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RESILIENCE INFRASTRUCTURE FOR COMMUNITY IN FLOOD-PRONE AREAS IN KELANTAN

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Abstract - The dependency of community on the functioning of infrastructure systems are very high particularly during flood disaster events. As flood disaster events are intensely and frequently happened in Kelantan, there is an extreme need to have resilience infrastructure systems. The resilience infrastructure systems can be define as an ability to resist, absorb, accommodate and recover from the effect of flood in a timely and efficient manner. In this case, the resilience infrastructure systems can be achieved through the implementation of resilience criteria (i.e. robustness; resourcefulness; rapidity; and redundancy). Therefore, the objective of this paper is to determine the most importance resilience criteria to strengthen infrastructure systems in flood-prone areas in Kelantan. Thus, cross-sectional survey was conducted among thirty-one (31) communities (government = 12; private sectors = 5; learning institution = 7; and communities = 7) who affected in flood-prone areas in Kelantan. A total 23 criteria (robustness = 5; resourcefulness = 6; rapidity = 6; and redundancy = 6) for resilience criteria were analysed by SPSS version 22 subjected to descriptive analysis. The result obtained from the analysis found that robustness is most significant criteria while availability of manpower is most significant sub-criteria for resilience infrastructure for community in flood-prone areas in Kelantan.
Keywords - Disaster, Flood, Infrastructure, Resilience

1 INTRODUCTION

Malaysia, a country which geographically located outside the Pacific Rim of Fire is relatively free from any severe destruction of natural disaster like earthquake, volcano eruption and typhoon (Baharuddin et al., 2015). However, Malaysia is vulnerable to natural disaster like flood, landslide, storm and severe haze. Furthermore, flood become the biggest treat for Malaysia which caused severe disruption to livelihood and economic losses annually (Akasah & Doraisamy, 2015). Usually, Malaysia is facing two types of flood; monsoon flood and flash flood. Monsoon flood typically caused by the heavy rainfall occured from the Northeast Monsoon during November and March. Regularly, the monsoon flood struck on the east coast of Peninsula Malaysia, the northern part of Sabah and southern part of Sarawak (Hassan, Ab. Ghani, & Abdullah, 2006). Moreover, to make worse rapid development, unplanned urbanization, global climate change and enviromental degradation have increased the frequency and intensity of floods. For the greater concern, report by Department of Irrigation and Drainage Malaysia (2016), about 29,000 square kilometres or 9 percent of the total land of Malaysia and more than 4.8 million people are affected by flood every year.

Flood lead to harmful impact which refer to death, injuries, losses on livelihood, destruction of infrastructure, disruptions of economic activities and environmental damages. Based on Mohd, Daud, & Alias (2006), this harmful condition may lead to average anual flood damage as high as RM100 million and may increase in the future. In addition, as reported by Reliefweb (2016), the 2014 year end monsoon flood become the worst ever experienced by the Malaysia which affecting more than half million of victims in several states. The most affected state is Kelantan which affected more than 200,000 victims and caused thousands of houses were damaged. Moreover, damage to infrastructure systems alone was estimated at US670 million. The damaged infrastructure systems include electricity supply, water supply, sewage system, road and railway network, telephone and critical facilities (i.e. hospitals and shelters). Regarding to this matter, research finding by Said, Gapor, Samian, & Abd Malik (2013) found that damaged and insufficient of infrastructure systems impacted by flood has dramatically disrupted the livelihood in the affected areas. This finding was alligned with Opdyke, Javernick-Will, & Koschmann (2017) where infrastructure systems is not only represent significant financial investments, they also provide essential service to the community. Any disruption to infrastructure systems may create harmful impact to the affected communities.

Therefore, it is crucial to ensure the functionality of infrastructure systems during flood disaster events simultaneously reduce the impacts of disruption of livelihood of the community in flood-prone areas (Cutts, Wang, & Yu, 2015; Reiner & McElvaney, 2017). The significantly of functionality of infrastructure systems for community in flood-prone areas is align with the expected outcome of Sendai Framework for Disaster Risk Reduction 2015 – 2030 (UNISDR, 2015) which to reduce disaster risk and losses in lives, livelihoods and health and in the economic, physical, social, cultural and environmental assets of communities. The functionality of infrastructure systems for community can be achieved through enhancing resilience of infrastructure systems itself. 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"*. Therefore, it is crucial to enhance resilience of infrastructure systems in order to resist, absorb, accommodate, adapt to, transform and recover from the effects of flood in a timely and efficient manner. However, in way to achieve resilience infrastructure systems, it is required to fulfil certain criteria. Hence, the objective of this paper is to determine the most importance resilience criteria to enhance infrastructure systems in flood-prone areas specifically in Kelantan.

2 RESILIENCE CRITERIA

Based on the previous statement in Section 1, it is required to fulfil certain criteria in order to obtain resilience infrastructure systems. Through analysis on previous researches, authors have discovered the resilience criteria and sub-criteria to enhance resilience of infrastructure systems. The resilience criteria in this paper identified from 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 the purpose of this research; robustness, resourcefulness, rapidity and redundancy can be define as shown in Table 2 below:

Table 2 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 conditions exist that 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

Meanwhile, the sub-criteria to enhance infrastructure systems in this paper discovered through literature reviewed which covered several topics which are: 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 disaster itself, communities and cultural of each countries. 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 varies regarding 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 statement above, the authors seeks to determine the most importance 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 view in Table 3.

