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CRITERIA OF RESILIENCE INFRASTRUCTURE IN FLOOD-PRONE AREAS IN KELANTAN: A PILOT STUDY

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ABSTRACT

The resilience infrastructure systems can be described as capable of resisting, absorbing and recovering from flood effects in a timely and efficient manner. The resilience infrastructure systems can be achieved through the implementation of resilience criteria (i.e. robustness; resourcefulness; rapidity; and redundancy). The objective of this paper is to determine the most important resilience criteria to strengthen infrastructure systems in flood-prone areas in Kelantan. A cross-sectional survey was conducted among communities in flood-prone areas in Kelantan. A total of 23 criteria were analysed subjected to descriptive analysis. The results of the analysis showed that robustness is the most important criteria.

Keywords: *Disaster, Flood, Infrastructure, Resilience*

INTRODUCTION

Malaysia, a nation outside the Pacific Rim of Fire, is relatively free from significant devastation of natural disasters such as earthquake, volcano eruption and typhoon (Baharuddin et al., 2015). However, Malaysia is vulnerable to natural disasters such as floods, landslides, storms and severe haze. Besides, floods have become Malaysia's biggest threat that caused severe disruption to livelihood and annual economic losses (Akasah & Doraisamy, 2015). Malaysia usually face two kinds of flooding; monsoon flooding and flash flooding. Monsoon flood is typically caused by the heavy rainfall of the Northeast Monsoon which occurs between November and March. Additionally, monsoon floods periodically occurred on the east coast of the Malaysian Peninsula, northern Sabah and southern Sarawak (Hassan, Ab. Ghani, & Abdullah, 2006). To make matters worse, rapid growth, unplanned urbanization, global climate change and environmental degradation have increased flood frequency and intensity. Furthermore, the report by the Department of Irrigation and Drainage Malaysia (2016) found that 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.

Flood leads to harmful effects involving death, injury, loss of livelihood, destruction of infrastructure, economic disruption and damage to the environment. According to Mohd, Daud, & Alias (2006), this adverse condition may result in average annual flood damage of RM100 million and may increase in the future. In addition, Reliefweb (2016) reported the 2014 year-end monsoon flood as Malaysia's worst-ever event, impacting over half a million people in several states. The most severely affected state was Kelantan which affected more than 200,000 victims and caused damage to thousands of homes. Moreover, the damage to infrastructure systems alone was estimated to be USD670 million. The damaged infrastructure systems include electricity supply, water supply, sewage system, road and railway networks, telephone and critical facilities (i.e. hospitals and shelters). Regarding this matter, research findings by Said, Gapor, Samian, & Abd Malik (2013) found that damaged and insufficient flood-impacted infrastructure systems have severely disrupted livelihoods in the affected areas. The findings were aligned with Opdyke, Javernick-Will, & Koschmann (2017) where infrastructure systems not only represent significant financial investments but also provide vital community service.

Any disruption to infrastructure systems can have devastating effects on the communities.

Therefore, it is important to ensure the functionality of infrastructure systems during flood disaster events to simultaneously minimise the impact of disruption upon communities' well-being in flood-prone areas (Cutts, Wang, & Yu, 2015; Reiner & McElvaney, 2017). The significance of functionality of infrastructure systems for community in flood-prone areas is aligned with the expected outcome of Sendai Framework for Disaster Risk Reduction 2015 – 2030 (UNISDR, 2015) which aims to reduce disaster risk and losses in lives, livelihoods and health as well as the economic, physical, social, cultural and environmental assets of communities. The functionality of infrastructure systems for the community can be achieved through enhancing the resilience of infrastructure systems. According to UNISDR (2017), resilience is defined 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". To resist, absorb, accommodate, adapt to, transform and recover from the effects of flood in a timely and efficient manner, thus it is important to strengthen the resilience of infrastructure systems. Nonetheless, it is necessary to fulfill those requirements to create resilient infrastructure systems. Hence, the objective of this paper is to determine the most important resilience criteria to enhance the existing infrastructure systems in flood-prone areas specifically in Kelantan.

