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CRITICAL INFRASTRUCTURE (CI) PROTECTION FOR FLOOD RISK ASSESSMENT AND FLOOD VULNERABILITY INDEX IN SUNGAI PINANG, PULAU PINANG

Y F Wahab[a,d*], N E Alias[b,c], A Anuar[a], S Taib[b], K N Bashah[d], N Baslan[e]

[a]Malaysia Japan International Institute of Technology, Universiti Teknologi Malaysia, Kuala Lumpur
[b]Faculty of Civil Engineering, Faculty of Engineering, Universiti Teknologi Malaysia, 81310, UTM Johor Bahru Johor
[c]Centre for Environmental Sustainability and Water Security (IPASA), Research Institute for Sustainable Environment (RISE), Universiti Teknologi Malaysia, 81310, UTM Johor Bahru.
[d]Technology Development Sector, Construction Industry Development Board, Kuala Lumpur
[e]Centre of Built Environment, Construction Research Institute of Malaysia, Kuala Lumpur

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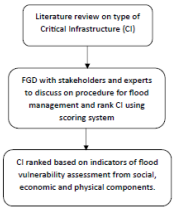
*Corresponding author
yusrinfaiz@gmail.com

Graphical abstract



Ranking of CI.

	No of FGD Panellist													
Indicator	1	2	3	4	5	6	7	8	9	10	11	12	Total	Rank
Residential areas	7	8	9	9	9	7	6	9	5	7	9	8	165	1
Institution and public facilities	7	7	7	9	9	7	9	8	8	5	9	9	160	2
Infrastructure and utilities	9	9	9	9	9	7	8	9	8	9	7	9	102	3
Transportation	9	9	9	9	9	6	7	9	8	8	8	9	100	4
Commercial areas	6	4	5	5	5	5	4	5	5	6	6	7	65	5
Open space and recreational areas	3	9	4	5	5	3	4	9	8	6	1	7	64	6
Industrial areas	6	5	6	1	1	6	5	5	6	1	5	5	58	7

Abstract

Infrastructure that is rated "critical" has a significant long-term impact on a large number of people when it fails. This study's objective is to rank Sungai Pinang's Critical Infrastructure (CI) for flood risk assessment and vulnerability index. According to the literature research, there are seven (7) indicators that are linked to CI, including industrial areas, infrastructure and utilities, institutions and public facilities, commercial areas, transportation, residential areas, and open space and recreational areas. Experts from local governments and technical agencies in the state of Pulau Pinang that are concerned with and related to CI ranked the indicators during the focus group discussion. The most significant degree of CI was used to order these indicators. According to the results, residential areas received the maximum score of 165 points. With a total score of 160, institutions and public buildings are the second-ranked indicator. Infrastructure and utilities, which are ranked third, received 102 points, while transportation, which is ranked fourth, received 100 points. The fifth-ranked indication is commercial areas (65 marks). Open space and recreational areas are the indicator that came in sixth (64 marks). Industrial area ranks last among the indicators (58 marks).

Keywords: critical infrastructure; flood; risk; vulnerability; focus group discussion

1.0 INTRODUCTION

Systems that physically connect metropolitan regions, neighbourhoods, and communities are referred to as infrastructure. They also make it easier for local, regional, and global economies to expand. Infrastructure may also be described as the basic facilities, services, and installations needed for the functioning of a community or society such as transportation and communications systems, water and power lines, and public institutions including schools, post offices and prisons. A community's health, safety, security, or economic well-being could be seriously harmed if CI, which comprises of physical and information technology facilities, networks, services, and assets, is interrupted or destroyed.

All networks and structures that are necessary for society to function both during flood occurrences and during the recovery period following one are referred to as CI. CI is considered 'critical' because an outage of the infrastructure has a serious effect on many people over a long period. CI is referred as a set of engineered systems, assets, and facilities that are essential for day-to-day societal functions as well as continued economic and

societal function following a disaster [1]. "Those infrastructure whose services are so critical that their disruption would have a substantial, long-term impact on the economy and society," according to the definition.

Energy supply, transportation, information and telecommunications, water, and solid waste systems are examples of physical CIs [2]. 'Crucial infrastructure' in Europe refers to a wide range of physical assets, functions, and systems that are critical to ensuring the health, wealth, and security of European citizens [3]. Existing transportation systems, renewable and non-renewable energy producing plants, industrial, water supply networks, and education and health infrastructure are all included in this description. Damage or destruction from extreme events, which are predicted to rise as a result of climate change, are the greatest dangers to infrastructure assets [4]. Seven indicators, including industrial area, infrastructure and utilities, institutions and public facilities, commercial area, transportation, residential area, and open space and recreational area, are associated to CI, according to the literature research that was conducted. This study's objective is to rank Sungai Pinang's CI for flood risk assessment and vulnerability index using the Focus Group Discussion (FGD) methodology.

