



*Review*

# The Acceptance of Using Information Technology for Disaster Risk Management: A Systematic Review

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**Abstract.** The numbers of natural disaster events are continuously affecting human and the world economics. For coping with disaster, several sectors try to develop the frameworks, systems, technologies and so on. However, there are little researches focusing on the usage behavior of Information Technology (IT) for disaster risk management (DRM). Therefore, this study investigates the affecting factors on the intention to use IT for mitigating disaster's impacts. This study conducted a systematic review with the academic researches during 2011-2018. Two important factors from the Technology Acceptance Model (TAM) and others are used in describing individual behavior. In order to investigate the potential factors, the technology platforms are divided into nine types. According to the findings, computer software such as GIS applications are frequently used for simulation and spatial data analysis. Social media is preferred among the first choices during disaster events in order to communicate about situations and damages. Finally, we found five major potential factors which are Perceived Usefulness (PU), Perceived Ease of Use (PEOU), information accessibility, social influence, and disaster knowledge. Among them, the most essential one of using IT for disaster management is PU, while PEOU and information accessibility are more important in the web platforms.

**Keywords:** Disaster risk management, information technology, systematic review, technology acceptance.

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## 1. Introduction

The most common natural disaster events between 2011-2018 are 'floods' and 'extreme weather' with approximately 50 percent cases reported annually [1]. These disaster events affected human life, causing people to injure, die and displace. In the last decade, *the death rate per year* or the annual mortality rate softened to a hundred thousand due to learning experience and better preparedness comparing to the fatality report in the early 1900s. [1]. In 2000s, the recorded data shows that *over half of death rate* or more than 50 percent of the death rate was caused by earthquakes [1]. Among all disasters known to mankind, the 2011 earthquake was the costliest disaster; The figure was unprecedented and secured the most priced disaster in the history until date [1]. For instance, the impact of the 2011 Great East Japan Earthquake was disastrous. These were over ten thousand deaths, fifteen thousand missing and three hundred thousand people encountered the basic survival needs deprivation (i.e. lacking of food, water, shelter, and medical care) [2]. This event affected the national economy, particularly in the industrial production such as automotive and steel production, and the global supply chains [2]. The estimated loss of property was around 16 trillion Yen (USD 193.28 billion) according to the study [2]. The impacts of the 2011 mega flood in Thailand were likewise but with reported extension to the agricultural sector and the total of seven industrial parks. [4]. Whereas in the Caribbean and the Americas, hurricane was the most powerful natural event known for life-taking and damaging [5]. For instance, Hurricane Sandy in New York City in 2012 worth USD 53.3 billion, regardless of early forecast and advance preparation provision. It caused power outages, major flooding, transportation system shut down, and evacuation. In scenery of the coastal area of the city was covered with beach erosion and damaged boardwalk. In 2017, there were three hurricanes affected or hit the United States. First, Hurricane Harvey made the highest damages of USD 95 billion expense [5]. It is the second costliest of United States tropical cyclone history, after the 2005 Hurricane Katrina. It produced the maximum inundation levels of six to ten above the ground in Texas [6]. Even though the 2017 Hurricane Irma caused damages at USD 81 billion. The storm affected populations in many states especially in Barbuda and Saint Martin [6]. Public infrastructures and facilities were destroyed. Trees were uprooted. Second, the 2017 Hurricane Maria caused the total damages of USD 70 billion [5]. The major damages covered Dominica and Puerto Rico [6]. Roofs blown off. Communication, power and internet service were cut off. The event caused inundations, injuries, and deaths [6]. The 2019 Typhoon Hagibis is one of the strongest typhoons hitting Japan in the last decade. It caused heavy rainfalls and damages in the North and Northeastern Japan. Japanese government discovered river overflow and collapsed levees. The houses, cars, trains and power infrastructure were destroyed. The report shows wide impacts, concluded

with 99 deaths, 100,000 affected people and 50,000 inundated houses [7].

Because of these damages, several sectors including private and public organizations tried to develop the policies, frameworks, and systems for coping with future disasters. Take an example from Japan, after the 2011 Great East Japan Earthquake, Japanese government established the emergency response headquarters [2]. They have heavily invested in public disaster education, raised people awareness and provided training courses [8]. For Thailand, the government proposed strategies and measures for flood prevention covering the local level and industrial areas, river dredging, dikes, water gates, and others water management systems [4]. They also included upgrading infrastructure, technical assistance, and river plan.

In the past two decades, disaster risk management (DRM) has been highlighted. The United Nations Office for Disaster Risk Reduction (UNDRR) defines 'DRM' as the processes of using directives, organizations and capacities to implement strategies, policies and improve capacities in order to decrease impacts of disasters [9]. The DRM cycle consists of four phases: mitigation, preparedness, response, and recovery. This approach was also adopted in the Sendai Framework for Disaster Risk Reduction 2015-2030, aiming to reduce risk in disasters, and losses in businesses and communities [10].

Information Technology (IT) applications are used to store, process, and distribute information [10]. IT could be useful for the entire phases of DRM. First, IT is needed for spatial and geographic information in mitigation plan. It helps identify appropriateness of land-use, resources, and development plan [10]. Second, preparedness focuses on learning and awareness before taking actions. So, IT is useful for improving strategies, evacuation plan, and exercises. Third, response phase requires IT in order to alert target groups, provide impacts, and communication in affected areas. Fourth, IT is needed for damage assessment, evaluation of development plan, and monitor activities [10]. However, some issues such as accessibility and availability or exceed the IT capacity. For example, radio and TV have benefits in speed and ease of broadcasting, but it is a one-way technology and one content for all groups [10]. In case of mobile technology, people can reach the local contents and interact with the audiences, but it still has a limitation of the ownership. Recently, many researchers have studied about using IT with disaster management for prediction, monitoring and training. The popular tools such as Geographic Information System (GIS), Social Networking Services (SNS) and applications have adopted for coping disaster. For example, mobile application was proposed for tsunami evacuation drills as education tool exercise [11, 12]. The survey in Miyagi Prefecture, Japan, found that when people got more information, they realized more about evacuation route and checking safety [11]. The GIS technology was used to understand risk and disaster via providing an online risk map for protecting metrological events [13] and assess the risk of disasters for business [14].

IT is also linked with sustainable development in many countries in Asia and the Pacific. It brings significant impacts in synergic manner of three dimensions: economic, social, and environment [14]. IT can reduce inequalities and end poverty. Enabled timely information can make a difference for agriculture such as water availability and market prices which lead to increase incomes [15]. In addition, IT improves an access to health care by facilitating faraway communication, monitoring system, and enabling education [15]. Many countries and territories in the Asia-Pacific have used 'Telemedicine' extensively. IT increases educational opportunities and reach underserved all groups of people [15]. IT can help displaced persons and migrants to communicate with long distance friends and family and provide services during emergencies. In the environmental aspect, IT has the major role of collecting data and enhancing the monitoring and warning systems. In order to maximize the usefulness of IT, there is a need to understand its potentials and limitations.

Nevertheless, there are many challenges and factors which should be considered in implementing IT. The first important issues are reach and access [15]. Contents are another challenge which should covers facilitating interactive, understanding target group, as well as user friendliness [15]. Effective use of IT needs actions in all levels: nation and local levels. Therefore, policies and plans should be motivated by multi-stakeholders [15]. Government can play as a key role in implementation. Moreover, people-centric approach is more important than the IT-centric approach for project succeed [15].

Although, the publications of IT emerged with disaster management and mentioned to users' behavior were found to be increased, it has not been systematically analyzed yet to understand the evolution of IT and human acceptance. A systematic review of big data in disaster management analyzed roles of technology for effective solutions [16]. They presented technological topics with disaster management phases to mitigate hazard effects. Nonetheless, there is lacking of making better understand users' behavior. For the effective and successful implementation, this study aims to explore and collect the factors from previous publications that affected users' behavior to use IT for DRM. As mentioned, the access and people-centric approach are mentioned to be two challenges in adopting IT. In addition, there are other factors related to human behaviors. Therefore, the behavior models are mentioned in this study. When IT is fit with people, these factors could be useful in reducing losses and enhancing resilience.

