance practices towards better situational awareness. For instance, the integration of IoT technologies with unmanned aerial vehicles for crowd surveillance was examined and found efficient and reliable for person detection [42]. In environmental disaster management, for more than a decade, wireless sensor networks have been used for monitoring volcanoes’ activities [43]. This capability is extremely important for smart disaster governance by providing accurate and credible location data of hazards in a timely manner.

Connectivity is a key capability that technologically consolidates the utilization of generated information. A major advantage of IoT technologies is the ability to establish connections to any object. Although data collected from hazardous locations are large in size and heterogeneous, the capability of IoT in connectivity is pointed out to be reliable in communicating these data to the different actors involved in governing in the disaster [25]. Wired and wireless IoT communication technologies and protocols, such as machine-to-machine (M2M) communication protocols, are the infrastructure underpinning disaster governance. The disaster governing body can remotely manage the disaster.

Real-time analytics is by no means less important than the other capabilities. The abrupt nature and the massive losses that are brought about by disasters signal the criticalness of prompt data gathering as well as information analysis to manage resources more efficiently and effectively. In particular, disastrous sites may generate a huge amount of heterogeneous data, which may require large amounts of time to analyze and then generate useful information for intervention. The possible integration between IoT technologies and Big Data analytics ensures the ability of real-time analytics [25], and thus enhances responsiveness to disasters.

An accurate prediction in emergency management for early warnings can be realized by utilizing IoT technologies [27]. For instance, automated image-based monitoring of urban floods for early flood warnings was established by utilizing an IoT architecture [2, 44]. In general, notable advancements in disaster prediction are being recognized by successfully utilizing IoT and machine learning...
techniques [25]. These growing advancements are paving the way for improved preparedness and mitigation in the pre-disaster phase and, thus, for setting up a prepared disaster governance system.

4.2. Second Module: Disaster Governance Functionalities—Activities

The functions of smart disaster governance are expected to enhance coping and recovery capacities. That is, a smart disaster governance system ought to set forth a group of arrangements in a way that builds capacities of stakeholders, efficiently utilizes all resources, and handles all external and internal factors that amplify vulnerabilities to disasters. To develop a general smart disaster governance framework, the authors need to identify basic functionalities that can be applied to any disaster governance context. Six functionalities or activities were marked to be critical to smart disaster governance.

The first function of disaster governance is to be informative. The abundance of information is a key prerequisite for an aware and credible disaster governance system. In the case of smart disaster governance, utilizing IoT technology will supply the governing body with reliable information about disaster characteristics, location features, and the actual on-site situation. Thus, more reliable and fitting arrangements will be made by the disaster governance system.

Participation is almost the most influential functionality in attaining a good disaster governance system. Generally, in new governance, dependence on actors other than the government is growing, and the significance of the participatory process in risk governance is also becoming more remarkable [45]. As a matter of fact, in disaster governance, in addition to the community that is susceptible to the disaster, multiple stakeholders are involved, such as the private sector, civil society, and international organizations. In addition, multiple scales of public-sector entities are related to governing the disaster, such as state, city, and district authorities. This wide array of stakeholders signals the necessity of adopting a participatory approach to disaster governance and decision-making. Although stakeholders’ participation, especially public participation, is well recognized, to be a more effective process, it requires several enhancements, such as clarity of objectives and sharing of knowledge and resources [46]. For that purpose, smart disaster governance can promote the participation of stakeholders in governing the disaster through a more efficient and reliable sharing of information and enhancement of the communication among the various stakeholders. Based on the enhanced collaboration among stakeholders, the efficacy of the disaster management processes can be increased.

The variance in capabilities among the stakeholders, in addition to the different roles of each stakeholder, points out the exigency of the supportive governance functionality. In addition, support complements participation by strengthening its expected outcomes. Thus, it is not enough to merely include the stakeholders in disaster governance and decision-making, but also, it is mandatory to share expertise, provide funding, and build capacities of the less privileged actors. For instance, professionals can contribute with their expertise and technical support, international organizations can secure funds, and civil society organizations may provide educational and training programs. Enhancement of the supportive functionality of disaster governance can be attained by the employment of punctually shared information and predictions and through facilitation of communication channels among the stakeholders. That is, updated information about capabilities, resources, roles, and responsibilities of different actors and stakeholders, in addition to the well-established communication channels among them, will increase their capacity to manage the disaster and thus maximize the possibilities of supporting other stakeholders.

