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Relative Importance Index For Infrastructure Resilience Components For Flood-Prone Areas in Kelantan

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Abstract

Natural disasters have become more frequent and intense worldwide and have caused severe disruptions that have affected extensive lives and property losses to people in the affected areas. There is no exception for Malaysia, where the flood is the most catastrophic natural disaster to have struck this nation. Floods have caused massive damage and disruption to infrastructure resilience components such as energy and water supply, transportation and telecommunication systems, and critical facilities like hospitals and shelters, particularly in Kelantan. Thus, there is an extreme need for infrastructure resilience components to resist, absorb, accommodate, and recover from the effects of floods in a timely and efficient manner. This study aims to identify the most important infrastructure resilience components for flood-prone areas in Kelantan by using relative importance index analysis. The descriptive analysis used was the Relative Importance Index (RII), supported by mean analysis using IBM SPSS version 26 to identify the most important level of infrastructure resilience components. In addressing the research aim, this study identified the top five most important infrastructure resilience components: critical facilities, radio networks, television broadcasts, air transportation, and water supply systems.

Keywords: Disaster, Infrastructure, Resilience.

Introduction

Natural disasters are catastrophic events that occur due to natural processes. These disasters include earthquakes, hurricanes, floods, wildfires, tsunamis, and volcanic eruptions. They can happen suddenly and unpredictably, devastatingly impacting various aspects of human life, the environment, and economies. Natural disasters can result in the loss of human lives and cause injuries. For instance, between 2003 and 2023, natural disasters killed 1.385 million people, 6.631 million people were injured, 35.524 million were left homeless and 3.5 billion people were affected. In the meantime, the disaster-hit countries experienced direct economic losses valued at approximately USD 2.9 billion. In the Malaysian context, it is safe from severe natural disasters such as earthquakes, hurricanes, and volcanic eruptions, as it is outside the Pacific Ring of Fire. However, the Centre for Excellence in Disaster Management and Humanitarian Assistance (CFE-DM) noted that Malaysia is vulnerable to natural disasters such as floods, landslides, drought, forest fires and seismic activities (CFE-DM, 2019).

Consequently, Baharuddin et al. (2015) stated that floods are an annual incident of varying harshness on Peninsular Malaysia's east coast. Previously, communities in Mount Jerai (Gunung Jerai), Kedah, faced floods from the foothills on 18 August 2021. The heavy downpour caused water surges and landslides in Gunung Jerai, later hitting Yan, Kuala Muda, and Bandar Baharu districts with muddy floods. These locations were severely damaged. Damaged road access from the affected flood location hindered the response and rescue of the victims believed to have drowned and been swept away by the flood's strong current. The floods have affected approximately 4,395 people in the affected area of Yan district and 430 people in Kubang Pasu district (ReliefWeb, 2021). On 16 – 18 December 2021, Malaysia faced heavy and continuous rainfall, resulting in floods in eight states nationwide, affecting over 125,000 citizens. Selangor and Pahang states were reported as the two states that faced widespread flood damage. The Malaysian Reserve (2021) stated that Nanding Hulu Langat Selangor was the most affected area. Almost all the houses in the area were partially damaged, while about ten were destroyed. Most of the Nanding residents were just not prepared for the floods. The situation is unpredictable because the residents rarely face year-end floods (The Sun Daily, 2021). However, the 2014 flood was the most significant in Malaysian history, particularly Kelantan. It was considered a "tsunami-like disaster" in which over 230,000 flood victims were misplaced and caused USD 284 million in economic loss (CFE-DM, 2019). This flood was called "Bah Kuning" (yellow-coloured) because of its high mud content. At the end of December 2014, during the Kelantan flood disaster, 1,827 houses were washed away (Parlimen, 2015).

In addition, as stipulated by Irwin et al. (2016) and Lal et al. (2012), damage to the infrastructure and disruption to their services can have severe social and economic implications for the overall system. Other than that, to achieve a disaster-resilient community, the community and the infrastructures they rely on (energy, water and waste, transportation, telecommunication and buildings) must be adapted to withstand the future dynamic consequences of natural disasters while simultaneously addressing global sustainability measures defined by the United Nations across multiple goals, including Goal 9 regarding resilient infrastructure and Goal 11 regarding resilient cities and human settlements including Priorities 3 Sendai Framework for Disaster Risk Reduction 2015 – 2030 which to invest in disaster risk reduction for resilience and strengthen critical infrastructure in particular schools, hospitals and physical infrastructures (Chester et al., 2021; UNDP, 2022; UNISDR, 2015b). Therefore, this study aims to identify the most important infrastructure resilience components for flood-prone areas in Kelantan by using relative importance index analysis.

