INTERNATIONAL JOURNAL OF ACADEMIC RESEARCH IN BUSINESS & SOCIAL SCIENCES

Vol 9, Issue 2, (2019) E-ISSN: 2222-6990

# Resilience Criteria to Strengthen Infrastructure Systems towards Floods: A Literature Review

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**To Link this Article:** http://dx.doi.org/10.6007/IJARBSS/v9-i2/6959 DOI:10.6007/IJARBSS/v9-i2/6959

***Published Date:*** 03 March 2019

**Abstract**

Natural disasters have become more frequent and intense around the world. Malaysia has no exception where the flood is the most devastating natural disaster experienced by this country. Flood has caused massive damage and disruption particularly to infrastructure systems such as electricity supply, water supply, sewage system, road and railway networks, telephone including critical facilities such as hospitals and shelters. Nowadays, people are highly dependent on infrastructure systems. As flood has caused severe damage to infrastructure systems, there are extreme needs to strengthen infrastructure systems towards resilience infrastructure systems which can absorb, recover and operate appropriately during the flood. Therefore, this paper aims to identify resilience criteria to strengthen infrastructure systems towards floods. This paper is written based on an overview of literature from journal, articles, newspaper, book and report from the previous researches. The results obtained from this paper can be used by other researchers in strengthening the infrastructure systems towards flood.

**Keyword:** Flood, Infrastructure, Resilience

## Introduction

Natural disasters have become more frequent and intense around the world and have caused severe damage and disruptions which caused great lives and property losses to people in the affected areas. Between 1998 and 2017, natural disasters killed 1.3 million people and left a further 4.4 billion injured, homeless, displaced or in need of emergency assistance. While the majority of fatalities were due to geophysical events, mostly earthquakes and tsunamis, 91% of all disasters were caused by floods, storms, droughts, heat waves and other extreme weather events. Meanwhile, between 1998 and 2017, disaster-hit countries experienced direct economic losses valued at US$ 2,908 billion, of which climate-related disasters caused US$ 2,245 billion or 77% of the total. This is up from 68% (US$ 895 billion) of losses (US$ 1,313 billion) reported between 1978 and 1997. Overall, reported losses from extreme weather events increased by 151% between these two 20-year periods (Preventionweb, 2018). Moreover, there is a higher likelihood that more frequent and intense disasters particularly natural disasters are likely to occur in the future. The increased numbers of natural disasters like floods, droughts, cyclones, typhoons and landslide would be a significant threat to the people livelihood (Joerin, Shaw, Takeuchi, & Krishnamurthy, 2013; Shaw, Razafindrabe, Gulshan, Takeuchi, & Surjan, 2009).

In the context of Malaysia, this country is geographically outside the Pacific Rim of Fire and is relatively free from any severe ravages and destruction caused by natural disasters. However, Malaysia is vulnerable to natural disasters such as floods, landslides, storm and severe haze every year (Baharuddin et al., 2015). Flood becomes the most significant threat facing by Malaysia where it caused a lot of life and economic losses (Akasah & Doraisamy, 2015). There are two types of floods in Malaysia: monsoon flood and flash flood. Monsoon flood caused by heavy rainfall which occurred from Northeast Monsoon during November to March. This Monsoon Flood took place on the east coast of the Peninsula Malaysia, the northern part of Sabah and southern part of Sarawak (Hassan, Ab. Ghani, & Abdullah, 2006).

Moreover, rapid development, unplanned urbanisation, climate change and environmental degradation have caused the worse and more frequent occurrence of flash floods, especially in urban areas. Based on the report by Department of Irrigation and Drainage Malaysia (2016), about 29,000 square kilometres or 9 per cent of the total land of Malaysia and more than 4.8 million people are affected by flood every year. The following **Error! Reference source not found.** shows the history of flood events in the past 20 years which affected several states in Malaysia.