The disaster governance system is characterized by being reactive [14]. This is due to the abrupt nature and unpredicted scale of disasters; thus, according to each disaster, interventions for response and recovery are decided. However, the disaster governance system must also be proactive by enhancing pre-disaster planning for mitigation and post-disaster recovery, and it requires more accurate predictions and early warning systems before the occurrence of the disaster. It is especially critical that it is indicated that the lack of proactive strategies in disaster management leads to more
human and economic losses [39]. However, the technological advancements in information and communication technologies are paving the way for better situational analysis and will thus provide more accurate predictions, which, in turn, will enhance proactive strategies and pre-disaster plans.

Normally, the disaster governance system aligns with the laws and regulations of the broader governance system. However, flexible disaster governance is highly important due to the wide variations in the settings of disasters. Flexibility can be visible in the delegation of the power of control over a disaster situation, for example, from the state disaster governing body to the local authority, which may be mandatory if higher capabilities are available in the local authority. So, if higher powers are transferred to the local authority, the local authority’s ability to manage and control the disastrous situation will be increased. In fact, aligning with the laws is mandatory, yet it is necessary to have flexible disaster governance systems and adaptive institutions in the changing contexts, and to thus be more responsive to stakeholders’ needs or to emergent technologies that may contribute to enhancing the whole system.

Transparent disaster governance is a vital functionality. Transparency in disaster-related decisions and actions informs the public and all stakeholders and thus raises their awareness, in addition to motivating them to participate in the disaster governance processes. In addition, transparency enhances the accountability and credibility of decision-makers, actors, and the whole disaster governance system. Similarly to critical infrastructure crisis management, where trust is perceived as a factor that influences crisis management decisions [47], if higher accountability and credibility qualities of the disaster management actors are established, more effective relationships are expected to include the various stakeholders of the disaster situation. In fact, it was demonstrated that there is a significant role of utilizing ICTs in promoting transparency and, therefore, reducing corruption and empowering the public in smart city governance [31]. That is, the enhancement of transparent disaster governance is highly possible by employing IoT technologies.

4.3. Third Module: Disaster Coping Capacities—Outputs

The four enhanced disaster coping capacities—awareness, responsiveness, control, and preparedness—are the prospective output of the integration of IoT technology capabilities and disaster governance functionalities. These capacities can be recognized as the foremost applications for confronting disasters. If a system can promote and employ these capacities, then its ability to prevent, mitigate, cope, and recover from disasters will be extremely enhanced. Thus, a smart disaster governance system is anticipated to amplify the competence of these four capacities.

Awareness of the disastrous situation is the basic output of a smart disaster governance system. For the system to be aware, it requires access to relevant and accurate on-site information, in addition to the ability to share this information with the governing body and other actors. That is, the potential of obtaining reliable and comprehensive information, monitoring the disaster location, and the ability to disseminate this knowledge to other stakeholders create the first characteristics of a successful smart disaster governance system.

Due to the criticalness of the disaster situation, responsiveness is crucial to the efficiency and effectiveness of the disaster governance system. The enhancement of this capacity is attainable through several capabilities of IoT, such as efficient connectivity and real-time analytics. In addition, participation among stakeholders, provision of support to the less capable groups, and flexibility of the disaster governance institutions may play a major role in forming a responsive disaster governance system.

A successful disaster governance system requires actors to be in control of the operations and the physical and technological resources of the system. Although the disaster governance system is polycentric, if participation and support are functioning well, a seamless control can take over the various operations of the disaster governance. In addition, the flexibility of institutions will facilitate delegating control, whether giving away or receiving more powers and responsibilities. Moreover, controlling operations—for example, rescue and evacuation operations—requires prompt gathering of
information. Thus, the global characteristic of the IoT, its ability to connect to any object regardless of any boundaries that may exist [20], provides the appropriate environment for controlling the disaster context and realizing a ubiquitous disaster governance system.

Preparedness for disasters is the output that contributes the most to reducing vulnerabilities to disasters and ensuring the sustainability of governing the disaster. Prepared disaster governance reflects the readiness of the disaster governing bodies, resources, and processes, in addition to adequately setting proper plans for governing the disaster. That is, reliable information, collaborative work, knowledge sharing among stakeholders, capacity building for the actors, resource enhancement, and preparation of several alternative scenarios for confronting disasters and recovery are required. The employment of IoT’s capabilities and its integration with advanced Big Data and machine learning analysis and prediction applications will promote better-informed decision-making and produce a more effective and prepared disaster governance system.