RESILIENCE CRITERIA

Based on the previous statement in Section 1, certain criteria are required to be fulfilled that will lead to resilient infrastructure systems. Through the analysis of previous studies, the authors have discovered the resilience criteria and sub-criteria to enhance the resilience of infrastructure systems. The resilience criteria in this paper identified from a group of researchers at MCEER (Multidisciplinary Centre of Earthquake Engineering to Extreme Events) which identified four (4) main criteria (Cimellaro, Reinhorn, & Bruneau, 2010). These criteria are robustness, resourcefulness, rapidity and redundancy (Bruneau et al., 2004). For this research; robustness, resourcefulness, rapidity and redundancy can be defined as shown in Table 1 below:

Table 1: Definitions of Resilience for Infrastructure Systems

Resilience criteria	Definition
Robustness	the ability of infrastructure systems to withstand disaster forces without significant degradation or loss of performance
Resourcefulness	the ability to identify problems, establish priorities and mobilise resources when existing conditions threaten to disrupt the infrastructure systems
Rapidity	the capacity to meet priorities and achieve goals promptly to contain losses and avoid future infrastructure systems disruption
Redundancy	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

Source: Author

Meanwhile, the sub-criteria to enhance infrastructure systems in this paper discovered through literature reviewed which covered several topics include: resilience for floods, resilience for seismic activities, resilience for tsunamis and drought from various countries. However, Kafle (2012) in his study argued that resilience criteria should be both location and disaster specific due to diversities of the disaster itself, communities and culture of each country. His argument was in line with Norris et al. (2008), Ostadtaghizadeh et al. (2015), Renschler, Frazier, Arendt, Cimellaro, et al. (2010), Shaw & Sharma (201) and Sherrieb, Norris, & Galea (2010) where the variables of framework may vary regarding the types of disaster (i.e. flood resilience strategies may differ from those required for drought hazards), locations (i.e. disaster risk reduction program in certain countries may differ, yet both face comparable levels of flood) and culture (i.e. level of economic, social, physical, institutional and natural). Based on the statement above, the authors seek to determine the most important resilience criteria to enhance infrastructure systems in flood-prone areas specifically in Kelantan. A summary of the resilience criteria and sub-criteria to strengthen infrastructure systems from various researches can be found in Table 2.

Table 2: Resilience Criteria to Strengthen Infrastructure Systems

Resilience criteria	Sub-criteria	References
Robustness	Corrective maintenance	(Giovinazzi, Hart, Cavalieri, & Kongar, 2014; Keating et al., 2014; Labaka, Hernantes, & Sarriegi, 2016; Mattsson & Jenelius, 2015)
	Preventive maintenance	(Dick, Russell, Souley Dosso, Kwamena, & Green, 2019; Giovinazzi et al., 2014; Keating et al., 2014; Labaka et al., 2016; Mattsson & Jenelius, 2015)
	Safe design	(Giovinazzi et al., 2014; Labaka et al., 2016; Panteli & Mancarella, 2015)
	Material upgrade	(Giovinazzi et al., 2014; Mattsson & Jenelius, 2015; Panteli & Mancarella, 2015; Winderl, 2014)
	Newer structures	(Giovinazzi et al., 2014; Mattsson & Jenelius, 2015; Panteli & Mancarella, 2015; Winderl, 2014)
Resourcefulness	Information to reduce flood damage	(Atreya & Kunreuther, 2016; Bruneau et al., 2004; Keating et al., 2014; Labaka et al., 2016; Mattsson & Jenelius, 2015; Oravec, 2014; Sajoudi, Wilkinson, Costello, & Sapeciay, 2007; Tierney, 2008; Winderl, 2014)
	Training	(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)
	Availability of 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)
	Availability of equipment	(Atreya & Kunreuther, 2016; Bruneau et al., 2004; Keating et al., 2014; Labaka et al., 2016; Oravec, 2014; Tierney, 2008; Tierney & Bruneau, 2007; Winderl, 2014)
	Availability of financial aid	(Bruneau et al., 2004; Keating et al., 2014; Labaka et al., 2016; Oravec, 2014; Tierney, 2008)
	Availability of manpower	(Bruneau et al., 2004; Keating et al., 2014; Oravec, 2014; Reliefweb, 2016; Tierney & Bruneau, 2007)