Flood is conditioned with the potential to cause severe damage and loss. Flood lead to harmful consequences which refer to death or injuries, losses on property or livelihoods, damaged infrastructure systems, disruptions concerning the economic activity or environmental damages. This adverse condition has caused severe damaged and loss of millions of Ringgit. Average annual flood damage is as high as RM100 million (Mohd, Daud, & Alias, 2006). Besides, the 2014 year end monsoon and floods were the worst ever in the Malaysian history which affects more than half a million victims in several states. Damage to infrastructure systems alone was estimated at USD670 million (Reliefweb, 2016). Damage to infrastructure systems concerns electricity supply, water supply, sewage system, road and railway networks, telephone including critical facilities such as hospitals and shelters. Based on research finding by Said, Gapor, Samian, & Abd Malik (2013), insufficient and damage of infrastructure systems caused by floods has dramatically disrupted the livelihood of the victims in affected areas. Thus, the functionality of infrastructure systems is vital particularly during the flood. Infrastructure systems not only represent significant financial investments, but they also provide essential service to the people (Opdyke, Javernick-Will, & Koschmann, 2017). Therefore, it is crucial to strengthen the infrastructure systems in a way to withstand flood-generated force simultaneously reduce the impacts of disruption of livelihood of the victims in affected areas (Cutts, Wang, & Yu, 2015; Reiner & McElvaney, 2017). Based on Bruneau et al. (2004), the damage and disruption caused by disasters can be reduced by focusing and implement the resilience criteria: robustness, resourcefulness, rapidity and redundancy, and integrates with infrastructure systems. Hence, the purpose of this paper is to identify the resilience criteria needed to strengthen infrastructure systems towards floods based on four (4) criteria as stated by Bruneau et al. (2004). In this paper, authors do not attempt to challenge established constructs and frameworks from previous researches, but instead, attempt to analyse and integrate the diversity of research perspectives taken to study infrastructure systems resilience around the world.

Table 1
*Flood disasters in Malaysia for the period of 1998 to 2018 by the total number of death, affected and damage*

| No | Year | Location | Disaster type | Total death | Total affected | Total damage ('000 USD) |
|---|---|---|---|---|---|---|
| 1 | 2018 | Pahang, Johor & Terengganu | Flood | 2 | 12000 | - |
| 2 | 2018 | Sarawak | Flood | - | 4900 | - |
| 3 | 2017 | Penang, Kedah & Perak | Flood | 7 | 3500 | - |
| 4 | 2017 | Kelantan, Terengganu, Johor, Pahang, Melaka, Selangor, Perak & Sabah | Flood | - | 5481 | - |
| 5 | 2017 | Kelantan & Terengganu | Flood | 2 | 13000 | - |
| 6 | 2017 | Kelantan, Terengganu, Perak, Pahang, Johor, Sabah & Selangor | Flood | - | 25000 | 132000 |
| 7 | 2016 | Kedah & Penang | Flood | - | 441 | - |
| 8 | 2016 | Johor, Melaka, Negeri Sembilan & Sarawak | Flood | - | 6000 | - |
| 9 | 2016 | Terengganu | Flood | - | 400 | - |
| 10 | 2015 | Sarawak | Flood | 1 | 3000 | - |
| 11 | 2014 | Sabah, Kelantan, Pahang, Terengganu, Perak, Johor, Selangor & Perlis | Flood | 17 | 230000 | 284000 |
| 12 | 2013 | Kuala Lumpur, Pahang, Terengganu, Johor & Kelantan | Flood | 4 | 75000 | 2000 |
| 13 | 2011 | Selangor | Flood | 16 | 6 | - |
| 14 | 2011 | Johor | Flood | 2 | 20000 | - |
| 15 | 2009 | Terengganu | Flood | - | 9082 | - |
| 16 | 2009 | Kedah, Terengganu, Kelantan & Perak | Flood | - | 1793 | - |
| 17 | 2008 | Pahang, Kelantan & Terengganu | Flood | - | 2000 | - |
| 18 | 2007 | Johor, Kelantan, Pahang & Terengganu | Flood | 29 | 29000 | 363000 |
| 19 | 2007 | Johor & Pahang | Flood | 17 | 137533 | 605000 |
| 20 | 2006 | Johor | Flood | - | 1112 | - |
| 21 | 2006 | Terengganu, Pahang & Kelantan | Flood | - | 4906 | - |
| 22 | 2006 | Melaka, Negeri Sembilan, Pahang & Johor | Flood | 6 | 100000 | 22000 |
| 23 | 2006 | Perak | Flood | - | 500 | - |
| 24 | 2006 | Kelantan, Terengganu, Kedah, Perlis & Perak | Flood | 9 | 30000 | - |
| 25 | 2005 | Sabah | Flood | 4 | 600 | - |
| 26 | 2004 | Johor | Flood | | 9138 | - |
| 27 | 2004 | Pahang, Kelantan & Terengganu | Flood | 13 | 15000 | 10000 |
| 28 | 2004 | Sabah | Flood | - | 2000 | - |
| 29 | 2004 | Sarawak & Johor | Flood | 3 | 6900 | - |
| 30 | 2003 | Kedah, Pahang & Perak | Flood | 3 | 13800 | - |
| 31 | 2002 | Pahang, Kelantan & Terengganu | Flood | 11 | 18000 | - |
| 32 | 2001 | Sabah | Flood | - | 5000 | - |
| 33 | 2001 | Penang | Flood | - | 10000 | - |
| 34 | 2000 | Kelantan, Kedah, Terengganu | Flood | 12 | 8000 | 1000 |
| 35 | 1999 | Pahang, Johor & Terengganu | Flood | 1 | 2000 | - |
| 36 | 1998 | Penang & Kedah | Flood | - | 2500 | - |