4.4. Fourth Module: Smart Disaster Governance Gains—Outcomes

Generally, disaster resilience is the aggregate outcome of smart disaster governance. In fact, smartening the disaster governance system is not an objective in itself, but rather enhancing the disaster governance system and raising disaster resilience. By developing the set of relationships and arrangements constituting the framework of disaster governance, the prospective enhancements will bring about better disaster coping capacities in addition to more adaptive recovery capabilities. In sum, these enhancements will lead to a resilient system, contributing to a more disaster-resilient society that is less vulnerable to disasters, capable of reducing its impacts, and prepared for quick and continuous recovery from disaster.

Apparently, the four capacities of a successful smart disaster governance system are prerequisites for enhancing the disaster coping capacities. Nevertheless, these characteristics contribute to enhancing recovery capabilities after the disaster. Although recovery plans may depend on the broad governance system’s development plans and its support for the disaster governance system, still, the highly aware, resource-controlled, and well-prepared system will most likely possess more ability to recover rapidly and continuously. Consequently, an enhanced disaster governance system resilience can be achieved.

4.5. Hypothetical Application of the Conceptual Framework: The Case of the Kerala Floods in 2018

An investigation of the applicability of the proposed framework is necessary to validate its appropriateness for adoption in the disaster governance realm. Therefore, the case of the 2018 Kerala floods was used for validating our framework. From June to August 2018, the Indian state of Kerala experienced heavy rainfall that was higher than the predicted rainfall by 42% on average, leading to severe flooding and landslides almost all over the state [48]. The human losses, as well as the economic and social losses, were enormous, where around 500 lives were lost and there were nearly 4 billion USD of economic costs, in addition to the displacement of around 1.5 million inhabitants [49].

To validate the conceptual framework for smart disaster governance, the authors examined how the utilization of the framework would have enhanced the performance of the Kerala disaster stakeholders in confronting the 2018 flooding. Thus, we focused on the challenges in governing the Kerala disaster through the pre-, during-, and post-disaster phases, as well as the potential enhancements that might have been brought about by adopting the smart disaster governance framework.

In the pre-disaster phase, several issues were found to be hindering the development of a proper response to the disaster. For instance, there was a lack of accurate information due to the variance in the records of rainfall amounts and water flow rate estimations [48]. In addition, the absence of early warning systems prevented the Kerala state government from being warned about the floods and securing a higher level of preparedness [50]. Meeting the challenge of lack of information and accurate predictions is obviously among the main advantages of smartening the disaster governance system, where utilizing the IoT’s accessibility, monitoring, and prediction capabilities would ensure more accurate information gathering and predictions. Thus, a highly aware disaster governance
Sustainability 2020, 12, 9536 system will be progressing towards a more disaster-resilient system. Furthermore, the deficiency of the community’s capacity and their lack of awareness regarding disaster preparedness plans and local resources were evident in the Kerala case [51]. This challenge points out the necessity of the participatory, supportive, and proactive functionalities of the smart disaster governance system. That is, the more accurate the information and predictions are, in addition to higher capabilities of communication among the different stakeholders, such as the national government, state government, local government, and community, the more effective the support and capacity building that will be provided will be. Moreover, acquiring accurate information and predictions paves the way for developing more suitable pre-disaster plans and strategies; subsequently, a proactive governance functionality would be created. In other words, informative, participatory, supportive, and proactive governance will facilitate the identification of the most vulnerable areas and groups, and thus the governing body can provide ad hoc training and a wide share of information in coordination with other stakeholders, which, in turn, will improve the whole system, including the community, the level of awareness, and the capacity for confronting the disaster.

During the disaster, the governing bodies of Kerala state experienced a lack of connectivity with affected areas and rescue operators, whether due to the lack of routes leading to these areas or because of the failure of power and communication networks [52]. However, utilizing IoT technologies along with peer-to-peer cloud networks can smarten the disaster governance system by providing remote access to information in hazardous areas in case of network failure [37]. Attaining such information, in addition to the employment of real-time analytics for the large amount of data that can be generated from the hazardous areas, would have improved the response of the system towards realizing the situation of the isolated areas and allocating the needed resources for rescue operations more efficiently. In addition, it would have enhanced the capabilities of the governing body for coordination with the other stakeholders, who might have had better access to these isolated areas. This means that the system would have generated reactive and flexible functions, and thus provided appropriate and well-informed interventions that were fitting to each affected area according to its real situation and with higher responsiveness and control capacities.