A systematic review is conducted in order to find the important factors influencing acceptance of IT for DRM. Even though it sometimes takes considerable time and requires perseverance and attention to details, it provides the effective and high quality method for evaluating extensive literatures [17]. The 11 keywords are searched in ScienceDirect database between 2011 - 2018 and collected relating data. The significant findings between factors and technology acceptance are explained. The research design

is shown in Section 2. Next, the preliminary results such as the trend of selected disaster, the number of technologies in top ten countries/territories and technology platforms are shown in Section 3. Section 4 describes the affecting factors of using IT for disaster mitigation and relationship between factors and platforms. Section 5 is the discussion of highlights on factors and technologies. The last section summarizes conclusion.

## 2. Research Design

To investigate the relationship between IT on DRM and acceptance behaviors, several perspectives need to be considered. A systematic review is an overview of primary studies that use explicit and replication method [18]. It provides essential meaning and evidence for academics and practitioners to improve decisions and to narrow the knowing-doing gap [17, 19].

In management field, it often serves decision making as evidence aware rather than evidence base [17]. Whether the replication of existing study, development work or new study to fulfill gap, the research questions or problems are specified in this study [17]. A more systematic review process can help to justify final research significance [17]. For instance, the explicit methods decrease bias in identifying studies [17].

Initially, the scopes and size of study should be identified in order to delimit subject area and to avoid volume of information. Next, searching strategy for relevant studies and criteria for inclusion and exclusion should be planned [17]. These two processes were explained in the first sub-section. After that, the selected studies were extracted for important data which was mentioned in the Sub-section 2.2. Then, the analysis method is drawing about methods to present results in Sub-section 2.3.

### 2.1. Search Strategy

The research objective is to investigate the affecting factors on using IT for DRM. The keywords are later identified as focusing on IT and disaster. Since this research explores acceptance of technologies such as what are the concern of using IT for mitigate disaster impacts, the ten models related to human behaviors are searched combined with disasters. In the last decade, those are frequently used to predict individual behavior in several field such as IT (e.g., information systems, applications), business management (e.g., purchasing, tourism) and health sciences (e.g., medication). Each model considers decision to take action from different aspects. Some mentioned models had been continuously developed from the initial theory of 'Theory of Reasoned Action' (TRA) which describes relationship between attitudes and human behaviors. TRA is useful for study behaviors caused from attitude and beliefs [20]. Most of TRA research were used to study in medical and technology field. For example, it was used to explore adoption of Green Information Technology [21]. 'Theory of Planned Behavior' (TPB) was

an extension of TRA which was added personal control factors [22]. Hence, TPB was used to study human actions in specific or difficult situations [23]. For Social Cognitive Theory (SCT), it explains human behaviors that influenced from social environment and learning experiences [24]. Theory is suitable for study with behavior changing such as health practices [25]. ‘Technology Acceptance Model’ (TAM) is used to predicts user acceptance of technology or system for individual target [26]. Almost of TAM researches related to investigating intention to use technologies in various types such as SNS, organization system and web application. Next, ‘Model of PC Utilization’ (MPCU) is used for specific prediction on personal computer’s using [27]. ‘Diffusion of Innovations Theory’ (DOI) is used to study spreading of new idea in social system [28]. Theory highlights to investigate how long new ideas distribute and adoption by which channels of communication in a group. ‘Decomposed Theory of Planned Behavior’ (DTPB) was expanded from TAM and TPB [29]. It studies individual behavior of using technology which affect from different users’ experience. ‘Motivation Model’ (MM) describes individual behavior based on intrinsic and extrinsic motivation [30]. Therefore, it is suitable to study performing behavior caused from social factors and motivational environment. ‘The Unified Theory of Acceptance and Use of Technology’ (UTAUT) was combined the prominent points from previous eight models [31]. It explains action on technology acceptance from several determinants and moderate factors such as gender, experience and voluntariness. Although those nine models are used to study human behaviors and focused on factors about attitudes, norms and performance, but they do not much mention to factors about protective behavior. Therefore, ‘Protection Motivation Theory’ (PMT) was included for review. Theory predicts individual’s coping behavior when people face with uncertain event and risk [32]. As a result, there are 11 keywords which are “*Information Technology*” AND “*disaster*”, “*Theory of Reasoned Action*” AND “*disaster*”, “*Protection Motivation Theory*” AND “*disaster*”, “*Theory of Planned Behavior*” AND “*disaster*”, “*Social Cognitive Theory*” AND “*disaster*”, “*Technology Acceptance Model*” AND “*disaster*”, “*Model of PC Utilization*” AND “*disaster*”, “*Diffusion of Innovations Theory*” AND “*disaster*”, “*Decomposed Theory of Planned Behavior*” AND “*disaster*”, “*Motivation Model*” AND “*disaster*”, “*Unified Theory of Acceptance and Use of Technology*” AND “*disaster*”.

The first criterion for collecting the publication is containing at least one natural disaster or emergency event in the article. Second, at least one IT application is used for DRM. In addition, only articles published in an academic journal in ScienceDirect Database are retrieved. It contains large database in the fields of physical sciences and engineering and social sciences and humanities. The next criterion is focusing on English text-based publications for the matter of mass comprehension and information accessibility.

The year 2011 is found to contain the two major disasters: the 2011 Great East Japan Earthquake and the 2011 Thailand floods; deeply affected many lives, as well as local and global economics [2]. The recorded data in 2011 showed that the highest damage cost came from earthquake following by flood [1]. Consequently, the duration of this research is scoped to be from January 1, 2011 to December 31, 2018. The systematic review approach is frequently applied with the studies that use quantitative methods such as randomized controlled trials, experimental designs and cost benefit analysis [17]. On the contrary, it is a challenge for qualitative methods which have no explicit standard process and sometimes depend on subjective experience [17]. Although many systematic reviews of medical research analyzed using raw data, in management research, these data may not be shown in articles [17]. Therefore, selection of studies is based on the subjective findings and conclusion [17]. This research collected the studies in both quantitative and qualitative methods because quantitative methods show the values of significant factors while qualitative methods could show other findings and raised issues.

The studies which meet the mentioned criteria are selected. Searching was conducted during February 4-12, 2019. Following 11 defined keywords between 2011-2018 in ScienceDirect database, the 3,301 publications were found. About 80% of journals come from keywords “*Information Technology*” AND “*disaster*”. Then, the titles and abstracts of the journals were reviewed. The journals which did not cover the entire criteria and were duplicated were removed. There are 733 inclusive articles. The outstanding contents and conclusion were screened based on research objective. Many studies did not mentioned relationships between technologies and outcomes or users’ behavior, thus removed. Finally, 103 articles were retrieved to use to review all contents.

## 2.2. Data Extraction

Owing to some parts of review process require subjective experience to select the studies. In order to reduce human errors and bias, systematic review needs data-extraction forms which contain general information (e.g. titles, author names, publication details), specific information (e.g. details, method) and findings (e.g. key results, additional notes) [17]. The ‘Cochrane Collaboration’ presented that data-extraction forms provide at least three important functions [33]. First, the form supports connecting to review question and the planned assessment providing visual presentation [33]. Second, it is a historical record of the decision made during the process [33]. Third, form is the data-repository leading to emerge and analysis [33]. The development of data-extraction is flexible depending on the nature of study [17]. The data-extraction of this research was conducted on computer based which is easier to analyze. Form contains general information (i.e. title, authors, journal, publication year, countries/territories of studies), study features (i.e. objectives, methods, disaster types, IT, usage, keywords)

and findings (i.e. results, limitations, notes). The retrieved studies were reviewed and important information was filled into the form. Those data were used to analyze the review. The results such as trends are shown in the next section. The whole filtered articles are considered the results of developing and using IT for DRM. Key issues often mentioned in researches are pointed out. Lastly, the selected articles are categorized onto the topics. The adaptation of those findings is explained in Section 4.