**Methodology**

This paper is written based on an overview of literature from journal, articles, newspaper, book and report as floods become the primary threat to Malaysia which caused severe damage and disruption particularly infrastructure systems, the review focus about local and other country experiences regarding flood effect in infrastructure systems and their action to strengthen infrastructure systems.

**Resilience**

The term of resilience typically used in the same way as the concept of "*bouncing back*" and was derived from Latin root "*resiliere*" which means to "*jump back*" (Paton & Johnston, 2001). This term has become an important term in the language of many disciplines ranging from ecology, hazards, psychology, geography, sociology and public health (Cutter, Burton, & Emrich, 2010; Mayunga, 2007). Thus, the definition of resilience may differ, and it's hard to find a consensus on this matter (Mayunga, 2007). However, in term of hazard discipline, UNISDR (2017) defined it as *"the ability of a system, community or society exposed to hazards to resist, absorb, accommodate, adapt to, transform and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through risk management".*

Nowadays, the notion of resilience became recognise realising that natural disasters are inevitable (Alshehri, Rezgui, & Li, 2015; Cutter, 2016; Sharifi, 2016). Now, policymakers, practitioners and scholars are turning their focus and effort that can strengthen resilience against various types of natural disasters (Cimellaro et al., 2014). Moreover, they realise and come to accept that people cannot prevent every risk of hazard but rather must learn to absorb, recover and operate from the impact of disasters in a timely and efficient manner (Asharose, 2016). Disasters can lead to large-scale consequences and cascade effects for the nation (Cutter, 2012). The impact of not paying attention to strengthen resilience towards natural disasters can lead to severe consequences to people livelihood (Alshehri et al., 2015). Either frequent small, medium impact or single intense disaster events can severely impact the people including loss of life, injury, disease and another harmful effect on human physical, mental and social well-being, together with damage to property, destruction of assets (Lindell, 2011), loss of services, social and economic disruption and environmental degradation (UNISDR, 2009). One way to reduce the impact of disasters on people is to strengthen their resilience towards natural disasters (Joerin, Shaw, Takeuchi, & Krishnamurthy, 2012). Resilience has become a focal point of the United Nations of International Strategy for Disaster Reduction (UNISDR) to reduce the impacts of natural disasters worldwide. As evidence, the decade of 2005 – 2015 (the Hyogo Framework for Action) and 2015 – 2030 (the Sendai Framework for Disaster Risk Reduction) will gain attention to what affected people can do for themselves, and how best to strengthen and enhance them in the light of disaster risks they face (UNISDR, 2005, 2015)

**Resilience Criteria**

In this section, a comprehensive review of literature research on the resilience criteria towards flood was conducted. Based on the analysis of previous researches, authors have identified the resilience criteria and sub-criteria to strengthen infrastructure systems. The resilience criteria in this study discovered from the group of researchers at MCEER (Multidisciplinary Centre of Earthquake Engineering to Extreme Events) which identified four (4) main criteria along that can strengthen resilience (Cimellaro, Reinhorn, & Bruneau, 2010).