2.0 ISSUES AND PROBLEM OF FLOOD MANAGEMENT

2.1 Pre-Flood Preparation

From the FGD, the relevant agencies are normally responsible to gather and disperse crucial information to the relevant authorities and citizens, especially to those in the affected flooding areas. This is especially important to manage the flooding situation even before it started. In addition to that, it is also informed that there is an Memorandum of Understanding (MOU) between the neighbouring states to extend flood aids to cross borders during the crisis. On flood monitoring, the process of monitoring vulnerable flooding areas are also parts of the flood management activities. Respondent iterated that, Pulau Pinang City Council (Planning Department) is responsible to identify and monitor areas vulnerable to flooding constantly using ArcGIS software applications. On another note, the same respondent also mentioned that his department is on constant monitoring of on-going development projects to curb flooding. It is also crucial to monitor existing projects since they might contribute to the flooding.

Some agencies are concerned with ways and methods to resist flooding effects by utilizing current approaches and practices within the development realm. In order to resist and reduce flooding occurrences, it is important to plan effectively, spatially. There is also an on-going effort to link recreational activities to the river to reduce flooding threats. Another approach is to integrate flood mitigation projects with sustainable (recreational) development, although it is still at an infancy stage. The use of appropriate construction materials would contribute to the flood resistance efforts as well. Buildings in flood prone areas should also be equipped with resistant building materials as alternatives to assessing cost of damages to the buildings. The SMART CITY concept is another approach that was brought up in the FGD. The use of such concept would prove to be useful to the monitoring of river and flooding situations. CCTV and Censors as aids for the authorities and public during flooding are among the effective mediums employed by the concept.

2.2 During And Post Flood

During the flood, one of the most frequent occurrences is the cutting off the supply of electricity to the affected areas which has caused recurring problems especially to the public. The electricity cut-off by TNB is necessary to avoid further difficulties due to the fact that most water and sewerage tanks are either shut-off or malfunction during flooding. The supply of water is also badly affected during and after the flooding. The forced closure of water tanks to avoid contamination would pose difficulties to all parties involved. Respondent from Pulau Pinang City Council (Engineering Department) stated that during flooding, the operation of pump houses is activated to replace the water tanks as temporary solutions to supply water to the affected areas.

During and post flooding pose yet another issue on the logistics of the operational procedures of the authorities. The police would normally be involved in preparing and making available safety boats to the rescuers while the city council would be preparing the transportation logistics and the opening of rescue centres. The agencies are also responsible for the welfare of the victims during and post flooding periods. Some affected occupants would normally be paid certain number of compensations to ease the difficulties. As preparation, one of the agencies, Indah Water Konsortium (IWK) is solely responsible for the cleaning and maintaining water and sewerage tanks which can be considered as a crucial operational component during and post flooding. Similarly, Suruhanjaya Perkhidmatan Air Negara (SPAN) is also responsible to prepare mobile/portable water tanks or water supply to the affected areas. These amenities are needed to compensate the closure and malfunction of water tanks. On the cleaning of wastes, the leftover garbage and wastes pose a big task to be fulfilled by the relevant agencies. Respondent from Pulau Pinang City Council (Services Department) revealed that the cleaning of wastes is a big part of their flood operations. In terms of health risks, the closure and malfunction of the water supplies during flooding pose some health threats to the public. The incoming of contaminated water into the water supply system would normally be considered as dangerous since it would be potentially spreading various kind of diseases.

3.0 METHODOLOGY

FGD method was used in this study to rate the ranking of CI. The purpose of the FGD i) to capture the SOP implementation of these agencies before and during the flood and to invoke their opinion on assessing the risk and vulnerability of Sungai Pinang in flood situations. Specifically, it is to relate issues brought about by flood management and monitoring to the river's risk of flooding and its vulnerability to flooding. Data and information are analyzed using transcribing techniques through keyword components of the discussions. The main component of flood management is the identification of issues and problems that would have arisen before, during and after the flood. It is

necessary for these issues to be dealt with to reduce the risk and vulnerability of the river to future flooding; ii) to rate the CI for flood risk assessments and flood vulnerability index in Sungai Pinang involving relevant professionals from local authorities, government agencies and industry. The agencies included:

Respondent 1: SPAN (Planning)
Respondent 2: MBPP
Respondent 3: MBPP
Respondent 4: PDRM SPU
Respondent 5: MBPP (Engineering)
Respondent 6: MBPP (Services)
Respondent 7: IWK (Planning)
Respondent 8: MBPP
Respondent 9: IWK

The ranking form of CI were developed and distributed to the respondents during the FGD. Below (Table 1) is the ranking form of CI.