Table 3 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)

3 RESEARCH METHODOLOGY

The questionnaire survey method was utilised for this research based on resilience criteria (i.e. robustness, resourcefulness, rapidity and redundancy) as discussed in Section 2. Consequently, the 5-point Likert-scales (i.e. ranging from 1 "strongly disagree" to 5 "strongly agree") were adapted to measure the extent of importance of the resilience criteria. Moreover, respondents were asked to indicate the level of agreement on the importance of those factors and criteria. For the purpose of this research, the purposive sampling used based on respondents' experience towards floods disaster events. However, the selection was mainly focused on community in flood-prone areas in Kelantan. Based on study by Pour & Hashim (2016) and Syed Hussain & Ismail (2013), the flood-prone areas in Kelantan involving several district 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 these several districts which recognized as flood-prone areas in Kelantan. In addition, by referring to MERCY (2016), in term of disaster, community can be categorized into four (4) main groups: government, private sectors, learning institutions and communities. Thus, the survey was distributed to these several districts among four most important target groups.

A total of 100 questionnaires were distributed among the community in flood-prone areas in Kelantan over a month period (15th May 2018 – 14th June 2018). Out of this, only 31 questionnaires were completed which indicated response rate of 31 per cent. The low responses rates are caused by the data collection are still on-going for the purpose of 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 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 centers, schools) (n=7) and communities (i.e. head of communities, elderly, villagers, youth) (n=7). Then, the outcomes of the questionnaires were analysed by using IBM SPSS Statistics Version 22 for descriptive analysis.

4 FINDING

Table 4 represents the descriptive analysis of resilience criteria while

Table 5 represents the descriptive analysis of resilience sub-criteria to enhance resilience of infrastructure systems for community in flood-prone areas in Kelantan. In this section, the analysis deals with ranking of resilience criteria based on their mean values to determine the level of importance for each criterion.

Based on Table 4, the results revealed that *'robustness'* is the most importance 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 build new structures (mean=3.3871), the infrastructure systems would be more robust simultaneously enhance its resilience towards flood. This is in-line with Christodoulou, Fragiadakis, Agathokleous, & Xanthos (2018) where robustness can be seen as a major criteria 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 4, the importance of other resilience criteria (i.e. rapidity, resourcefulness and redundancy) towards resilience of infrastructure systems cannot be taken for granted. The overall mean values of 'rapidity', 'resourcefulness' and 'redundancy are not much differ from 'robustness' significantly indicate the importance of those criteria for resilience infrastructure systems for community in flood-prone areas in Kelantan.

Table 4 Resilience criteria

Resilience criteria	Resilience sub-criteria	N	Mean	Overall mean	Ranking
Robustness	*Corrective maintenance*	31	3.5161	3.4516	1
	Preventive maintenance	31	3.4516		
	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		
Resourcefulness	*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					

Meanwhile, as shown in
Table 5, 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 in a timely manner to address physical components disruption (Bruneau et al., 2004; Keating et al., 2014). Keating et al. (2014) and Oravec (2014) added, the ability to supply human resources is essential to enable restoration and reconstruction of damage infrastucture 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 of 23 resilience sub-criteria which show mean score above 3 indicate that they are also important to ensure the resilience of infrastructure systems for community in flood-prone areas in Kelantan.

Table 5 Resilience sub-criteria

Resilience criteria	N	Mean	Std. Deviation	Ranking
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				

5 CONCLUSIONS

Kelantan has been prone to flood in recent years. The flood has been negatively impacting the community which cause by devastation of infratructure systems. Though, this adverse impact can be significantly reduced by enhancing resilience of infrastructure systems. Enhancing resilience of infrastructure systems is crucial in the face of expected increase of the frequency and intensity of flood in the future. It can be done by focusing on the robustness of the infrastructure systems. A well-conduct corrective and preventive maintenace, implementation and enforcement of safe design, effective ugrading of material for insfrastructure systems and satisfactorily construction of new infrastructure systems including the availability of manpower to restore and reconstruct damaged infrastructure systems are believed can ensure the resilience of infrastructure systems during flood disaster events.

Moreover, the authors believed this paper provided an outcome which is: importance resilience criteria to enhance infrastructure systems in flood-prone areas specifically in Kelantan. The outcome revealed that 23 resilience criteria are rated ‘fairly agree’ by the respondents where *‘availability of manpower’* are ranked first. However, based on four (4) main resilience criteria: robustness, resourcefulness, rapidity and redundancy, ‘*robustness*’ are the most importance criteria to be implemented in order for better resilience.

Finally, even the number of respondents (n=31) is small for this paper, the results could not be discredited. The finding presented in this paper is a part of on-going PhD research study which is mainly aim to develop a framework of resilience infrastructure systems for community in flood-prone areas in Kelantan. Furthermore, the authors believe this study can serve as a platform for other researchers to launch 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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