These criteria are robustness, resourcefulness, rapidity and redundancy (Bruneau et al., 2004). Robustness can be defined as the ability of infrastructure systems to withstand disaster forces without significant degradation or loss of performance (Bruneau et al., 2004). Meanwhile, resourcefulness relates to the ability to identify problems, establish priorities and mobilise resources when conditions exist that threaten to disrupt the infrastructure systems. Sajoudi et al. (2007) added resourcefulness refers to the ability to expertly get ready for, react to, and manage a disaster as it occurs and capacity to organise needed resources and services in natural disaster events. Moreover, rapidity is defined as the capacity to meet priorities and achieve goals promptly to contain losses and avoid future infrastructure systems disruption (Bruneau et al., 2004). Finally, redundancy can be defined as the extent of infrastructure systems that are substitutable and capable of satisfying the functional requirement in the event of disruption, degradation or loss of functionality (Bruneau et al., 2004).

Meanwhile, the sub-criteria to strengthen infrastructure systems in this paper discovered through literature reviewed which covered several topics which are: resilience for transportation systems, resilience for energy systems and resilience for sewerage systems. A summary of the resilience criteria and sub-criteria to strengthen infrastructure systems from various researches can be view in **Error! Reference source not found.**. Each of the resilience criteria as shown in **Error! Reference source not found.** is discussed thoroughly in the following sub-section.

Table 2
*Resilience criteria to strengthen infrastructure systems*

| Resilience criteria | Sub-criteria | References |
|---|---|---|
| Robustness | Maintenance | (Giovinazzi, Hart, Cavalieri, & Kongar, 2014; Keating et al., 2014; Labaka, Hernantes, & Sarriegi, 2016; Mattsson & Jenelius, 2015) |
| | Design | (Giovinazzi et al., 2014; Labaka et al., 2016; Panteli & Mancarella, 2015) |
| | Upgrading | (Giovinazzi et al., 2014; Mattsson & Jenelius, 2015; Panteli & Mancarella, 2015; Winderl, 2014) |
| Resourcefulness | Information | (Atreya & Kunreuther, 2016; Bruneau et al., 2004; Keating et al., 2014; Labaka et al., 2016; Mattsson & Jenelius, 2015; Oravec, 2014; Sajoudi et al., 2007; Tierney, 2008; Winderl, 2014) |
| | Material | (Atreya & Kunreuther, 2016; Bruneau et al., 2004; Keating et al., 2014; Labaka et al., 2016; Oravec, 2014; Tierney, 2008; Tierney & Bruneau, 2007; Winderl, 2014) |
| | Financial | (Bruneau et al., 2004; Keating et al., 2014; Labaka et al., 2016; Oravec, 2014; Tierney, 2008) |
| | Manpower | (Bruneau et al., 2004; Keating et al., 2014; Oravec, 2014; Tierney & Bruneau, 2007) |
| Rapidity | Mobilisation | (Bruneau et al., 2004; Keating et al., 2014; Simonovic & Peck, 2013; Tierney, 2008) |
| | Restoration | (Amico & Currà, 2014; Bruneau et al., 2004; Mattsson & Jenelius, 2015; Winderl, 2014) |
| | Reconstruction | (Bruneau et al., 2004; Rose & Krausmann, 2013; Winderl, 2014) |
| Redundancy | Duplication of components | (Bruneau et al., 2004; Oravec, 2014; Simonovic & Peck, 2013; Tierney, 2008; Xu, Chen, Jansuwan, Heaslip, & Yang, 2015) |
| | Alternative components | (Amico & Currà, 2014; Atreya & Kunreuther, 2016; Bruneau et al., 2004; Keating et al., 2014; Mattsson & Jenelius, 2015; Oravec, 2014; Panteli & Mancarella, 2015; Sajoudi et al., 2007; Simonovic & Peck, 2013; Tierney, 2008; Tierney & Bruneau, 2007; Winderl, 2014; Xu et al., 2015) |
| | Capacity of components | (Bruneau et al., 2004; Keating et al., 2014; Panteli & Mancarella, 2015; Winderl, 2014; Xu et al., 2015; Zhong, 2014) |

**Robustness**

As discussed earlier, robustness defines as an ability of infrastructure systems to withstand disaster forces without significant degradation or loss of performance. The ability of infrastructure systems to withstand disaster forces without significant degradation or loss of performance can be achieved by implementing proper maintenance, proper and safe design and upgrading and renewal the infrastructure systems.