For the post-disaster phase, it may seem that smartening the disaster governance system would not have many contributions to enhancing this phase, but the process of disaster governance can be perceived as a cumulative process. That is, the functions and activities that take place before and during the disaster would have a presumed impact on the post-disaster phase. For instance, after the Kerala disaster, there were no psychological care or community advisory services for guiding and supporting the victims, although these would be quite important for their mental health and their socioeconomic recovery [51]. If the governing bodies were functioning with smarter informative and participatory qualities before and through the disaster, it would have been able to identify the community’s needs after the disaster and would be more able to provide the necessary supportive activities and resources. In addition, if the disaster governance system were more transparent, it would have gained more trust from the community as well as other stakeholders throughout the three phases of the disaster, whether by complying with legislation concerning building codes in risk areas before the disaster, cooperating in rescue operations during the disaster, or participation in recovery activities. This promotion of the disaster governance functionalities is expected to strengthen the disaster governance system’s four capacities and, thus, to raise its resilience.

5. Discussion

The conceptual analysis shows that a smart disaster governance system is a system that operates using disaster governance’s traditional functions and arrangements in a more elegant way. The system requires an enabling environment, which is manifested through the six spheres presented in Section 3.2, where the potential for promoting the disaster governance functions and enhancing disaster coping capacities is recognizable. In addition, the hypothetical application of the integrative smart disaster governance conceptual framework indicates the logical possibility of improving upon the disaster
governance in Kerala in 2018 and enhancing the disaster resilience of the state. Notwithstanding, the smart disaster governance framework might not be able to directly influence some challenges, such as lack of resources for rescue operations [52] and delay in rebuilding damaged houses [51].

However, the logical reasoning of the relationships and expected constructs between the different elements of the framework are used to reach a sufficient level of generalizability, through which the authors conceptualized how this framework may bring about a smarter disaster governance system. For instance, information and communication spheres are axiomatic for a smart system, where the processes of data collection, analysis, and transfer are realizable through the IoT’s accessibility, monitoring, and connectivity capabilities. These three capabilities will promote the informative, participatory, supportive, and transparent disaster governance functionalities, which, in turn, contribute to raising the awareness capacity of the system. Another sphere is timeliness, which ensures a high responsive capacity. It is quite anticipated that real-time analytics, in addition to the connectivity capabilities of IoT, will enhance the supportive, proactive, and flexible functions of disaster governance, which are essential for an agile and responsive system. In addition, the informative, supportive, and proactive functionalities enhanced by IoT increase control over disaster operations and resources, reflecting on the reliability of the whole system. In an effective and efficient disaster governance system, IoT’s prediction capability enhances the proactivity and flexibility functionalities, which are fundamental to a well-prepared system. Moreover, a ubiquitous disaster governance system can be perceived as the accumulation of the other five spheres. When a full and timely awareness of the disaster situation and resources, effective and proactive operations and plans, and reliable decisions and actions are achieved, then the system is ubiquitous and signals a smart disaster governance system.

An example of utilizing IoT technologies to smarten disaster governance system can be seen in the establishment of the City Hall Operations Center of Rio de Janeiro, Brazil. This center was established as a response to the 2010 landslides, and it operates to monitor and gather various city data to prepare the city for emergencies and responses to disasters [53]. In this case, the informative functionality of disaster governance is enhanced by the gathered sensor data and other types of data, where more accurate and timely data are obtained. In addition, the integration with other analytical software allows prediction of emergencies, which improves the capability of developing better emergency plans, thus promoting a proactive disaster governance. Obtaining more accurate data, generating more effective and proactive emergency plans, and disseminating the information among the public through social media and other ways of communication [53] are indeed facilitators for enhancing the supportive function of the disaster governance system. Another example is the IoT-technology-based early warning system for river flooding that was developed for the National Unit for Disaster Risk Management of the Colombian government. The system sends an automatic alarm to the local authorities in the case of risk, and it also allows storage of the data in cloud storage [53]. This points out a flexible disaster governance system where the information transfers directly to the local authority to decide the level of risk. Thus, the authority may take proper action towards the emergency response. In addition, enabling the public with access to the gathered data reflects enhanced transparent functionality where the authorities will hold higher accountability and, moreover, improves participation activities, as higher levels of collaboration among the stakeholders would be anticipated.