Rapidity	Mobilization of material	(Bruneau et al., 2004; Keating et al., 2014; Simonovic & Peck, 2013; Tierney, 2008)
	Mobilization of equipment	(Bruneau et al., 2004; Keating et al., 2014; Simonovic & Peck, 2013; Tierney, 2008)
	Mobilization of financial aid	(Bruneau et al., 2004; Keating et al., 2014; Simonovic & Peck, 2013; Tierney, 2008)(Asharose, 2016)
	Mobilization of manpower	(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; Hosseini & Izadkhah, 2008; Rose & Krausmann, 2013; Winderl, 2014)
Redundancy	Duplication of systems	(Bruneau et al., 2004; Hecht, Biehl, Barnett, & Neff, 2019; Nowell, Bodkin, & Bayoumi, 2017; Oravec, 2014; Simonovic & Peck, 2013; Tierney, 2008; Xu, Chen, Jansuwan, Heaslip, & Yang, 2015)
	Alternative systems	(Amico & Currà, 2014; Atreya & Kunreuther, 2016; Bruneau et al., 2004; Keating et al., 2014; Mattsson & Jenelius, 2015; Nowell et al., 2017; 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 systems	(Brown, Seville, & Vargo, 2017; Bruneau et al., 2004; Keating et al., 2014; Panteli & Mancarella, 2015; Winderl, 2014; Xu et al., 2015; Zhong, 2014)
	Stability of systems	(Auer, Kleis, Schultz, Kurths, & Hellmann, 2016; Johnsen & Veen, 2013; Sage, Sircar, Dainty, Fussey, & Goodier, 2015; Samsuddin, Takim, Nawawi, & Syed Alwee, 2018)
	Risk of complete failure of systems	(Inaoka, Takeya, & Akiyama, 2019; Pickering, Dunn, & Wilkinson, 2017; Samsuddin et al., 2018; Serre & Heinzlef, 2018)

	Failure of redundant systems	(Murdock, de Bruijn, & Gersonius, 2018; Pickering et al., 2017; Samsuddin et al., 2018; Serre & Heinzlef, 2018)

METHODOLOGY

The questionnaire survey method was utilised for this research and was based on resilience criteria (i.e. robustness, resourcefulness, rapidity and redundancy) as discussed in Section 2. Consequently, the 5-point Likert-scale (i.e. ranging from 1 "strongly disagree" to 5 "strongly agree") was adapted to measure the extent of the importance of the resilience criteria. Moreover, respondents were asked to indicate the level of agreement on the importance of those factors and criteria. For this research, purposive sampling was used based on the respondents' experience towards floods disaster events. However, the selection was mainly focused on the community in flood-prone areas in Kelantan. Based on the study by Pour & Hashim (2016) and Syed Hussain & Ismail (2013), the flood-prone areas in Kelantan involved several districts such as Kota Bharu, Pasir Mas, Tumpat, Tanah Merah, Machang, Kuala Krai, Jeli and Gua Musang. All of these districts straddle several main rivers including Sungai Kelantan, Sungai Lebir, Sungai Galas and Sungai Pergau. Hence, the survey was distributed to the abovementioned districts which were recognized as flood-prone areas in Kelantan. Additionally according to Mercy (2016), in terms of disaster, the community can be categorized into four (4) main groups: government, private sectors, learning institutions and communities.