### 2.3. Analysis Method

A good systematic review is a synthesis of previous researches that support quick learning for practitioners. In management research, it can be reported in two stages. The first stage is to provide a descriptive analysis which uses data-extraction form in tabular or graphical format. [17]. It should also present specific exemplars and justify conclusion [17]. Therefore, in preliminary results, the trend of publications in disaster type, research countries/territories, and technology platforms are explained and shown as graphic information. Trend of publications in disaster indicates the awareness of the issue and the growing interest of the events during the periods. Presenting research countries/territories could be useful for social issues and trends in developing IT in each country/territory. In addition, technology platforms show changing of technologies and adaptation. For the second stage, a systematic analysis, either from aggregative or interpretative approach, needs to be reported [17]. It may be focusing on key identifying emerged with themes and research objective and linking themes across several core contributions [17]. Consequently, Section 4 presents the affecting factors of IT adoption for DRM and match technology platforms to each factor.

The entire selected factors are from both of quantitative and qualitative studies. In quantitative studies, the significant factors from statistical analysis such as correlation analysis and regression were collected. In qualitative studies, factors were considered from important findings and conclusions. Those results lead to the answer to the research question and conclusion. Microsoft Excel 15.0 is used for collecting the concluded data. The number and proportion are represented to show the trends of data. Moreover, the keywords of IT's performance are used to analyze major concerns of user behavior on IT usage. Eventually, the lists of key factors are explained one by one. EndNote X9 is used to manage documents' references.

## 3. Preliminary Results

To present the evolution of human behaviors on IT emerged with DRM, it is important to analyze the number and growth of publications. Therefore, this section presents the overview of descriptive results which are gained from literature reviews. The preliminary findings are illustrated as figures. There are publication trends of

disaster type, the top ten research countries/territories, and technology platform trends during 2011-2018.

### 3.1. Trend of Disaster IT Research: Types of Disaster

Recently, technology is variously developed and used in many fields, one including the disaster management. It could be useful and lessen damages from unexpected events. Disaster is an abnormal situation or event that exceeds the capacity of local response and stimulates an immediate assistance from nation or international actors [5]. Disaster can be separated into two major groups: Natural disaster and technological disaster (manmade or by technologies) [34]. This research focuses on natural disaster as the event is inevitable and the damage caused by is unpredictable. Natural disaster can be categorized into six types [34]. First, *geophysical disaster* is disaster causing from solid earth such as earthquake and volcanic activity [34]. Second, *meteorological disaster* defined as short duration disaster from atmospheric conditions like fog and storm [34]. Next, *hydrological disaster* means disaster caused by occurrence and movement of surface of fresh water and salt water [34] such as floods and landslides. Fourth, *climatological disaster* is a long duration disaster resulting from middle to large scale of atmosphere and climate such as drought and wildfire [34]. Fifth, biological disaster is a hazard related to the living organisms and their toxic substances or diseases such as epidemic like malaria [34]. The last one is extraterrestrial disaster which hazard comes from asteroids, meteoroids, and comets and change of interplanetary conditions [34].

These categories are used to present the trend of publications that meet research criteria in each year during 2011-2018. Extraterrestrial disaster articles were not found in any selected article. So, it is not shown in the graph. In addition, disaster that was not specified or mentioned as the whole disaster is included in category of general disaster. For example, the framework of Information and Communication Technologies (ICT) was proposed for coping with every disaster in community [35]. They separated method of response with disaster into many phases and technologies for enhancing disaster resilience [35]. As mentioned, the research only focuses on using IT for DRM that concern users' behavior factors. So, it may be not all number of disasters in a period. It only shows which disaster corresponds to the interest of development and adaptation with IT. The number is presented as six disaster groups between 2011 - 2018 in Fig. 1.

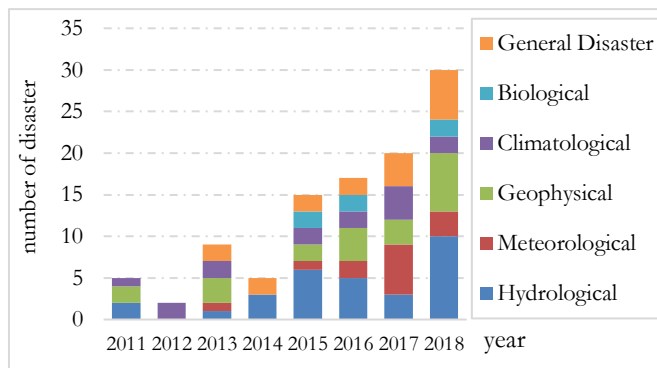


Fig. 1. The number of IT for DRM researches in each disaster type.

The figure indicates that the number of publications about IT for DRM. In the first four years, there are small and fluctuated numbers of published disaster IT topics concerned users' behavior. Disaster types did not cover the entire categories. The number of publication is also on the surge on the latter years. The figure shows that IT publication trend began to associate with various disaster categories. As shown, hydrological disaster has the highest published numbers given that floods and landslides are common annual occurrences of many countries. Geological disaster becomes the second rank with heavy mentions on earthquakes. The strongest earthquake measured magnitude 9.0 happened in Japan in 2011. The third one is general disaster founded during 2013-2018. The meteorological disaster of storm comes next with reference to numerous hit in the US back in 2017. The publication number have dramatically risen since 2015. This implies that researchers pay more attention to developing technologies together with focusing on users' behavior which could be useful for enhancing IT role for DRM.

### 3.2. Trend of Disaster IT Research: Countries/Territories

In this study, the total research countries/territories are 38. The top ten countries/territories are shown in Fig. 2 by ratio. Most DRM researches are related to disaster events which these countries/territories have experienced. According to the figure, the US has the highest ratio of research in IT for DRM which is 15%. They had experienced with various disasters such as storms, floods, and wildfires. Storms, such as hurricanes, became the highest study topic in the US because of its powerful damages and losses especially in the economic realm [5]. The worst four hurricanes that put world economy into recession belong to the US. These are the 2017 Hurricane Harvey, the 2017 Hurricane Irma, the 2017 Hurricane Maria, and the 2012 Hurricane Sandy [5]. Financially, US report the total loss of USD 944.8 billion during 1998-2017. This massive financial woe explained the increasing publications on technologies related to metrological disasters in the past years.

In China, the ratio of IT for DRM research is 14%. Hydrological and geological disasters such as earthquakes

and landslides accounted for about 50% of the country's damages [35-40]. In 2017, there are four significant earthquakes in China with >7.5 magnitude. These devastations resulted in deaths and destroyed infrastructures worth more than USD 1 million [1].

Other eight countries/territories have the IT for DRM research's ratio of 3-5%. In Australia (5%), three-five research is about climatological disasters such as wildfires. The developed IT for DRM in this country pay attention to applications for wildfire risk reduction and preparation [41, 42]. Taiwan, Greece, Indonesia and the United Kingdom have the same ratio of 4%. Taiwan conducted research with various disasters including floods, landslides, earthquakes, and climate change [43-46]. In Greece, half of the selected researches related to metrological disasters [47, 48].

Most of the publications in Indonesia focused on hydrological and geological disasters including floods, volcanic eruptions, and tsunamis. In 2017, Indonesia had four significant volcanic eruptions which could cause tsunamis and major earthquakes [1]. Floods also frequently affected their communities and hence an online flood risk map was developed for showing their risk areas [49]. The UK has various IT for DRM studies such as outbreaks, heavy snows, and climate change [50-52]. Germany and Italy have the same ratio at 3% and they also studied the similar disasters (i.e. floods and landslides) [53-55]. Lastly, Japan (3%) focuses on coping with geological disasters because they have high risk of earthquakes. Many tools such as 'Web access' was developed for monitoring volcanic eruption and social media was used for post disaster recovery [56, 57].