However, the smart disaster governance system aims to raise disaster resilience. According to [54], there are four factors to measure any system’s resilience: technical, organizational, social, and economic factors. Likewise, social, economic, institutional, infrastructure, and community capacities were identified as the main drivers affecting disaster resilience [55]. The disaster governance system can, perhaps, partially affect some of these drivers, but neither fully nor simply. That is, attaining a disaster-resilient society requires broader structural developments in the society that are outside the scope of disaster governance systems. A smart disaster governance system can push forward the broad governance system towards the necessary developments within those drivers. For instance, a smart, informative, and transparent disaster governance system informs the broad governance system with reliable information and predictions, and thus alerts the broader system to vulnerabilities.
underlying some of the resilience drivers. In addition, a smart participatory disaster governance system can bring about consensus or public acceptance towards necessary changes within social, economic, or infrastructure dimensions.

Furthermore, a smartened supportive, proactive, and flexible disaster governance system is anticipated for promoting the readiness of institutions and communities for disastrous threats and raising their awareness towards the resilience of the whole society. Apparently, a smart disaster governance system is likely to contribute significantly to enhancing the disaster resilience of society.

6. Conclusions

As might be expected, the smart disaster governance concept is found to be an unexplored theme in the disaster management realm. This paper presented a novel conceptualization of smart disaster governance, and the realization of the prospective benefits of utilizing IoT technologies in enhancing disaster governance systems was discussed. The authors elaborated on six spheres that constitute for the characteristics of a smart disaster governance system. Linkages between IoT technologies and disaster governance functions can process and generate advantageous outcomes. Furthermore, an integrative smart disaster governance conceptual framework and a logic model were introduced. The capabilities of IoT technologies are perceived as the inputs to the smart disaster governance system, whereas disaster governance functionalities were marked as the system activities. Subsequently, enhanced disaster coping capacities are expected to be the outputs leading to the outcome of disaster resilience. The authors introduced a hypothetical application of the conceptual framework through the case of the 2018 Kerala floods, which indicated probable improvements in the governance during the disaster. This integrative conceptual framework can act as a policy guide for confronting disasters by utilizing IoT solutions, in addition to constructing a basis for future research on smart disaster governance.

Further research is required in order to apply the proposed framework to various contexts’ use cases. Accordingly, examining the cost efficiency of deploying IoT devices and technologies is required, as it is expected to be a serious challenge in developing countries, which are more vulnerable to disasters due to their lower socioeconomic status. Moreover, this framework introduced the elements that constitute a smart disaster governance system. However, more research is needed on the political, economic, and social challenges of each component within the context of the smart disaster governance system.

Author Contributions: Conceptualization, E.S.; methodology, E.S.; validation, E.S.; formal analysis, E.S.; investigation, E.S.; writing—original draft preparation, E.S.; writing—review and editing, C.T.H. and C.Y.; visualization, E.S.; supervision, C.T.H. and C.Y.; project administration, C.T.H. and C.Y.; funding acquisition, C.Y. All authors have read and agreed to the published version of the manuscript.

Funding: This work was supported by Ministry of Interior and Safety and the National Disaster Management Research Institute in Korea (2018-MOIS33-003).

Conflicts of Interest: The authors declare no conflict of interest.

References

1. CRED. Natural Disasters 2018; CRED: Brussels, Belgium, 2019.
2. Ray, P.P.; Mukherjee, M.; Shu, L. Internet of Things for Disaster Management: State-of-the-Art and Prospects. IEEE Access 2017, 5, 18818–18835. [CrossRef]
3. Gubbi, J.; Buyya, R.; Marusic, S.; Palaniswami, M. Internet of Things (IoT): A vision, architectural elements, and future directions. Futur. Gener. Comput. Syst. 2013, 29, 1645–1660. [CrossRef]
4. Miorandi, D.; Sicari, S.; De Pellegrini, F.; Chlamtac, I. Internet of things: Vision, applications and research challenges. Ad Hoc Netw. 2012, 10, 1497–1516. [CrossRef]
5. Li, S.; Xu, L.D.; Zhao, S. The internet of things: A survey. Inf. Syst. Front. 2015, 17, 243–259. [CrossRef]
6. Atzori, L.; Iera, A.; Morabito, G. The Internet of Things: A survey. Comput. Netw. 2010, 54, 2787–2805. [CrossRef]
7. Asghari, P.; Rahmani, A.M.; Javadi, H.H.S. Internet of Things applications: A systematic review. **Comput. Netw.** 2019, 148, 241–261. [CrossRef]