Maintenance can be dividing into two types: preventive and corrective maintenance. Preventive and corrective maintenance is essential to ensure the integrity and operability of infrastructure systems during floods (Giovinazzi et al., 2014; Keating et al., 2014; Labaka, Hernantes, & Sarriegi, 2015). The maintenance activities must be performed periodically and continuously to ensure the infrastructure systems can withstand the flood-generated force as well reduces the magnitude of the impact and the time to recover (Giovinazzi et al., 2014; Labaka et al., 2016; Mattsson & Jenelius, 2015). In case of Indonesia, most of the dam located in a densely populated area in Jakarta, routine maintenance of the dam including floodgates and detention pumping are executed to reduce the susceptibility of the flood (Wardani & Muntohar, 2013). Meanwhile, in Australia, local authorities have to direct the regular and continuous maintenance of the drainage systems and levee as part of the practice to facilitate robust infrastructure towards floods (AIDR, 2013).

The proper and safe design is one of the resilience criteria to strengthen infrastructure systems. This criterion can be achieved by promotion, encouragement and implementation by the government. As an example, the Japanese government and their public entities has developed and enforced the regulation and building codes to be used as a guideline by the people (Ranghieri & Ishiwatari, 2012). Land-use regulations and rigorous implementation of the seismic reinforcement for infrastructure systems among the action taken to prevent excessive damage to infrastructures (Giovinazzi et al., 2014; Labaka et al., 2016), concurrently minimizing the effort required to restore their functions after disaster events (Atreya & Kunreuther, 2016; Panteli & Mancarella, 2015).

Moreover, upgrading (Panteli & Mancarella, 2015) and retrofitting (Winderl, 2014) the infrastructure systems represent a further strategy aimed to create robust infrastructure systems towards floods (Giovinazzi et al., 2014; Mattsson & Jenelius, 2015; Panteli & Mancarella, 2015). In Australia, the structures of infrastructure systems were designed for flood impact with suitable water-resistant structural material (AIDR, 2013). In the meantime, Japan has developed a disaster resilience infrastructure by retrofit road network including bridges which can minimise the damage and restoration efforts (Ranghieri & Ishiwatari, 2012). However, the upgrading and retrofitting activities need to be monitor and updated periodically and continuously to ensure the robustness of the infrastructure systems towards floods (Giovinazzi et al., 2014).

**Resourcefulness**

As define by Bruneau et al. (2004), resourcefulness relates to the ability to identify problems, establish priorities and mobilise resources when conditions exist that threaten to disrupt the infrastructure systems. Resourcefulness can be obtained by implementing these four (4) sub-criteria: resourceful of information, material and equipment, financial aid and manpower.

Resourceful of information refers to the ability of people to diagnose and prioritise the problem then initiate the solution by identifying and mobilise the resources that disrupt the infrastructure system during flood event (Keating et al., 2014; Mattsson & Jenelius, 2015; Oravec, 2014; Tierney, 2008; Winderl, 2014). It can be done by preparing the people with information to reduce the impact of the flood (Atreya & Kunreuther, 2016) and implementing training and planning for the time that flood struck (Petit, Eaton, Fisher, McAraw, & Collins, 2012; Sajoudi et al., 2007). For example in Indonesia, dissemination of tsunami brochures, posters, calendars, announcements, or exclusive reports and interviews on radio and television are action taken to disseminate the information among the people (Muhari, Diposaptono, & Imamura, 2007). Meanwhile, in Japan, training and evacuation drills including education are a fixture in Japan's schools. Regular training drills, education in the schools, and planning of hazard maps are the keys that save the lives of schoolchildren in Japan (Ranghieri & Ishiwatari, 2012). Also, on-going community training and education are required to ensure that the population is aware of emergency management plans against flood (AIDR, 2013).