The numbers of researches on IT for DRM were different in each country/territory. It can be interpreted as the result of their different disaster experiences they had considering factors such as economic losses, deaths and frequency. The USA faced several tremendous disasters. As a result, they had the highest number of researches on IT for DRM and high interest on users' behavior. Low-middle and low-income countries/territories had economic losses less than high income countries/territories, but if compared with their %GDP, they had high ratio [5]. In addition, low-middle and low-income countries/territories had higher deaths rate than high income countries/territories. But their contribution of research was not found in top ten. Therefore, the collaboration between developed and undeveloped countries/territories are needed to fill this gap which could be an advantage for the supply chains around the world.



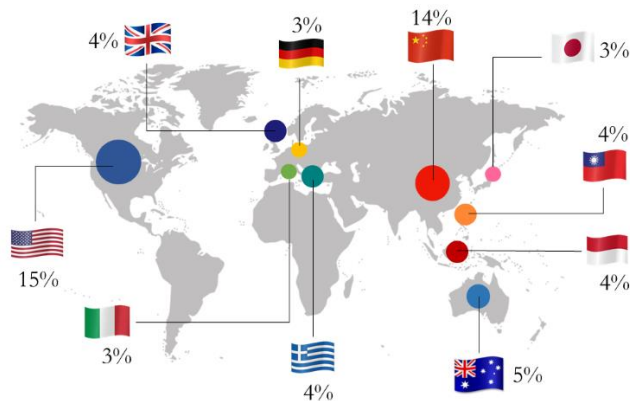


Fig. 2. The ratio of disaster IT research in country/territory.

### 3.3. Trend of Disaster IT Research: Technology Platforms

Specified types of technologies that are used for DRM signifies their appropriate usage. Hence, this study categorized technologies into nine platforms following their accessibility. Each platform is described in terms of its roles, benefits, and limitations. The total researches ratio between 2011-2018 is presented in Fig. 3.

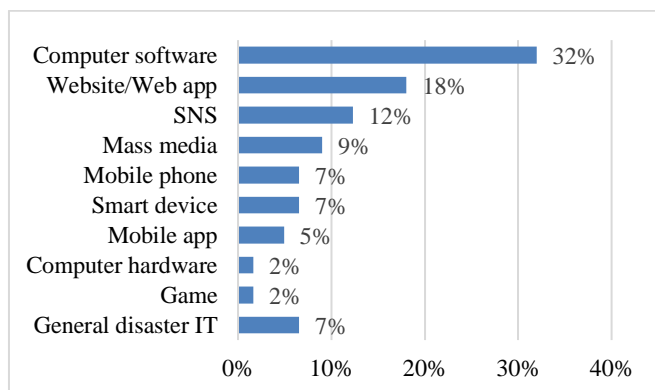


Fig. 3. The ratio of disaster IT research in each technology platform.

#### 3.3.1. Mass media

Mass media can reach large group of people through mass communication. It is one way and top-down communication flow [57]. It distributes information through technologies such as radios, televisions, video clips, and films. This media is easy to access and spread information widely. It can help large group of people acknowledge disaster information and reach the situation of events. However, it hinders people from real time broadcast and less specific information to grasp [10]. The ratio of mass media based on IT for DRM research is 9%.

TV contents have strong relationship with cultivating perception of disaster, especially on affected audiences [57]. It is influential on individual perception and sentiments about the future disaster and recovery plans [57]. Local media and newsletters were suggested to make the warning to communities in wildfire season [58]. In

addition, TV was found to be preferred source of warning information in the 2013 Typhoon Haiyan at the Philippines [59]. That event was studied to analyze the disaster warning system by using the Design and Engineering Methodology for Organization (DEMO) [60]. The system provided actor roles and clear responsibility which is easy to understand [60]. This allowed people to take prompt actions during the disaster. Moreover, production of video clip supported education about emergency prepare in campus was studied by Skurka et al. [61] and found that it was one of the powerful source to enhance the disaster response actions. Mass media-based DRM are indicated to reach large group of populations. And it is the most preferred tool especially for preparation and warning.

#### 3.3.2. Social media

Social media is a horizontal interactive communication platform [62]. Social Networking Services (SNS) operates in a dialogic transmission system that can send from many sources to many receivers. It motivates online interaction between media providers and audiences. The information such as texts, photos, and live videos can be sent across the globe rapidly. The platform requires an Internet along the access. SNS is the top three of technology research trend (12%).

The most popular SNS is 'Facebook' which there are consisting of 2.32 billion active users [63]. It can be accessed from devices such as mobile phones, laptops, or computers by an Internet connecting. Many researches use Facebook for exploring social media activities during natural disasters. Facebook was found to help users to communicate the effects of flood such as situations, damages, reliefs, and rescues [64]. Moreover, Facebook allows spaces for opinions and sensitivities and so the government can use the advantage to response appropriately [64].

'Twitter' is the one of the most popular SNS in disaster situation and famous for real time updates. Twitter was successfully used as a part on emergency warning system in Kazakhstan [45]. [45].

Other popular SNS include 'WeChat', 'Facebook', 'Instagram', 'LINE', 'YouTube', etc. The data from Twitter, YouTube and Flickr, are indexed and clustered for emergency management [65]. It is found to be useful especially for supporting emergency responders [65].

In conclusion, SNS was highlighted in a role of disaster communication in order to send a warning message, response, and rescue. It is one of the tools for enhancing the disaster resilience for rural communities [66]. In Japan, many railway companies utilize multiple platforms of SNS to passengers to inform urgent incident [67]. The use of Facebook messenger and LINE applications is also found important in the case of evacuation of Thai citizens in the 2016 Kumamoto Earthquake in Japan [68].

In China, 'Weibo' was useful for detecting accurate location where events were occurring [69]. The convenient

and fast communication of Weibo attracts wide audiences for information digest and is where disaster management plan depended upon.

### 3.3.3. Mobile phones

Mobile phone is a portable device that connects people via calls and messages. It also provides further features such as 'Bluetooth' connection. In this study, using of mobile phones for DRM refers to communication on mobile devices that are spontaneity without accessing websites or mobile applications. Communication on mobile phone was used for detecting population in disaster zone and location [41, 70]. It can be used to monitor water levels and send emergency alerts to authorities and population [71]. Take for example, in Rio de Janeiro State, Brazil, communication services on mobile phones are strongly related to flood risk perception [72]. Nevertheless, a phone call was not a preferred source of warning during the 2013 Typhoon Haiyan [59]. However, such case was perceived contradictory to the disease disaster management; the data based on mobile phone (i.e., call records and two-way messages) were collected and used to support the required disaster information [50]. Mobile phones are also useful for detecting user's location in disaster areas including communication. Thus, it is very useful for disaster warning and recovery.

### 3.3.4. Mobile applications

As smart phone trend is skyrocketing so does the creation of mobile applications. However, there are not many applications which are specifically developed for DRM which refers to a software application that is developed to use on mobile device. This research defines mobile application that is developed and used on mobile platform only. Social media applications are not included. Mobile applications could enhance communities' resilience to disaster [66]. It ensures preparedness and effective response [66]. Application was also developed as a 'Decision Support System' (DSS) based on transportation system and human decision making for flood evacuation. It provides safety information and guides users to the safer places [73]. In addition, the simulation results found that it could shorten the total time of evacuation [74]. A mobile application was proposed to estimate building damages from tsunamis in Japan [75]. It supported evacuation, risk analysis, building design by showing the estimated damage levels and collapse probability [75]. Also, there was a proposal of using a mobile application for tsunami evacuation drill and wildfire evacuation [11, 12, 76]. In this research, disaster mobile applications are mostly used for decision support system as they are most suitable for time sensitive disaster.