8. Ahrens, J.; Rudolph, P.M. The importance of governance in risk reduction and disaster management. **J. Contingencies Cris. Manag.** 2006, 14, 207–220. [CrossRef]

9. Kaufmann, D.; Kraay, A.; Zoido-Lobatón, P. Governance Matters October 1999; World Bank Policy Research Working Paper; World Bank Group: Washington, DC, USA, 1999; pp. 1–61.

10. La Porta, R.; Lopez-de-Silanes, F.; Shleifer, A.; Vishny, R. Investor protection and corporate governance. **J. Financ. Econ.** 2000, 58, 3–27. [CrossRef]

11. John, K.; Senbet, L.W. Corporate governance and board effectiveness. **J. Bank. Financ.** 1998, 22, 371–403. [CrossRef]

12. Lemos, M.C.; Agrawal, A. Legitimacy and effectiveness of environmental governance—Concepts and perspectives, in Environmental Governance. **Annu. Rev. Environ. Resour.** 2006, 297–325. [CrossRef]

13. Emerson, K.; Nabatchi, T.; Balogh, S. An integrative framework for collaborative governance. **J. Public Adm. Res. Theory** 2012, 22, 1–29. [CrossRef]

14. Tierney, K. Disaster Governance: Social, Political, and Economic Dimensions. **Annu. Rev. Environ. Resour.** 2012, 37, 341–363. [CrossRef]

15. Turner, I.B.L.; Kaspersion, R.E.; Matson, P.A.; McCarth, J.J.; Corell, R.W.; Christensen, L.; Eckley, N.; Kaspersion, J.X.; Luers, A.; Martello, M.L.; et al. A framework for vulnerability analysis in sustainability science. **Proc. Natl. Acad. Sci. USA** 2003, 100. [CrossRef]

16. Djalante, R.; Holley, C.; Thomalla, F. Adaptive governance and managing resilience to natural hazards. **Int. J. Disaster Risk Sci.** 2011, 2, 1–14. [CrossRef]

17. Melo Zurita, M.d.L.; Cook, B.; Harms, L.; March, A. Towards New Disaster Governance: Subsidiarity as a Critical Tool. **Environ. Policy Gov.** 2015, 25, 386–398. [CrossRef]

18. Bae, Y.; Joo, Y.M.; Won, S.Y. Decentralization and collaborative disaster governance: Evidence from South Korea. **Habitat Int.** 2016, 52, 50–56. [CrossRef]

19. Rumbach, A. Decentralization and small cities: Towards more effective urban disaster governance? **Habitat Int.** 2016, 52, 35–42. [CrossRef]

20. Cook, A.D.B.; Suresh, V.; Nair, T.; Foo, Y.N. Integrating disaster governance in Timor-Leste: Opportunities and challenges. **Int. J. Disaster Risk Reduct.** 2019, 35, 101051. [CrossRef]

21. Lam, L.M.; Kuipers, R. Resilience and disaster governance: Some insights from the 2015 Nepal earthquake. **Int. J. Disaster Risk Reduct.** 2019, 33, 321–331. [CrossRef]

22. Song, Z.; Zhang, H.; Dolan, C. Promoting Disaster Resilience: Operation Mechanisms and Self-Organizing Processes of Crowdsourcing. **Sustainability** 2020, 12, 1862. [CrossRef]

23. Albris, K.; Lauta, K.C.; Raju, E. Strengthening Governance for Disaster Prevention: The Enhancing Risk Management Capabilities Guidelines. **Int. J. Disaster Risk Reduct.** 2020, 47, 101647. [CrossRef]

24. Yang, L.; Yang, S.H.; Plotnick, L. How the internet of things technology enhances emergency response operations. **Technol. Forecast. Soc. Chang.** 2013, 80, 1854–1867. [CrossRef]