Additionally, resourcefulness can be further translated as the availability and ability to supply resources including materials and equipment, financial aid and manpower. Availability and ability to supply resources are crucial in flood recovery phase (Bruneau et al., 2004; Keating et al., 2014; Tierney, 2008; Winderl, 2014). As these resources used for restoration and reconstruction of damaged infrastructure system (Atreya & Kunreuther, 2016; Oravec, 2014). In Japan, the provision of storage facilities to supply materials and equipment is a critical element of their preparedness for future disasters. The stockpile of materials and equipment such as generators, cord reels, floodlight, mobile toilet sets, large-size tents for aid stations or shelters, and satellite phone are stored as these stockpiles been used during the disaster recovery phase (Ranghieri & Ishiwatari, 2012).

Furthermore, provision for material and equipment alone is not enough to cope with the occasional flood of high impact. Establishment of financial measures, such as insurance and restoration funds is crucial. In Japan, establish financial arrangement mechanisms between local authorities and the federal government have been established in advance to avoid delay in restoration work (Ranghieri & Ishiwatari, 2012. Insurance as an example helps people get back on their feet from suffering due to the impact of the disaster (Oravec, 2014). In this case, the federal government can play an essential role in fostering and enabling the private insurance industry to offer cost-effective and affordable insurance solutions to the disaster victims (Ranghieri & Ishiwatari, 2012).

Meanwhile, in the USA, a unified and coordinated operational structure and process that appropriately integrates all critical stakeholders through engagement among the community in affected areas along with the government and their public entities have been established and maintained (FEMA, 2015). The ability to organise the human resource is a crucial element to enable the restoration and reconstruction of damaged infrastructure systems in a shorter period (Keating et al., 2014; Oravec, 2014). In another way, as what implemented in Japan, the establishment of volunteer centres in the affected areas as well may provide the workforce for restoration and reconstruction work (Ranghieri & Ishiwatari, 2012).

**Rapidity**

Rapidity refers to the capacity to meet priorities and achieve goals promptly to contain losses and avoid future infrastructure systems disruption. In this case, the infrastructure system can be strengthening by achieving these three (3) sub-criteria: rapidity in mobilisation, restoration and reconstruction.

When the flood occurred, there is an essential human element. Flood is not only affected people, but people affect flood as well. The aspect of mobilisation of resources (material and equipment, financial aid, manpower) become complicated since it involves the engagement between victims in affected areas and government along with their public entities (Rivera &

Kapucu, 2015). Rapidity in the mobilisation of resources is critical as it lets to reduce unfavourable and harmful condition as well speed up the restoration and reconstruction of infrastructure systems in flood areas (Kuznecova, Romagnoli, & Rochas, 2014). As evidence, rapidity mobilisation of resources has been identified as one of the success factors in post-disasters reconstruction project in Indonesia, China and Sri Lanka (Ismail, Abdul Majid, Roosli, & Ab Samah, 2014; Moe & Pathranarakul, 2006). Based on Japan experienced, rapidity in the mobilisation of resources can be done by pre-agreement between government and private sectors. By pre-agreement made with private sectors, it allows for quick mobilisation of the needed resources then skip the procurement process and start restoration and reconstruction activities immediately (Ranghieri & Ishiwatari, 2012).

Flood creates significant losses and significant disruption to infrastructure systems. Thus, reinstating the infrastructure systems back to its original pre-flood condition is critical. The reinstating process of infrastructure systems can be viewed as the restoration and reconstruction activities (Rapp, 2010). However, there are differences between restoration and reconstruction activities. The restoration activities seek to repair existing structures to their original state while reconstruction activities look to demolish and rebuild the damage structures (Baroudi & Rapp, 2010). The restoration and reconstruction activities after the occurrence of flood involve the reinstatement of pre-disaster people activities that were disrupted by flood impact. Hence, to ensure people able to carry on with their normal pre-flood life, the restoration and reconstruction activities have to be performed rapidly and promptly (Amico & Currà, 2014; Bruneau et al., 2004; Mattsson & Jenelius, 2015; Rose & Krausmann, 2013). However, the restoration and reconstruction activities should be according to priority. According to FEMA (2015), it is crucial to stabilise critical infrastructure functions, minimise health and safety threats, and efficiently restore and regenerate systems and services to support a feasible and resilient community.