Thus, the survey was distributed to these districts among the four most important target groups. A total of 100 questionnaires were distributed among the community in flood-prone areas in Kelantan over a month (15th May 2018 – 14th June 2018). Out of this, only 31 questionnaires were completed which indicated a response rate of 31 per cent. The low response rate was due to the on-going data collection process , particularly for PhD main data collection. Out of 31 respondents, most of them live in Kota Bharu (n=18), Machang (n=4), Jeli (n=4), Tanah Merah (n=3), Kuala Krai (n=1) and Tumpat (n=1). Meanwhile for the composition of community it consists of government (i.e. federal, state, district agencies, emergency services, critical facilities services) (n=12), private sectors (i.e. private companies, non-governmental organizations, non-profit organizations, media) (n=5), learning institutions (i.e. universities, research centres, schools) (n=7) and communities (i.e. head of communities, elderly, villagers, youth) (n=7). Then, the outcome of the questionnaires were analysed by using the IBM SPSS Statistics Version 22 for descriptive analysis.

RESULTS AND DISCUSSIONS

Table 3 represents the descriptive analysis of resilience criteria while Table 4 represents the descriptive analysis of resilience sub-criteria to enhance the resilience of infrastructure systems for the community in flood-prone areas in Kelantan. In this section, the analysis deals with the ranking of resilience criteria based on their mean values to determine the level of importance for each criterion.

Based on Table 3, the results revealed that ‘robustness’ is the most important resilience criteria where the overall mean is 3.4516. By implementing corrective (mean=3.5161) and preventive maintenance (mean=3.4516), safe design (mean=3.4516), upgrading the construction material (mean=3.452) and building new structures (mean=3.3871), the infrastructure systems would be more robust simultaneously enhancing its resilience towards flood. This is in-line with Christodoulou, Fragiadakis, Agathokleous, & Xanthos (2018) where robustness can be seen as a major criterion in resilience. Robustness refers to the strength or ability of infrastructure systems itself to withstand a given level of stress or demand without suffering degradation or loss of function (Bruneau et al., 2004). Nevertheless, as shown in Table 3, the importance of other resilience criteria (i.e. rapidity, resourcefulness and redundancy) towards the resilience of infrastructure systems cannot be taken for granted. The overall mean values of 'rapidity', 'resourcefulness' and 'redundancy' do not differ much from 'robustness' significantly indicating the importance of those criteria for resilience infrastructure systems for the community in flood-prone areas in Kelantan.

Table 3: Resilience Criteria

Resilience criteria	Resilience sub-criteria	N	Mean	Overall mean	Rank
Robustness	Corrective maintenance	31	3.5161		
	Preventive maintenance	31	3.4516	3.4516	1
	Safe design	31	3.4516		
	Material upgrade	31	3.452		
	Newer structures	31	3.3871		
Rapidity	Mobilization of material	31	3.4839	3.4032	2
	Mobilization of equipment	31	3.4516		
	Mobilization of financial aid	31	3.3871		
	Mobilization of manpower	31	3.3871		
	Restoration	31	3.3226		
	Reconstruction	31	3.3871		
Resourceful-ness	Information to reduce flood damage	31	3.3548	3.3925	3
	Training	31	3.1935		
	Availability of material	31	3.3548		
	Availability of equipment	31	3.3871		
	Availability of financial aid	31	3.5161		
	Availability of manpower	31	3.5484		

Redundancy	Duplication of systems	31	3.2581	3.2473	4
	Alternative systems	31	3.2903		
	Capacity of systems	31	3.3226		
	Stability of systems	31	3.3226		
	Risk of complete failure of systems	31	3.1935		
	Failure of redundant systems	31	3.0968		
Valid N (listwise)		31			
1= strongly disagree 2= disagree 3= fairly agree 4= agree 5= strongly agree					