25. Shah, S.A.; Seker, D.Z.; Hameed, S.; Draheim, D. The rising role of big data analytics and IoT in disaster management: Recent advances, taxonomy and prospects. **IEEE Access** 2019, 7, 54595–54614. [CrossRef]

26. Shah, S.A.; Seker, D.Z.; Rathore, M.M.; Hameed, S.; Ben Yahia, S.; Draheim, D. Towards Disaster Resilient Smart Cities: Can Internet of Things and Big Data Analytics Be the Game Changers? **IEEE Access** 2019, 7, 91885–91903. [CrossRef]

27. Du, C.; Zhu, S. Research on urban public safety emergency management early warning system based on technologies for the Internet of Things. **Procedia Eng.** 2012, 45, 748–754. [CrossRef]

28. John Wellington, J.; Ramesh, P. Role of Internet of Things in disaster management. In Proceedings of the 2017 International Conference on Innovations in Information, Embedded and Communication Systems, ICIIECS 2017, Coimbatore, India, 17–18 March 2017; pp. 1–4.

29. Boersma, F.K.; Ferguson, J.E.; Mulder, F.; Wolbers, J.J. Humanitarian Response Coordination and Cooperation in Nepal. In **Coping with Challenges and Dilemmas**; Vrije Universiteit Amsterdam: Amsterdam, The Netherlands, 2016; pp. 1–23.

30. Hirschheim, R. Some Guidelines for the Critical Reviewing of Conceptual Papers * Some Guidelines for the Critical Reviewing of Conceptual Papers Overview of the IS Research Perspectives Section. **J. Assoc. Inf. Syst.** 2008, 9, 432–441. [CrossRef]
31. De Guimarães, J.C.F.; Severo, E.A.; Felix Júnior, L.A.; Da Costa, W.P.L.B.; Salmoria, F.T. Governance and quality of life in smart cities: Towards sustainable development goals. *J. Clean. Prod.* 2020, 253. [CrossRef]

32. Lovehagen, N.; Bondesson, A. Evaluating sustainability of using ICT solutions in smart cities – methodology requirements. In *Proceedings of the First International Conference on Information and Communication Technologies for Sustainability, Zürich, Switzerland, 14–16 February 2013*; Hilty, L., Aebischer, B., Andersson, G., Lohmann, W., Eds.; ETH Zürich: Zürich, Switzerland; pp. 175–182.

33. Kang, H.S.; Lee, J.Y.; Choi, S.; Kim, H.; Park, J.H.; Son, J.Y.; Kim, B.H.; Noh, S. Do Smart manufacturing: Past research, present findings, and future directions. *Int. J. Precis. Eng. Manuf. Green Technol.* 2016, 3, 111–128. [CrossRef]

34. Bolivar, M.P.R.; Meijer, A.J. Smart Governance: Using a Literature Review and Empirical Analysis to Build a Research Model. *Soc. Sci. Comput. Rev.* 2016, 34, 673–692. [CrossRef]

35. Careem, M.; De Silva, C.; De Silva, R.; Raschid, L.; Weerawarana, S. Sahana: Overview of a disaster management system. In *Proceedings of the 2006 IEEE International Conference on Robotics and Automation, Orlando, FL, USA, 15–19 May 2006*; pp. 361–366. [CrossRef]

36. Scholl, H.J.; Scholl, M.C. Smart Governance: A Roadmap for Research and Practice. *iConference 2014*. [CrossRef]

37. Chung, K.; Park, R.C. P2P cloud network services for IoT based disaster situations information. *Peer-to-Peer Netw. Appl.* 2016, 9, 566–577. [CrossRef]

38. Bryson, J.M.; Crosby, B.C.; Bloomberg, L. Public value governance: Moving beyond traditional public administration and the new public management. *Public Adm. Rev.* 2014, 74, 445–456. [CrossRef]

39. Moe, T.L.; Pathranarakul, P. An integrated approach to natural disaster management: Public project management and its critical success factors. *Disaster Prev. Manag. Int. J.* 2006, 15, 396–413. [CrossRef]

40. Busby, J.; Iszatt-White, M. The Relational Aspect to High Reliability Organization. *J. Contingencies Cris. Manag.* 2014, 22, 69–80. [CrossRef]