Resilience Infrastructure

The decade 2005 – 2015 (the Hyogo Framework for Action) and now 2015 – 2030 (the Sendai Framework for Disaster Risk Reduction) experienced increased attention to what affected people can do for them and how best to strengthen them in the light of disaster risks they face. Resilience, derived from the Latin "esali", which means to bounce back, has become an essential term in the language of many disciplines ranging from psychology to ecology (CARRI, 2013). However, UNISDR (2017) defines in the context of disasters resilience can be defined as the ability of a system, community, or society exposed to disasters to resist, absorb, accommodate and recover from its effects on time, including the preservation and restoration of its essential basic structures and functions. Inherent in the above definitions are the ideas of "vulnerable to" and "recover from" hazards and building and strengthening long-term resilience. However, resilience infrastructure can refer to developing and implementing energy, water, and waste, as well as transportation, communication, and building assets that can withstand, adapt to, and recover from various shocks and stresses. These shocks and stresses can include natural disasters such as earthquakes, hurricanes, floods, wildfires, tsunamis, and volcanic eruptions. The critical components of resilience infrastructure in this study were derived from the previous resilience framework, which highlighted the key components of infrastructure. The key components are then prioritized based on the literature reviewed and tabulated, as shown in Table 1. Key components of resilience infrastructure include:

1. Energy
   Resilient energy systems incorporate renewable energy sources, fuel supply and electrical distribution to ensure a continuous supply even during disruptions. This helps maintain essential services like hospitals, emergency response and communication.
2. Water and waste
   Ensuring clean water supply and sanitation facilities, especially during and after disasters, is crucial for public health. Resilience in this context involves building redundant water supply systems and improving wastewater treatment.
3. Transportation
   Resilient transportation systems focus on maintaining mobility during and after disasters. This can involve improving evacuation routes, flood-resistant road networks and efficient public transportation systems such as waterways, air and railway systems.
4. Telecommunication
   Telecommunication resilience refers to the ability of a telecommunications network, such as an internet connection, television broadcast, telephone and radio network, to maintain its functionality and continue providing services during and after disruptive events or adverse conditions. Ensuring resilience in telecommunication systems is crucial because they play a vital role in modern society, providing essential communication services for the community during and after disaster events.
5. Building
   This includes critical buildings such as hospitals, police and fire stations, and residential and commercial buildings designed and constructed to withstand various disasters. For example, buildings can be built to be earthquake-resistant or designed to handle increased flooding due to climate change.

Table 1
Infrastructure Resilience Key Components

Key components	Subcomponents
Energy	Sufficient electricity supply
	Enough fuel supply
	Acceptable renewable energy supply (i.e. solar, wind and biomass energy)
Water and waste	Plenty of water supply
	Appropriate wastewater management
	Proper solid waste management
Transportation	Accessible road network
	Accessible railway system
	Accessible air transportation system
	Accessible water transportation system
Telecommunication	Connection to internet
	Connection to the telephone network
	Connection to the radio network
	Connection to the television network
Building	Access to well-functioned critical facilities (i.e. healthcare facilities, police station and fire station)
	Access to conducive residential building (i.e. housing and shelters)
	Access to well-operated commercial buildings (i.e. retail store, bank and petrol station)

Research Methodology

The questionnaire survey method was utilized for this study. Thus, the 7-point Likert scales ranging from 1, "strongly disagree" to 7, "strongly agree", were adapted to measure the extent of the importance of infrastructure resilience components. Respondents were asked to indicate the level of agreement on the significance of those components. Purposive sampling was used for this study based on respondents' experience with flood disaster events. However, the selection was mainly focused on the community in flood-affected areas in identified districts in Kelantan. Based on Pour & Hashim (2016) and Syed Hussain & Ismail (2013), the flood-affected areas in Kelantan involving several districts such as Kota Bharu, Pasir Mas, Tumpat, Tanah Merah, Machang, Kuala Krai, Jeli and Gua Musang. These districts are located on several main rivers, including Sungai Kelantan, Sungai Lebir, Sungai Galas, and Sungai Pergau. Hence, the survey was distributed to several districts recognized as flood-affected areas in Kelantan. Besides, by referring to MERCY (2016), the community can be categorized into four (4) main groups: government, private sectors, learning institutions, and communities regarding the disaster. Thus, the survey was distributed among these districts' four most important target groups. The questionnaires' outcomes were then analyzed using IBM SPSS Statistics Version 26 for descriptive analysis.