**Redundancy**

Redundancy can be defined as the extent of infrastructure systems that are substitutable and capable of satisfying the functional requirement in the event of disruption, degradation or loss of functionality. Based on Bruneau et al. (2004). The infrastructure systems can be strengthened by applying duplicative of the infrastructure systems, alternative infrastructure systems and capacity of infrastructure systems to satisfy the functional requirement during the flood.

In term of infrastructure systems, the redundancies can be viewed as the duplication (Bruneau et al., 2004; Simonovic & Peck, 2013; Xu et al., 2015) and alternative (Amico & Currà, 2014; Atreya & Kunreuther, 2016; Keating et al., 2014; Panteli & Mancarella, 2015) systems that capable to fulfil the functional requirement in the flood events. However, it must be highlighted that the "duplication" and "alternative" infrastructure systems are dissimilar. The duplication of infrastructure systems refers to a system that is an exact copy of existing systems. For instance, multiple telephone networks could increase the redundancy by providing duplicate telephone network if one or more telephone networks are disturbed by the disruption. In this case, if one telephone network fails in a time of crisis, people still can use another telephone network to communicate (Xu et al., 2015). Meanwhile, the alternative of infrastructure systems refers to a component that is the substitute or replaces with other systems. For example, if the telephone network fails in a time of crisis, the radio network can be a good alternative for substitution (Sajoudi et al., 2007).

Also, the capacity of infrastructure systems refers to the ability to absorb and withstand in time of flood events (Keating et al., 2014; Winderl, 2014). Nevertheless, the capacity is not only referred to the ability to absorb and withstand in time of flood events but also it needs to deal with the ability to absorb and resist with additional demand in that time. In that view, additional infrastructure systems could help increase the capacity as it provides operational flexibility and remains functional in disaster situations (Zhong, 2014) as well as contribute to the prevention of greater failure (Panteli & Mancarella, 2015). Take the redundant telephone network, internet connection, radio network and television broadcast as example, all of these telecommunication systems have the extra capacity to serve if others fail, for instance, if internet connection fail in time of flood situation, telephone network, radio network and television broadcast can be used as alternative medium to communicate and disseminate information in the affected area (Sajoudi et al., 2007).

In the case of Japan during earthquake and tsunami in 2011, social media that use the internet to connect people (i.e. Twitter and Facebook) were extensively used for searches, rescues, and fundraising. In other hands, Emergency FM radio also played a crucial role in the aftermath of the disaster. When the emergency communication systems in many areas broke down because of power failures and lack of emergency backup power, community radio stations act as a substitute for telephone network and were able to get useful information out to people. About 20 emergency broadcasting stations dedicated to disseminating disaster information were set up in a certain area. In the immediate aftermath of the disaster, these community radio stations began to provide information about times and locations for the distribution of emergency food, water, and goods. In the following months, they gradually shifted to providing other information to help victims in their daily lives or to raise the spirits of people in local communities (Ranghieri & Ishiwatari, 2012).

**Conclusion**

Floods are an event that occurred all over the world particularly in Malaysia. They leave with the remarkable impact on the livelihood and utterly devastating. Although flood is caused by nature and inevitable, being aware and prepared is something that should look thoroughly. As known, the flood has given an adverse effect on infrastructure systems. However, this adverse effect can be significantly reduced by strengthening the resilience of infrastructure systems in the face of the expected increase of the flood in the future.

The authors believe this paper has provided a general view on how to strengthen infrastructure systems resilience towards flood. The most common and fundamental resilience criteria to strengthen infrastructure systems resilience were reviewed and listed from the previous researches. The authors believe it can serve as a platform for other researchers to launch into this field and find a way to strengthen infrastructure systems resilience towards natural disasters in general.

**Acknowledgement**

The authors wish to acknowledge the Institute of Postgraduate Studies (IPS) and the Universiti Teknologi MARA Perak Branch for providing necessary research facilities and supervision.

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