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Research paper

Flood Risk on Hospital Utility and Mitigation Measures

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Abstract

Malaysia is geographically located outside of the Pacific fire circle that is free of any incidents and property destroyed by natural disaster such as hurricanes, earthquakes and volcanic eruptions. However, Malaysia is also vulnerable to natural disasters such as floods, landslides and haze. In Malaysia, flood is one of the most frequent catastrophic disasters that have caused major damage to property and loss of life. The floods in 2014 had a significant impact on the hospital, especially in Kelantan, Malaysia. Flooding of hospital result in interruption of utilities supplies such as water, electrical power, fuel and medical gas. This paper try to explore major and potential challenges faced by the operation of hospital specifically related to utilities supplies and reduce flood risk of the hospital utilities supplies through the best measures. From the discussion, the risk of floods especially on the supply utilities hospitals can be mitigated through the best identified measures as well as can maintain the daily hospital treatment of patients, particularly ill patients.

Keywords: *(flood impact) (hospital utilities supplies) (reduce risk)*

1. Introduction

The impacts of natural disaster not only affect humans and property, but also affect the services and activities of industry and society [1]. Malaysia is geographically located outside of the Pacific Circle of Fire which is free of any incidents and property destroyed by natural disasters such as earthquakes, hurricanes and volcanic eruptions. However, Malaysia is also vulnerable to natural disaster such as floods, landslides and severe haze [2]. Annually in Malaysia, disasters such as floods contribute to the total number of victims, disease outbreaks, property and plant damage and other significant losses [3]. Among the most high-impact risk is the risk of floods that is common in Asian countries. The source of floods is caused by natural factors such as heavy rain, high tide, etc., and human factors such as improper use of land, deforestation in river basin and drainage channel blocking. Malaysia have recorded several big floods such as in 1886, 1926, 1931, 1947, 1954, 1957, 1970/1971, 1988, 1993, 1996, 2000, 2006/2007, 2008, 2009, 2010 and 2014. The flood scene named as a storm forest flood has destroyed hundreds of square kilometer of forest in the lowlands of the Kelantan and Besut rivers. Records show that the flood was accompanied by strong winds [4]. The flood that occurred in December 2006 in Johor, Malaysia has affected more than 100,000 people and has been transferred to more than 100 flood relief center [5].

Flooding that occurred in late 2014, is the worst flood recorded in Malaysia especially in Kelantan. A total of 202,000 victims affected by floods and had to be evacuated and also caused widespread collapse of public infrastructure [6 ,7]. The floods in Kelantan 2014 also affect hospital services such as Hospital Raja Perempuan Zainab II (HRPZ II), Hospital Kuala Krai (HKK), Hospital Pasir Mas (HPM), Hospital Gua Musang (HGM) and Hospital Tanah Merah (HTM) [8]. The hospital services are disrupted due to loss of electricity, lack of fuel supply to drive generators, lack of medical gas supply and lack of clean water supply. As a result of this disruption has affected the critical patients and had to be transferred to another hospital [9].

Hospitals are among the most important institutions where it provides high quality medical and treatment facilities to inpatients and outpatients [10]. Besides, hospital also becomes a major reference center that provides diagnostic and treatment services. The hospital buildings is equipped with modern building facilities and state-of-the-art medical equipment as well as involving professional staff to provide medical services and treatments to patients [11]. The sudden-onset flood has caused significant pressure on local communities and public health utility [12]. Utility failure can be driven by disaster intensity or by vulnerability. One of the major characteristic of healthcare facilities is that they are highly depend systems such as critical infrastructure [13].Hospital dependence on critical infrastructure such as gas, electricity and water has been found to be a major risk during extreme weather events as they may also experience serious disruptions [14]. Utility plays an important role in the continuation of medical services such as ensuring continuity of care especially in critical areas, equipment supply, maintaining environmental quality of enclosures and connecting facilities with external [13]. Within this context, the purpose of this paper is to explore major and potential challenges faced by the operation of hospital specifically related to utilities supplies and reduce flood risk of the hospital utilities supplies through the best measures. This article presents a literature review for addressing critical challenges that could mitigate the risk of flood disaster on utilities supply hospital.