The descriptive analysis was the Relative Importance Index (RII) supported by mean analysis. These two methods support each other due to existing arguments related to the mean analysis. Muniandy & Kasim (2019) statistically emphasized that the results of the mean analysis are still considered valid, with the condition value of standard deviation being positive. The mean score method is a simple and effective method of ranking relative importance, and it has been used in several built environment studies (Wang et al.,2018). Muniandy & Kasim (2019) suggested that a higher mean indicates the most influential factors in each circumstance.

The Relative Importance Index (RII) analysis was used to identify the importance level of infrastructure components as it is an appropriate tool to prioritize and rank the importance level of infrastructure components as rated in Likert-type scales questionnaires given to the respondents (Rooshdia et al., 2018; Yasmin et al., 2017). Based on previous studies, Adewunmi et al. (2012) used RII to identify important factors, while Ikediashi et al. (2014) used RII to analyze key drivers of sustainability research.

Sodangi et al. (2014) suggested that RII is one of the best and most widely used methods. They added that this method uses a weighted score to compare the relative importance of the elements for the research. RII can transfer the seven-point scale to relative importance indices for each element. The RII in this study was calculated using the following expression:

$$RII = \frac{\sum W}{(A \times N)}$$

Where:

RII : Relative Importance Index

W : The weight is given to each factor by the respondents from 1, 2, 3, 4, 5, 6 and 7, respectively.

A : is the highest weight (i.e., 7 in this study)

N : the total number of respondents

The importance level for RII can be interpreted as shown in Table 2. The highest ranking refers to the highest RII value. Waidyasekara et al. (2016) stated that a low RII indicates the factor is less applicable and relevant, whereas a high index indicates higher applicability, agreement and relevance. The individual numerical ratings of each identified variable from the Likert scale were then transformed into relative factors (Yasmin et al., 2017).

Table 2

Importance Level of RII

RII Values	**Importance Level**	
$0.8 \leq RII \leq 1$	High	H
$0.6 \leq RII \leq 0.8$	High-medium	H-M
$0.4 \leq RII \leq 0.6$	Medium	M
$0.2 \leq RII \leq 0.4$	Medium-Low	M-L
$0 \leq RII \leq 0.2$	Low	L

Finding

Table 3
Mean Scores and Relative Importance Index (RII) for Infrastructure Resilience Components

Ranking	Variables	N	Mean	Std. Deviation	Relative Importance Index (RII)	Importance Level	
1	Critical facilities (healthcare facilities, police and fire stations)	151	5.1258	1.10938	0.7323	High-medium	H-M
2	Radio network	151	4.8940	.98761	0.6991	High-medium	H-M
3	Television broadcast	151	4.8609	.99358	0.6944	High-medium	H-M
4	Air transportation	151	4.8411	1.12008	0.6916	High-medium	H-M
5	Water supply system	151	4.7881	1.03027	0.6840	High-medium	H-M
6	Residential (housing, shelters)	151	4.7881	.90634	0.6840	High-medium	H-M
7	Waterway system	151	4.6556	.86446	0.6651	High-medium	H-M
8	Electricity	151	4.5828	1.07924	0.6566	High-medium	H-M
9	Fuel	151	4.5762	.94824	0.6537	High-medium	H-M
10	Telephone network	151	4.5563	1.08711	0.6509	High-medium	H-M
11	Internet connection	151	4.5033	1.08243	0.6500	High-medium	H-M
12	Commercial (retail stores, bank or financial institutions and petrol stations)	151	4.3907	1.14876	0.6272	High-medium	H-M
13	Road network	151	4.1987	1.07095	0.5866	Medium	M
14	Railway system	151	4.0728	1.07765	0.5818	Medium	M
15	Wastewater	151	4.0397	1.01902	0.5771	Medium	M
16	Solid waste	151	3.9139	.91608	0.5591	Medium	M
17	Renewable energy	151	3.2252	1.11458	0.4607	Medium	M
	Valid N (listwise)	151					

Table 3 shows the Relative Importance Index (RII) for all infrastructure components, which ranges from 0.7323 (high-medium importance level) to 0.4607 (medium importance level). Based on the rank shown by the RII, twelve (12) infrastructure components were identified as high-medium importance levels, where the RII ranges from 0.7323 to 0.6272. Meanwhile, five (5) infrastructure components were identified as medium importance levels where the RII ranges from 0.5866 to 0.4607.