Table 1. Ranking of CI form.

No	Indicator	1	2	3	4	5	6	7	8	9
1	Industrial areas									
2	Infrastructure and utilities									
3	Institution and public facilities									
4	Commercial areas									
5	Transportation									
6	Residential areas									
7	Open spaces and recreational areas									

4.0 RESULTS AND DISCUSSION

4.1 Flood Risk Assessment And Flood Vulnerability Index

Table 2 below shows the simplified matrix of impacts gathered by the FGD with the government agencies which is targeted to reveal their SOP implementation in pre-flood (before), during the flood and post-flood (after) to invoke their opinion on assessing the risk and vulnerability of Sungai Pinang in flood situations. The matrix is divided into several sections namely the issues/problems (in flood management), the respondent's responses, the outcome of the responses, the expected impact and its score.

Expected Impact/ Score:
1 = Low
1.5 = Low to Moderate
2.0 = Moderate
2.5 = Moderate to High
3.0 = High

The FGD discussions has generated 18 issues/problems that the agencies have had experiences in dealing with in previous floodings. Out of these issues, 15 are expected to have some positive impacts while 3 are negatives. The issues/problems that are being viewed as negative are those with costly implementation effects such as the cutting off of the electrical supply would surely be problematic to all involved. The cleaning process in post-flood situations would also prove to be costly not only to the authorities but also the public while the appearance of various diseases as a consequent of flooding cannot be taken lightly by all parties since it would be a serious threat to the public.

The matrix also shows that out of the Total Score of 54, the positive impacts is placed at 39 points/54 total points (or 72.2%) while the negative impacts is at 9 points/54 total points (or 16.8%). Thus, it can conclude that the FGD has shown that the expected positive impacts outweigh the negatives which means that the current ways of managing and monitoring flood situations (particularly within the Sg Pinang basin) commendable as they generate positive impacts.

Table 2. FGD Matrix.

Issues/Problems	Responses	Outcome	Score	Expected Impact
Pre-flood				
Flood Information				
-Informing all contingency parties prior and during flood	Respondent 1 SPAN	Moderate to High	2.5	
	Respondent 1 SPAN			Positive
-MOU of flood aids between neighbouring states		Moderate to High	2.5	
	Respondent 8 MBPP			Positive
Flood Monitoring	Respondent 2 MBPP			
-Identification of vulnerable flooding areas	Respondent 2 MBPP	High	3.0	
-Monitoring of on-going development projects				Positive
	Respondent 8 MBPP	Moderate to High	2.5	
-Preparation of temporary drainage systems by developers	Respondent 8 MBPP			Positive
		Low to Moderate	1.5	
Flood Resistance	Respondent 6 MBPP			Positive
-Linking of recreational activities and rivers				
-Integration of flood mitigations and sustainable development		Moderate	2.0	
				Positive
-Utilization of SMART CITY concept		High	3.0	
				Positive
		High	3.0	
During and post flood				
Physical amenities	Respondent 1 SPAN	High	3.0	Negative
-Electrical supply cut-off	Respondent 6 MBPP			
-Operation of pump houses as temporary water supply	Respondent 5 MBPP	Modetate to High	2.5	Positive
Operational procedures	Respondent 4 PDRM	High	3.0	Positive
-Preparation of safety boats	Respondent 2 MBPP	Moderate to High	2.5	Positive
-Compensation for the victims	Respondent 6 MBPP	High	3.0	Positive
-Transportation logistics	Respondent 6 MBPP	High	3.0	Positive
-Opening of rescue centre	Respondent 7 IWK	Moderate to High	2.5	Positive
-Maintenance of water tanks	Respondent 1 SPAN	Moderate to High	2.5	Positive
-Preparation of mobile/portable water supplies				
Cleaning wastes	Respondent 6 MBPP	High	3.0	Negative
-Cleaning of leftover solid wastes	Respondent 7 IWK			
Health risks				
-Contaminated water supplies and spreading of diseases	Respondent 6 MBPP	High	3.0	Negative

4.2 Ranking of CI and Indicator for Vulnerability Assessment

The health, safety, security, and economic well-being of communities may be seriously harmed if critical physical and information technology infrastructures, networks, services, and assets were disrupted or destroyed. All networks and structures necessary for society to function both during flood occurrences and during the recovery period following one are considered to be part of CI. When vital infrastructure goes down, it has a significant, long-lasting impact on a large number of people. According to the literature review that was done, there are seven indicators that are related to CI: industrial area, infrastructure and utilities, institution and public facilities, commercial area, transportation, residential area, and open space and recreational area. These seven indicators are related to CI in various ways.