### 3.3.5. Websites and web applications

Website is a huge information source that could be accessed by link addresses and Internet connection. Web application is a software application that runs on a web platform. It uses web browser and the internet to access without installation. This research refers websites and web apps as IT that can only access through a web platform whether on PCs or mobile devices by an Internet. Web sites and web apps are widely used in IT for DRM research (over 18%). For example, a web service named 'WEEZARD' was developed for debris-flow hazard assessment to provide information through a simulation system [77]. Wildfire monitoring application was developed as a web service [78]. It was also used as a tool developing real time monitoring system for flood that provided flood forecasting, simulation, digital maps of a relief, and inundation visualization [79]. Whereas for the worldwide volcanic information can be searched on 'WOVOdat' [56]. The web app provided users' interaction such as visualization, comparison, etc. [56]. Moreover, a web-based system was used as a flood communication channel to distribute flood knowledge [80]. The research on web apps and websites during 2011-2018 showed that they were mostly used for monitoring and sharing disaster information for better preparedness.

### 3.3.6. Games

Game is a developed technology for enjoyment while could be used for educational purpose. Sometimes, games are used for DRM which strategizes preparedness and demonstrates the effectiveness. A serious game platform and drill script were developed for showing the affected buildings in an earthquake event [43]. It enhances users' awareness and educates people for disaster response [43]. In addition, a video game was created for earthquake preparedness [81]. It showed players the probability and consequences of risk and preventive behavior [81]. Therefore, using game platforms in disaster can be a choice that influences people to become aware of damages from disasters in the most pleasant way

### 3.3.7. Smart devices

Smart device is a developed technology based on convenient devices with the least complicate connection. One of the products is a smart watch. This singularity comes with multiple purposes, from collecting health data to making a phone call. . Innovations from smart devices are growing; Smart home devices and smart cars are some of the examples. This study refers smart devices as the devices that have special properties and was improved function for more convenience.

For instance, laser night vision cameras at watchtowers were used in automated wildfire monitoring system [82]. Video cameras were set in wildfire risk zone and used as a wildfire detector and alarmist. This sets a great example for a combination of technology for



protecting wildfire. Smart wearable devices and sensor-equipped suits were developed for disaster application [74]. Some devices were used as a tool of flood knowledge and communication channel [80]. 'Google Home' and 'Amazon Echo' provide users' flood information access and allow human-device interactions [80]. It reduced steps of information accessibility which often prolonged on devices such as mobile phones or web applications. Smart devices perform at maximum when combined with other technologies.

### 3.3.8. Computer software

Computer software is the most found technology platform in the selected articles (32%). It is a developed program for serving particular objectives. Computer software can provide various functions. It commands computer to work following requirements by building machine's language. This research considers computer software as the software platform that is developed and used on PC without web access. 'GIS software' is the popular software for DRM. For example, 'thematic map' was used for exploring dengue outbreak spreading in Pakistan [83]. GIS software was used as simulation technologies in automated marine monitoring system [47]. For fire and weather disasters, GIS was used to predict information on 'WIFIRE' project [84]. GIS could also be integrated with 'remote sensing' and other technologies in 'Wildfire Evacuation Decision Support System' [76]. In addition, 'NetLogo' is a useful software providing agent-based evacuation modelling platform [63]. It was used to simulate and analyze location of the vertical evacuation shelter related to mortality rate [85] and to suggest the evacuation location to decision makers or communities [85]. To sum up, computer software is major used in simulation and observing spatial data.

### 3.3.9. Computer hardware

Based on the findings, computer hardware fails at a solidarity mention (2%) but received wider attention when making reference with other technologies. 'Graphical Processing Units' (GPUs) and 'Field Programmable Gate Arrays' (FPGAs) hardware were proposed for simulation of wildfire spreading [86]. They speeded up development and implementation which resulted in high accuracy [86]. In addition, hardware platforms, such as sensor-board and gateway 'MIB520', were used in wildfire monitoring and communication [87]. They could measure temperature, light, acceleration, humidity, and pressure [87]. Computer hardware was used in the similar way as computer software, but more specific and demand more requirements.

Another 7% represented as general IT refers to platform that was not specified in one technology such as 'Internet of Things' (IoT). 'Big data' and IoT were integrated to build smart flood monitoring and forecasting architecture [88]. It provided quality of services and efficient system which offered more reliable forecasting

data. In addition, various applications of IT were combined with wireless sensor network in order to help communities in times of earthquakes [89]. It supported disaster relief and rescue operations and useful for alerting people to evacuate from disasters. They focused on emerging technologies for unspecific DRM.

The nine platforms of IT for DRM are used in various functions. Computer software seems to be the most popular platform in order to cope with disasters. Because of time saving and convenience, SNS is a useful tool for DRM in terms of communication issue. The mass communication SNS provided makes the device an excellent tool for disaster preparedness and response. For instance, mobile phone is used for detecting user's location and sending warning. Smart devices are also an alternative choice for DRM. Computer hardware and games are not much preferred as other platforms in the selected research articles.

In summary, the preliminary results were shown by divided into 3 parts. The first part shows research trend of disasters separated in categories. It indicates the increasing trend from 2011 to 2018. Hydrological and geophysical disasters are the most included topics in the researches. The second part presented the ratio map of top ten countries/territories developing IT for DRM. The US is the country that has the highest number of research articles on this topic. National published articles share relationship with their countries/territories past experience. Lastly, the trend of technology platforms is shown. Among them, computer software such as GIS is very popular and useful in several ways.

## 4. Affecting Factors of Adoption IT for DRM

Many technologies are developed for coping with disaster impacts. However, not all technologies are effectively practical used and accepted, possibly, due to learning of use, ease of use, user friendliness, efficiency, etc. The UN-APCICT indicated the challenges in implementation IT with disasters were access and users [10]. Therefore, users' behavior on technologies should be studied. This research tried to find the important factors which are often discussed in using IT for DRM, and factors affecting users' adoption-behavior. After exploring highlighted issues in qualitative studies and significant factors in quantitative studies, the major factors were concluded as five affecting factors. Other factors which has less concerned will be discussed later. Each factor is discussed particularly on how they are essential to IT emerged with disasters. Moreover, the relevance between technology platforms and factors is shown in Fig. 4.

### 4.1. Perceived Usefulness (PU)

'Perceived Usefulness' (PU) is an important factor of TAM. The model is used for describing and predicting user acceptance of technology for individual target [59].

Therefore, PU is defined as “the degree to which an individual believes that using a particular system would enhance his or her job performance” [31]. PU is frequently mentioned during using IT or systems. Many articles discussed about how technology is useful for DRM. When people see that technology can help them to perform any task better, they will likely to place dependency on the system and thus prolong its existence. This research considers PU as a better performance when using with technology. PU is referred in terms of effectiveness, efficiency, accuracy, and usefulness. Examples on how the factor enhances acceptance of IT for DRM will be discussed later

‘Location-based mobile government services’ for emergency management was exploring the social acceptance [41]. The results showed that accuracy and responsive of system affected PU for users. So, PU became a good predictor of behavior intention to user services [41]. An additional case of mobile phone is with the location feature. It was used for matching geographic population distribution in earthquake areas [70]. They found that the proposed ‘heat map’ was efficiently produced for locating the affected population [70]. This research found that an important point that IT could enhance efficiency and accuracy in disaster response phase. Even though technology is praised for its usefulness and convenience, the reliance was in a doubt. To fill the gap, a research of disaster application on smart wearable devices investigated the factors affecting of adoption [74]. PU was found to be a strong predictor of disaster application use [74]. Mobile phones and mobile devices are the fastest communication tools for contact. Thus, these tools are used in many ways in DRM. Based on the findings, PU had many discussions in results of using mobile devices and smart devices [50, 70, 71, 73, 90].

The integrated IT frameworks were used to enhance a role of improving resilience in rural community. Each technology could response to the situation differently [66]. Social media/SNS was found to be potential tools for supporting domains such as providing information, making alerts in less time, and monitoring [35]. Twitter is also often used for spreading information in emergency time because it collects trends of communication. Recently, SNS is one of the most popular tools for coping with disasters because it offers quick information grasping, more accuracy and real time updated information. Thus, there are many researchers studied SNS for DRM [35, 51, 64-66, 76, 89, 91, 92]. The important factors that users realize about using SNS for DRM are effectiveness, accuracy, and usefulness in spreading information with limited time.