Source: Author

Meanwhile, as shown in Table 4, the results revealed that 23 sub-criteria are rated as 'fairly agree' by the respondents where 'availability of manpower' is ranked first (mean=3.5484). Availability of manpower indicates the ability to supply human resources in the disaster recovery phase promptly to address physical components disruption (Bruneau et al., 2004; Keating et al., 2014). Furthermore, Keating et al. (2014) and Oravec (2014) stated that the ability to supply human resources is essential to enable restoration and reconstruction of damaged infrastructure systems in a shorter period. The mobilisation of human resources can be done through competency, preparedness and engagement of communities in flood-prone areas along with the government and their public entities. Although the 'availability of manpower' sub-criteria has the highest mean score, the other sub-criteria should not be taken lightly. All the 23 resilience sub-criteria which show a mean score above 3 indicates that they are also important to ensure the resilience of infrastructure systems for the community in flood-prone areas in Kelantan.

Table 4: Resilience Sub-Criteria

Resilience criteria	N	Mean	Std. Deviation	Rank
Availability of manpower	31	3.5484	.92516	1
Availability of financial aid	31	3.5161	.96163	2
Corrective maintenance	31	3.5161	.92632	3
Mobilization of material	31	3.4839	.88961	4
Preventive maintenance	31	3.4516	.92516	5
Material upgrade	31	3.452	.8500	6
Mobilization of equipment	31	3.4516	.85005	7
Safe design	31	3.4516	.99461	8
Mobilization of financial aid	31	3.3871	.91933	9
Availability of equipment	31	3.3871	.80322	10
Reconstruction	31	3.3871	.91933	11
Mobilization of manpower	31	3.3871	.84370	12
Newer structures	31	3.3871	.88232	13
Availability of material	31	3.3548	.87744	14
Information to reduce flood damage	31	3.3548	.95038	15
Stability of systems	31	3.3226	.94471	16
Capacity of systems	31	3.3226	.87129	17
Restoration	31	3.3226	.87129	18
Alternative systems	31	3.2903	.86385	19
Duplication of systems	31	3.2581	1.03175	20
Risk of complete failure of systems	31	3.1935	.94585	21
Training	31	3.1935	.94585	22
Failure of redundant systems	31	3.0968	.70023	23
Valid N (listwise)	31			
1= strongly disagree 2= disagree 3= fairly agree 4= agree 5= strongly agree				

Source: Author

CONCLUSION

Kelantan has been susceptible to flood in recent years. The flood caused the destruction of infrastructure systems and has been negatively impacting the community. Nonetheless, this adverse impact can be greatly reduced by enhancing the resilience of infrastructure systems. Enhancing the resilience of infrastructure systems is crucial, given the expected increase in the frequency and intensity of flood in the future. Moreover, it can be achieved by focusing on the robustness of the infrastructure systems. It is believed that well-conducted corrective and preventive maintenance, implementation and enforcement of safe design, effective upgrading of material for infrastructure systems and satisfactory construction of new infrastructure systems including the availability of manpower to restore and reconstruct damaged infrastructure systems can ensure the resilience of infrastructure systems during flood disaster events.

Moreover, the authors believed this paper provided an outcome which is: the importance of resilience criteria in enhancing infrastructure systems in flood-prone areas, particularly in Kelantan. The results revealed that 23 resilience criteria were rated ‘fairly agree’ by the respondents where ‘availability of manpower’ ranked first. However, based on four (4) main resilience criteria: robustness, resourcefulness, rapidity and redundancy, ‘robustness’ is the most important criteria to be applied to achieve greater resilience.

Eventhough the number of respondents (n=31) is low, the results should not be discredited. The findings described in this paper is a part of an on-going PhD research study which aimed primarily to develop a framework of resilient infrastructure systems for the community in flood-prone areas in Kelantan. Furthermore, the authors recommend that this study be used as a platform for other researchers to delve into this field and find a way to enhance the resilience of infrastructure systems towards flood in other flood-prone areas.

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