Table 3. Ranking of CI.

	No of FGD Panellist													
Indicator	1	2	3	4	5	6	7	8	9	10	11	12	Total	Rank
Residential areas	7	8	9	9	9	7	6	9	5	7	9	8	165	1
Institution and public facilities	7	7	7	9	9	7	9	8	8	5	9	9	160	2
Infrastructure and utilities	9	9	9	9	9	7	8	9	8	9	7	9	102	3
Transportation	9	9	9	9	9	6	7	9	8	8	8	9	100	4
Commercial areas	6	4	5	5	5	5	4	5	5	6	6	7	65	5
Open space and recreational areas	3	9	4	5	5	3	4	9	8	6	1	7	64	6
Industrial areas	6	5	6	1	1	6	5	5	6	1	5	5	58	7

During the focus group discussion, experts from the state of Pulau Pinang's local governments and government organisations that are concerned with and related to CI ranked the indicators. These factors were sorted by the amount of CI that is considered to be the most crucial: residential areas, institutions, and public facilities, followed by infrastructure and utilities. 4. transportation 5) A business sector, 6) recreational area with open space, and 7) Industrial area (Refer Table 3).

Residential areas, which received the highest score of 165, is ranked first in terms of CI importance, according to the data. This is because residential areas are places where people live and inhabit. If there are any residential areas that are disrupted or damaged, this could lead to further detrimental consequences. Damage to residential areas during flooding can cause people to face losses for their respective properties. In addition to this, residential areas also have a strong relationship with society and communities. Flooding can cause negative effects on residential area mainly by the virtue of people residing within these areas.

Institutions and public facilities, which received a total of 160 marks, are the second-ranked indication. This is because some of the educational institutions also act as a food supply collection centre and flood victims' relocation centre. This clearly demonstrates the importance of institutions and public facilities during flooding events.

Infrastructure and utilities are the third-ranked indicator, scoring 102 points. This is mainly due to the fact that loss of power supply can seriously impede the health service of an entire urban community.

The fourth-ranked indicator, transportation, is listed after this and has a score of 100 points. Disruptions to public transportation systems and infrastructure may hamper relief efforts to the affected areas which in turn may cause more inconveniences to the displaced communities.

With a score of 65 points, commercial areas are rated fifth among all the indicators. These areas may not be as significant as the residential areas as these commercial areas are only populated during office hours and are not inhabited continuously. The cascading effects of flood to these areas are not as critical when compared to the other higher ranked indicators.

Open space and recreational spaces, which had a score of 64, placed sixth among the indicators. The lower place ranking of this indicator is mainly due to the fact that these areas are not utilized on a permanent basis but rather more for temporary activities within the communities. These areas also do not have much high value assets that may be damaged by floods. Industrial area, which received a score of 58, is the indicator that received the lowest ranking. During flooding events, industrial areas are usually less affected or damaged. While it is still vital that industrial areas are also protected during floods, the total loss of CI aspects may be less than the other more critical areas.

5.0 CONCLUSION

In conclusion, when compared to the indirect effects of their outage, direct losses to the infrastructure are insignificant. More important than damage to the cables and power utility stations themselves are the indirect effects, including lost income from an electricity outage, deaths in hospitals brought on by communication breakdowns, loss of property in residential areas, damaged roads, or interruptions in electricity service. Furthermore, when assessing CI, the secondary effects of outage outside of the flooded areas as well as the interdependencies and cascading effects to other sectors are relevant and significant. Failure of the power grid for example, may affect a wide range of other infrastructure, for instance water supply and information technology. Vulnerability assessments need to determine the consequences and damages of such interdependencies.

The FGD involving relevant experts from local authorities and government agencies were responsible in ranking the CI and indicators of vulnerability assessment. The purpose of the ranking is to give priority among all indicators in terms of the levels of importance during floods. This will ensure that the recovery and relief process on the CI could be conducted based on the levels of importance of the indicators. This will further ensure the surrounding areas during floods will be considered and taken care of in the most effective manner possible.

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