The popular technology such as GIS is widely used in spatial data surveys. Risk maps and simulations were often developed based on GIS technology for many objectives such as understanding flood areas, rescue operations after disasters and epidemics [6, 83, 93]. Effectiveness and usefulness are important issues that users concerned when using GIS.

Figure 4 shows a relationship between factors and technology platforms. PU is the concerned issue in the whole nine technology platforms. In order to use IT for DRM, researches of computer hardware only focused on PU. The main issue of Mobile was also PU around 90%. In computer software and SNS research articles, PU was frequently mentioned as 67%. For example, GIS software for flood areas and heat map represented the effectiveness of using software [6, 93]. The developed model of seismic vulnerability roads based on GIS was also useful for assessment damages during earthquake [94]. Even, game platform, which is less found for DRM, half is considered in PU similar to mobile application. Disastrous game is useful in case of enhancing awareness and responders’ capability in real situation [43]. While mass media is the less concern in PU.

The effectiveness is the first issue that people realize when using IT. If it shows bad performance, it might be rejected by users and substituted by others. Many researchers found their developed technologies were effective by experiment, survey, and comparison with previous technologies [42, 48, 50, 77, 87, 88, 95-103]. Also, accuracy is also discussed in improving monitoring systems, early warning systems and simulation technologies because these systems require high precision for protection the damages. Thus, many developed technologies are tested, then considered about accuracy by users [36, 37, 44, 69, 78, 86, 104-108]. Next, several studies implemented technologies because they found useful outcomes [38, 43, 45, 53, 94, 109-114]. Efficiency was pointed out in developing IT for DRM as well [39, 79, 82, 85, 115, 116]. These important issues of PU were the most founded factors in the selected research articles. It can influence users to adopt behavior for disaster. Therefore, the usefulness should be the first focus on integrating IT with DRM.

## 4.2. Perceived Ease of Use (PEOU)

For technology use, ease is the one factor influencing that helps people decide whether to adopt the technology. Often more difficult-at-use system will be ignored. ‘Perceived Ease of Use’ (PEOU) is another main factor of TAM. It is defined as “the degree to which an individual believes that using a particular system would be free of physical and mental effort” [31]. This research considers PEOU as user friendliness, system satisfaction, and ease. It can affect technology acceptance particularly in case that requires an individual effort such as mobile applications and web applications. The short and clear processes of using can support users to achieve their goals easier.

The survey of flood exercise found that participants had satisfactory experience which triggers continuity is using information systems in emergency situations [54]. In addition, the modified TAM showed that PEOU was significant factor affecting user adoption on emergency software [117]. It indicated IT on DRM focusing about ease of use. In disease disaster, health professionals had higher risk. Therefore, a mobile application was developed

in order to prevent such accidents through risk information, knowledge and appropriate decision making in real time proposals [118]. The application platforms were tested with users and concluded to be satisfied applications [118]. A mobile web application was developed for post disaster management system [119]. The result was satisfactory among groups of students [119].

Many researchers use a survey method to see the results of the use of applications. The point shows that PEOU and satisfaction with platforms such as mobiles or web applications are major concern for users. Hence, further development should use the conclusion as a lesson learn and thus come up with the uncomplicated platforms. Education and training are crucial for preparedness and prevention. Especially in disaster risk zones, such as Taiwan, have faced various natural disasters, so they often held disaster training. The survey among community leaders for future training resources revealed that good instructors and the satisfied course design had significant influence on learning effectiveness [120]. In conclusion, PEOU can enhance effective knowledge learning. Several studies mentioned the significance of design web applications, online platforms and monitoring systems as complementary [49, 76, 84, 121].

As shown in Fig. 4, PEOU are necessary in four platforms: Web platforms, mobile app, mass media, and computer software respectively. PEOU is mostly mentioned in specific platforms which users have to intertwine with the processes. These platforms depend on individual learning effort and understanding. Then ease is very important. For example, fire map on web platform showed prediction and visualization of wildfire. The result raised important issue of ease to view and interact with information [107].

Developed technologies related with interface, web applications, and training courses are frequently tested and interviewed by real users. The interesting finding shows that most people pleased with the technological usage. So, testing with samples before implementation and practical use is an important part for improving any unfriendly functions. Another concern is an ease of use. It can help users feel free to interact with the system.

### 4.3. Information Accessibility (IA)

Information of global events broadens since the rise of IT. It is message which gives people an opportunity to cope effectively with disasters, both in preventing and preparing senses. Information can be shared through major applications, such as Twitter, Facebook and LINE. They are fast and facile communication channels. Mass media such as TVs and radios are also used for spreading information to large groups of people. Through these platforms, people are informed of prediction, warning, affected areas, and damages, and thus respond suitably. . Regardless of its importance and wide availability, some people faced limited access of the information on disasters and therefore prolonging and intensifying the damages

caused by disasters. Thus, this study concludes 'Information Accessibility' (IA) as one of the essential factors on the acceptance of IT for DRM. IT refers to the organized information that can be accessed from participants [122]. To illustrate how information accessibility is important, the raised topics from previous research articles are described.

Twitter data during the 2012 Hurricane Sandy were collected for analyzing social network interactions between government agencies and citizens [123]. The record showed that “#sandy” was top-ranked in the day after the US was severely hit [123]. Network analysis showed that government agencies used network interaction to extend outreach as many people for disaster response phase and provide information on the warm shelters [123]. The incident praises the advantage of the internet access. Americans might be suffered from the cold longer if they did not get prompt information using an online platform.

SNS is one of the main communication channels and thus, the government should pay special attention to policies SNS for DRM. 'Firemap' web platform was proposed for fire prediction and fire behavior visualization [84]. The interface was developed for predicting wildfire and illustrated visualization of data such as workflows and social information. It was claimed an easy access [84]. All results from the run map such as burned areas could be saved and shared among users [84]. Therefore, it is a useful tool to send warning messages, and it may help reduce risks. For volcanic protection, the World Organization of Volcano Observatories (WOVO) has an online database [56]. They provided volcanic information, comparative studies, basic research, and teaching which users can visualize and compare the volcanic activities [56]. The opened database is very useful for volcanic monitoring in risk zones. The accessible information supports improving protection, response, and rescue operations. The increasing of database although may affect to accurate prediction of disaster events, it helps more people to prepare before the affected time.

The gap between digital technologies and social practice are still problems for disaster reduction and resilient enhancement. The 'Data Poverty Index' (DPI) is used as an open source for evaluating global data access [124]. It revealed that African countries had lower accessed to IT than other regions [124]. The African researches on IT for DRM are not as much found. One of the reasons is due to a limitation to global Internet [124]. The problem triggers the need for free available data to all countries/territories [124]. In Africa, drought considers as the major concern. Geospatial information was crucial for risk assessment, developing monitoring and early warning systems [125]. In development of drought information systems, expensive resource about geospatial data was mentioned [125]. Consequently, it was necessary to improve accessibility and availability of information for effectively mitigation plan [125]. Most information systems indicated that their development required massive input data [80, 119, 126, 127].

Information accessibility received the most recognition in web platforms researches. Webs provide a lot of disastrous information and yet they posed access limitation to some countries. As same as computer software, it needs data to simulate and predict probability and consequences. Therefore, information accessibility is very important to cope with upcoming threats. Others are mentioned in terms of mobile applications, SNS, and smart devices.

There are many sources provided prediction and real time disaster information. Some sources could analyze the results by individual users. In some countries, lack of reaching the Internet resources is still a vital problem which could lead to more intense losses and damages from disasters. Therefore, information accessibility is the one of the major factors in acceptance of IT for DRM.