41. Alam, F.; Mehmood, R.; Katib, I.; Albogami, N.N.; Albeshri, A. Data Fusion and IoT for Smart Ubiquitous Environments: A Survey. *IEEE Access* 2017, 5, 9533–9554. [CrossRef]

42. Motlagh, N.H.; Bagaa, M.; Taleb, T. UAV-Based IoT Platform: A Crowd Surveillance Use Case. *IEEE Commun. Mag.* 2017, 55, 128–134. [CrossRef]

43. Lara, R.; Benítez, D.; Caamaño, A.; Zennaro, M.; Rojo-Álvarez, J.L. On real-time performance evaluation of volcano-monitoring systems with wireless sensor networks. *IEEE Sens. J.* 2015, 15, 3514–3523. [CrossRef]

44. Lo, S.W.; Wu, J.H.; Lin, F.P.; Hsu, C.H. Visual sensing for urban flood monitoring. *Sensors* 2015, 15, 20006–20029. [CrossRef]

45. Walker, G.; Whittle, R.; Medd, W.; Watson, N.; Kuhlicke, C.; Steinfuhrer, A.; Fernández, M.D. Risk Governance and Natural Hazards; CapHaz-Net WP2 Report; Lancaster Environment Centre, Lancaster University: Lancaster, UK, 2010; pp. 1–62.

46. Samaddar, S.; Yokomatsu, M.; Dayour, F.; Oteng-Ababio, M.; Dzivenu, T.; Adams, M.; Ishikawa, H. Evaluating Effective Public Participation in Disaster Management and Climate Change Adaptation: Insights From Northern Ghana Through a User-Based Approach. *Risk Hazards Cris. Public Policy* 2015, 6, 117–143. [CrossRef]

47. Hernantes, J.; Rich, E.; Laugé, A.; Labaka, L.; Sarriege, J.M. Learning before the storm: Modeling multiple stakeholder activities in support of crisis management, a practical case. *Technol. Forecast. Soc. Chang.* 2013, 80, 1742–1755. [CrossRef]

48. CWC. Kerala Floods of August 2018. 2018. Available online: https://reliefweb.int/sites/reliefweb.int/files/resources/Rev-0.pdf (accessed on 14 October 2020).

49. Thummarukudy, M.; Peter, B. Leaving No One Behind: Lessons from the Kerala Disasters; Thummarukudy, M., Peter, B., Eds.; The Mathrubhumi Printing and Publishing Company Limited: Kozhikode, India, 2019.

50. Joseph, J.K.; Anand, D.; Prajeesh, P.; Zacharias, A.; Varghese, A.G.; Pradeepkumar, A.P.; Baiju, K.R. Community resilience mechanism in an unexpected extreme weather event: An analysis of the Kerala floods of 2018, India. *Int. J. Disaster Risk Reduct.* 2020, 49, 101741. [CrossRef]

51. Neeraj, S.; Mannakkara, S.; Wilkinson, S. Build back better concepts for resilient recovery: A case study of India’s 2018 flood recovery. *Int. J. Disaster Resil. Built Environ.* 2020. [CrossRef]

52. Amritanand, S.; Anand, S.; Amritesh, A.R. Dynamic and Time Critical Emergency Management for Level Three Disaster. In *Proceedings of the 21st International Conference on Distributed Computing and Networking, Kolkata, India, 4–7 January 2020*; pp. 1–6. [CrossRef]
53. ITU. *Disruptive Technologies and Their Use in Disaster Risk Reduction and Management*; The International Telecommunication Union: Geneva, Switzerland, 2019.

54. Bruneau, M.; Chang, S.E.; Eguchi, R.T.; Lee, G.C.; O’Rourke, T.D.; Reinhorn, A.M.; Shinozuka, M.; Tierney, K.; Wallace, W.A.; Von Winterfeldt, D. A Framework to Quantitatively Assess and Enhance the Seismic Resilience of Communities. *Earthq. Spectra* 2003, 19, 733–752. [CrossRef]

55. Cutter, S.L.; Burton, C.G.; Emrich, C.T. Disaster Resilience Indicators for Benchmarking Baseline Conditions. *J. Homel. Secur. Emerg. Manag.* 2010, 7. [CrossRef]

**Publisher’s Note:** MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.

© 2020 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (http://creativecommons.org/licenses/by/4.0/).