It is not surprising that the critical facilities are the most important infrastructure components to the communities in flood-prone areas in Kelantan (1^{st} = 5.1258). Even the entire healthcare facilities may not need to be fully operational, but essential functions such as operation theatre, emergency room and life support systems should be operational as other services are restored (Chacowry, 2014; Mcdaniels et al., 2008). Likewise, police and fire stations are critical as they provide critical equipment and support services during the response phase (Hamdan, 2015).

On the other hand, telecommunication plays a vital role in physical components. Before a disaster, radio (2^{nd} = 4.8940) and television broadcasts (3^{rd} = 4.8609) can play a critical role in notifying and sensitizing people on the importance of preparedness. Television shows like educational programs, edutainment, talk shows, and panel discussions regarding disaster events are crucial. It could enhance preparedness and preventive measures toward disasters. Media can also share important information on disaster risk before a disaster strikes and inform people what to do (Alias et al., 2020; Shaw et al., 2021). In the meantime, radio networks could get helpful information when emergency communication systems in many cities broke down because of power failures and lack of emergency backup power. In fact, about 20 emergency broadcasting stations dedicated to disseminating disaster information were set up in the Tohoku area during Japan's earthquake tsunamis in 2011. In the immediate aftermath of the disaster, these community radio stations began to provide information about times and locations to distribute emergency food, water, and goods (Ranghieri & Ishiwatari, 2012).

In addition, when disaster strikes, air transport (4^{th} = 4.8411) plays an essential role in assisting communities in times of disaster. It is often the only feasible mode of transportation for first responders and urgently needed relief supplies. Following catastrophes like floods, earthquakes, tsunamis, or hurricanes, most roads, rail tracks and even ports become unusable, as they are blocked for days by debris. Air transport is the most suitable means for disaster relief and rescue missions that have to be executed speedily, far distances, or in impassable areas (Schlumberger, 2015; Xu et al., 2015).

Moreover, as previous studies found by Atreya & Kunreuther, 2016, Bruneau et al., 2004 and Keating et al., 2014, a safe and sufficient water supply is crucial for human consumption and personal hygiene. Especially for disaster victims who have lost their houses and are in overcrowded shelters, providing enough safe water supply for consumption and adequate sanitation facilities is fundamental for safeguarding their health. Moreover, critical facilities like hospitals, residential buildings, and commercial buildings need to be cleaned before routine activities can resume, for which water is essential.

Conclusion

Earlier, this study highlights the impacts of natural disaster events worldwide, particularly in Malaysia. Even though Malaysia is located outside the Pacific Ring of Fire, it is still vulnerable to floods, which leave a remarkable impact on livelihood and are utterly devastating. Despite the fact floods are caused by nature and are inevitable, being prepared for those events

should be looked at thoroughly. As mentioned earlier, floods adversely affect physical components like energy and water supply, transportation and telecommunication systems, and critical facilities. However, this adverse effect can be significantly reduced by strengthening infrastructure systems' resilience in the face of future floods that are expected to increase. Thus, this study aims to identify the most important infrastructure resilience components for flood-prone areas in Kelantan. Then, the respondents' outcomes were analyzed using IBM SPSS Statistics Version 26 for descriptive analysis using relative importance index analysis (RII). It was found that twelve (12) infrastructure components were identified as high-medium importance levels, and five (5) infrastructure components were identified as medium importance levels. Later, this study identified the top five most important infrastructure resilience components: critical facilities, radio networks, television broadcasts, air transportation, and water supply systems.
The authors believe this paper has provided a general view of the importance of the infrastructure system's resilience towards flood. The most common and fundamental infrastructure systems resilience were reviewed and listed from the previous research. The authors believe it can serve as a platform for other researchers to launch into this field and find a way to strengthen the infrastructure system's resilience towards natural disasters in general.

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