#### 4.4. Social Influence (SI)

Technologies is undeniably powerful in craving the perspective and forming of opinion to an individual and close ones. In many cases, people use technology through the command by seniors, and not on a voluntary basis. In IT for DRM, government and local authorities can be a channel supporting users to adopt the technology by proposing policies or providing useful tools. Private organizations also could be the agencies to support information and management. Hence, 'Social Influence' (SI) is an important factor. The 'Unified Theory of Acceptance and Use of Technology' (UTAUT defined SI as "the degree to which an individual perceives that important others believe he or she should use the new system" [31]. It was discussed in the same meaning as the subjective norm which is a main factor in many famous models such as TRA, TPB and TAM [31]. Subjective norms were divided into two perspectives. First, descriptive norms referred to the beliefs about what has been done by most people in one's social group [64]. Second, injunctive norms referred to one's belief pressure others to perform behaviors [64]. In this review, this study considers both descriptive norms and injunctive norms.

The video of emergency planning which highlight on safety actions was produced based on slogan "Run-Hide-Fight" [61]. TPB was used for behavioral testing the undergraduate students [61]. The results showed that injunctive norms had significantly positive to intention to take protective behaviors but descriptive norms had not [61]. This emergency video encouraged students to protect themselves. Sometimes, social pressures motivate people to adopt technology. For instance, the study of migration from climate change in Burkina Faso which was a dryland used agent-base model simulations combined with TPB [52]. They found that SI as peers influence was one of the factors of future migration [52]. Wildfire protection also used TPB for investigating homeowners' mitigation behaviors in Austin, Texas, USA [58]. Subjective norms were found to be a predictor [58]. As same as the case of flood risk perception in Brazil, local influences which are neighbors, family and, friends were one of the factors

affecting prevention measures [72]. The acceptance of information systems in emergency operation center was surveyed. The respondents were end-users from four popular 'EOCIS' software packages [117]. They found one of the most important implementation software is SI [117]. The influence among peers had directly affected the technological adoption [117]. Particularly in the organization, SI has the highest impact. The proposed model of earthquake hazard presented community and institutional factors to be the predictors of hazard preparedness in Nepal [128]. It was necessary to enhance the studies in disaster technology adaption in country/territory level [129]. The important findings were policy makers and innovators could be influencers in supporting improvement for IT for DRM [129]. So, it is essential to motivate innovators and encourage end-users with transferring IT information.

As illustrated in Fig. 4, a large proportion of mass media mentioned SI. Local media and authorities are assigned to support people disaster preparedness. For example, wildfire mitigation research reported that social pressure and community support had significant relationship to mitigation behavior [107]. Consequently, local media was proposed to enhance preparedness. To sum up, SI is a part of acceptance of information systems related to emergency operations.

These selected research articles indicated how SI affected to the adoption of IT for DRM. The command in organization or government agencies' policies can affect citizens' behavior; they can use an effective innovation for DRM in governance and introduced people to the framework. Another crucial influence comes from closed people in social group including family members, friends, and colleagues. Therefore, SI should be realized as a motivating factor for the technological adoption.

#### 4.5. Disaster Knowledge (DK)

'Disaster Knowledge' (DK) tends to affect mitigation behaviors [65]. People who have DK or received disaster information are more interested in mitigation behaviors than those who did not [65]. Some people know in advance what types of risks they need to deal with but do not know how to do them effectively. For instance, in case of flood, disaster preparedness needs the information of weather forecast, water level, and prone-to-affect areas. DK can be divided into two types [66]. First, local knowledge is a tacit knowledge. It is knowledge gathering from communities and developed over the time factors such as beliefs, perception and experience [66]. Second, an international knowledge is referred to as an explicit knowledge which is a process of learning or reading through collected information by individual [66].

From the 2011 Thailand floods, disaster preparedness plan was the most preferred information following by disaster warning before flood events [130]. After the 2004 Indian Ocean Tsunami, Thai Government established the National Disaster Warning Center (NDWC) for

monitoring and processing natural disaster information [131]. The analyzed processes of Thailand system included four important elements which are risk knowledge, monitoring, dissemination and communication, and response capability development [131]. However, accuracy and some processes, such as decision making, are required to be improved. It was also suggested that effective warning should come with good knowledge. Bangladesh frequently faced flood disasters which make losses every year. They examined the factors affecting flood reduction [132] and DK management was concluded to be an influent factor of effective preparedness which can lead to lesser damage [132]. Flood risk communication strategies integrating social networks were proposed to prepare and encourage the adaption for climate change [133]. Communication of flood risk with coping method was found to be more effective than communication without other knowledge [133]. This shows that spoon-fed information on risks was simply not enough; People need to actually learn on how to cope with situation in a practical manner.

Because of the increasing marine traffic in the Black Sea Basin, mathematical models and IT tools such as GIS were used for supporting real time automated marine monitoring system [47]. They improved environment of ports and surrounding coast through training and building stakeholders in the area [47]. They found realistic information and knowledge enhancement were needed for effective planning [47]. 'Knowledge Management System' (KMS) was proposed. The KMS focused on usage of 'Radio Frequency Identification' (RFID) and 'Database Management System' (DBMS) as a part of the rescue technology [62]. The model highlighted three factors namely human, disaster management knowledge, and technology [62]. Perceived own knowledge was a positive correlation to the actual earthquake hazard adjustment intentions as well [102]. In addition, government was found to have more hazard knowledge than others and thus they should use the privilege to inform the citizens on the issue [102]. Furthermore, they should collaborate with other agencies in the area and enhance the local resilience.

According to Fig. 4, half of researches relating to the game based on DRM mentioned DK. In case of computer software, their outputs could be useful information to increase effective of preparation and protection. Similarly, SNS and mass media provide many information and knowledge to people. Therefore, using these platforms require the realization of knowledge distribution. Recently, it is possible to gain the knowledge easier through online sharing. On the contrary, DK was not found in research about computer hardware and mobile.

Many studies indicated DK as an important factor for supporting DRM [40, 50, 57, 61, 80, 81, 134, 135]. People who received more disaster information are likely to become more aware to the measure for protecting themselves. In enhancing the disaster preparedness, people should be informed of threats, impacts, and how to cope with disasters. The idea has the potential to

support the people in managing their risk effectively. Thus, the damages can be reduced.

#### 4.6. Additional Factors

There are other factors related to IT for DRM adoption. 'Experience' seems to be one of the factors affecting usage of IT for DRM. People who have experience and direct impacts tend to prepare more coping methods. The study of flood and landslide in Brazil showed the strongest correlation on flood risk perception with experience and protective decision [72]. Furthermore, local people who live longer in the area and gained more experience had higher flood risk perception from historical floods and vulnerable areas [72]. This correlation can be useful to support the disaster management by integrated both knowledge and individual experience. The past disaster events warned people about damages. Consequently, they have more awareness than the inexperience.

Although some group of people know that their area is vulnerable to disaster, they ignore the advance preparedness. Hence raising the awareness issue may trigger an individual protective behavior. The studies of Twitter impacts on communication risk analyzed over ten thousand messages that announced by the UK government in case of heavy snow and riots [51]. Heavy snow in the UK in December 2010 affected many people, transport disruption, and power failures [51]. The households that did not prepare any emergency plan lived in a rather difficult situation. Twitter messages supported prompt providing of official updates, encouraging protective behavior, and increasing awareness [51]. In addition, the five-days of the UK riots in August 2011 brought disastrous consequences to social, economic, and infrastructural damages to the country [51]. The similar case to this is the heavy snow event. Through Twitter's prompt message-sharing platform, the impacts were less tensed thus narrowing damages into a capable of handling [51]. It is evident that Twitter is one of the fastest transmission channels that help raising the awareness and thus damage reduction [51].

When information go public, 'trust' becomes the most concerned issue. People hesitate to use systems and doubt in source's quality. This resulted in individual's reliance on past experience rather than information published by the authority. Consequently, they do not take disaster mitigation and preparedness, posing more damages. Take for example, model of prediction population preparedness in Nepal revealed that the communities relied on an assistance from public agencies during the disaster [128]. The reliable information and organization had impact on the rescue. However, trust was found low significant with hazard preparedness [62].

Demographics like 'gender', 'age', 'education', and 'income' also can affect behavior intention. For instance, social media behavior of Chinese during emergency events revealed that the number of female users had more communication than male users [136]. Moreover, the

online information outreach is far more popular among young group of people and the senior citizens [136]. Thus, the alternative channels of DRM should be provided to make it inclusive.

Video infographic about driving through floodwater and proving safety was developed for training. The results showed women had higher risk perception and self-barrier than men [125]. However, influence of demographics was different in each situation. It depends on individual behavior and perception in using the technology for mitigation disaster.

There are still other factors that may affect the intention to use DRM such as cost, time, risk perception, emotion, and voluntariness [137-146].

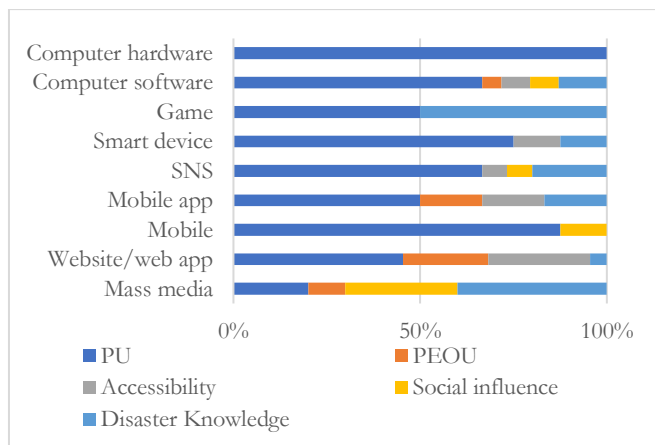


Fig. 4. Factors and technology platforms.

## 5. Discussion

Trend of IT on DRM research have increased during 2011-2018. The top two disasters' researches that were found in this review are hydrological and geological disasters. Researches of flood is found in every year except 2012. The impacts from these events are severe especially in the economic realm. To illustrate, in the last two decades, flood was the largest number that affected people [5]. While most fatalities caused from earthquake [5]. In term of economic losses, earthquake was the second to storms [5]. Therefore, many tools were developed for earthquake monitoring and researchers were assigned to ensure of their effectiveness. So, most flood publications proposed IT for prediction and recovery in order to mitigate losses. Even the number of climatological disaster (wildfire) researches spotted at third, but it was found to have less impacts in losses and deaths. However, using IT for DRM still need more empirical studies to verify significant relationships. Biological disaster has the least publications.

The US and China show the outstanding number of researches IT for DRM. The US experienced more and various disasters than the China. , The storms extremely affected their economic growth in 2017. Most of US's researches focused on social media and computer software for DRM and highlighted on PU as the main factors. China conducted major researches related to

hydrological and geological disasters. Studies of IT acceptance in China used various platforms such as computer software, mobile app, SNS, web platforms, and smart devices. In addition, PU and PEOU are their major concerns. The level of damages for each country/territory is uncommon. There are many other countries/territories that were damaged by disasters, but they do not sufficiently prepare for disaster protection. The developing countries/territories are lacking of technologies thus they are hindrance from disaster information exposure. . EM-DAT report showed that the proportion of deaths and affected people in low income counties was extremely higher than high income countries [5]. Therefore, it is necessary to concern about information accessibility and cover in wide areas. Research papers focusing on the decreasing measure to the disaster impacts should be distributed to low income countries. Furthermore, the authorities such as community leaders, local-central government, and private organization agencies should provide knowledge and technologies to their citizens. Leaders should take an advantage of their positions to raise more awareness on DRM.

In this research, PU is found to be the most important factor in accepting IT for DRM. It is the factor that received the least attention in all technology platforms except mass media. Disaster knowledge becomes major issue. The mass media such as TV and radio support to reach large groups of people with standard information. The access problem of mass media was not found in this research. Broadcasting the disaster news is extremely beneficial especially on the face of crisis. However, the communication, both the contents and the languages, may be too difficult for the mass to get a grasp on and thus they loss interest. .

In using IT for DRM, the most founded platforms are computer software which is popular in cases of simulation, forecasting, and monitoring. There are various tools which GIS is the most well-known for spatial data survey. The risk map can be built from GIS software and it helps users to know the vulnerable areas and useful for disaster preparedness. Moreover, simulation outcomes usually come from GIS. The developing of computer software requires the concern of all five factors but especially on PU, in term of effectiveness and accuracy, because it presents useful outcomes and visualized information to help calm the potential damages from disasters.

Recently, SNS applications are used more in disaster events because they help connect people and the prompt information spread. Facebook, which is the most popular SNS, is found to be a useful tool in communication during disasters. The information such as affected areas, damages, and the severity of the situations could be discussed and shared to many groups of people almost instantly. Moreover, online communication can identify the location of users. This facilitates in-time relief and rescue in post disaster. As well as Twitter, it is used for real time updating disaster situation. Disaster contents should therefore be provided online made online. To use SNS for disaster mitigation, PU is the most important factor followed by



disaster knowledge. Although SNS may have some limits on individual access, but it provides more specific information to people.

The sole reliance on the information on disaster risk is not enough for DRM. People have to know more about methods of disaster preparedness and response for a more effective DRM. DK will help people coping with the disaster accurately and appropriately with lesser impacts. Additionally, game could promote individual learning and prepare for the real situation.

Research on using web platforms for DRM have more focuses on three factors as PU, PEOU, and IA. The accessibility to web is still a problem in some areas. Therefore, research should extend focus to other countries. To developing web, most research papers used pilot test with the users before the implementation. Interfaces and user-friendly are often mentioned because it need physical effort to reach important information. Mobile application has the similar concerns as web platforms. This shows that PEOU is important in IT required interaction from people

Although, IT will be increasingly used for DRM and could mitigate disaster impacts. Limitations in several issues still posed as problems. Currently, studies paid more attention to PU because it is a core factor influencing people to adopt or reject technology. To eliminate limitations, other factors should also be concerned. After developing of IT, the studies of usability and acceptance from users should be more expanded. It could support users to interact with IT easier. In addition, IA is important to decrease damages in several counties equally.

DK will help affected people cope with disaster appropriately. All factors should be considered for IT and DRM. Studies on acceptance need more analysis to verify. The level of importance may be different in each type of IT and situation. Hence, researchers need to take a consideration on “*How technology could enhance DRM and is it effective enough?*”

## 6. Conclusion

In the past decade, major disaster events whether floods, earthquakes, storms and so on shows severity and tense impacts. They cause global damages such as deaths, displacement, and economic losses. The reason makes the finding of methods to mitigate those impacts important. IT was increasing used because it facilitates people to manage with information and cope with situation effectively. However, using of IT has some limits. Therefore, this study reviewed the usage of IT for DRM. The essential factors affecting users to accept the IT for DRM were observed from systematic review which based on the set criteria. Then, data extraction form was created to collect general information and important findings. Five potential factors related to adoption were found namely PU (Perceived Usefulness), PEOU (Perceived Ease of Use), IA (Information Accessibility), SI (Social Influence), and DK (Disaster Knowledge). Over 60% of the reviewed research articles highlighted on PU. It is the

most important factor influencing users' IT for DRM acceptance. Also, the factors are presented together with the related nine technology platforms. PEOU is very important for web platform development as the users concern about satisfaction of the systems and the uncomplicated processes. SI has more importance when mentioned by the leaders of communities or closed people such as family members and peers. IA is important in the usage of websites or web applications. If people cannot access the disaster information, they do not perceive their risks and thus ignore to protect themselves. Providing such disaster information together with knowledge is significant as well [147, 148]. Furthermore, additional factors such as experience, trust, awareness, and demographics affect in some technology platforms. To adopt IT for DRM, the developer should not only focus on technology development, but also on how users could use them at their maximum potential.

This study still has some limitations about the duration of searching year which was set to be between 2011 – 2018. Therefore, the disaster events and technologies might be limited and may not be applicable to other periods, both before and after. The study selected certain contents related to the natural disasters and technologies that were set as the search criteria.

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