2. Flood Risk on Hospital Utility

2.1. Challenges Facing Utility Supplies

Natural disasters can cause death and costly [15]. During the period 1900-2010, there was an increase of five times the number of reported natural disasters. Despite the gradual decline in the number of deaths, the number of reported persons affected has in-

creased rapidly in the last 40-50 years, an average of over 300 million in 2010. At global level, the frequency and magnitude of hazards associated with weather and climate are increasing, with floods being the most frequency disaster and affected most people [16]. From December 2010 to January 2011, a series flood hit Queensland in Australia where three quarters of the nation has been declared a disaster zone with more than 2.5 million people affected. Thirty-five people died, 29,000 homes and businesses suffered losses and floods ravaged an estimated budget of more than $ 5 billion [17].

Similarly, the Midwest floods of 2008 in the United States is regarded as one of the worst floods that caused extensive damage in the towns and cities in Iowa, Illinois, Missouri and Indiana, Although the major floods in the summer of 2008 triggered by heavy rain, one of the main reasons is the widespread damage to infrastructure such as drainage failure ruptured along the river, damaging bridges and roads, power plants, water and wastewater plants [18]. The healthcare infrastructure for the community not only its hospital but involve many related facilities such as community health center, primary care clinics, aged care center and rural nursing post. These facilities form a complex network of relationships that needs to work collectively to respond effectively to climate change in extreme weather such as floods and storm [19]. Flooding of health facilities resulting business interruption, increased patient, loss of utility supplies such as water, electricity, fuel and medical gas [20]. Loss of utility supplies can cause increasing difficulties in providing medical care and routine care for patients suffering from chronic diseases, such as diabetes, kidney failure, cystic fibrosis, cancer and mental illness [21]. There are many case study show disruption of utility affect medical services [22]. For example, Typhoon Nari hit the northern of Taiwan on the night of 16 September 2001 caused the healthcare system in Taipei to be badly damaged. Power backup cannot be used as storm water flooded the hospital's basement and caused limited power supply to the critical care unit, operating room and laboratory equipment is essential [23]. In United Kingdom, many of power stations are located in vulnerable areas such as the Dungeness power plant, which is built few meters above sea level on an unstable geological formation. The hundreds of power substations and water treatment plants that have been built in floodplain area where some of this infrastructure have higher probability to failure during recent events for example the Ulley reservoir (built in 1871) and the Walham substation during the 2007 summer floods [13].

Flooding that occurred in 2007 in New South Wales Hunter Valley has resulted in power outage in Morriset Hospital for nearly two days [24]. Floods at Gloucestershire Hospital in United Kingdom have disrupted medical operations due to water pollution [13]. Similarly, floods in the USA have caused hospital in Iowa loss of water supply and almost all phases of patients care and facilities have been affected [25]. In early 2011, transfers had to be made at both of the Cairns Base and Private Cairns hospitals for Cyclone encounters and this is an example of a graphic extension regarding pressure on facilities caused by extreme weather events [19]. Another vivid example of the vulnerability of healthcare infrastructure to extreme weather events are the floods that caused by Hurricane Katrina in New Orleans and in the UK were severely affected the health infrastructure built in flood-prone areas. According Carthey [26], the impact on the destruction of healthcare is of paramount importance which may be the most difficult to reduce. This is because almost two years after the floods only one of seven public hospitals in the city operates at a pre-hurricane level, the other two are partially open and four are closed. The impact on the destruction of healthcare has become the major factor that prevents the rise of the New Orleans' economy. The effects of the floods showed that the most affected group in society is made up of the poor, the elderly and critically ill patients.

In Malaysia, during the floods in 1995 and 2010, the Emergency Department of Hospital Kuala Lumpur and Hospital Kangar were flooded that cause disruption to hospital services. Similarly, the Hospital Alor Star patients need to be transferred to other hospitals due to lack of water supply and loss of electric power [27]. Besides, floods in 2014 have affected the daily operation of hospitals especially in Kelantan such as Hospital Raja Perempuan Zainab II (HRPZ II) and Hospital Kuala Krai (HKK) [28]. It is considered a "tsunami like
disaster" where 202,000 victims have been evacuated and the collapse of public infrastructure [6]. HRPZ II was the worst affected, since HRPZ II had to stop 80% of the services due the influx of flood water into the hospital and 200 patients had to be transferred to another hospital [8]. Loss of electricity and lack of medical gas supply have caused critical patients in HKK to be transferred to another hospital. This is because the hospital services are interrupted because the generator cannot be functioned due to lack of fuel supply. The increase in the number of flood victims in HKK caused shortages of medicine, clean water and food [9].

3. Mitigation Measures Floods Risk on Hospital Utility

The paper is written based on an overview of literature from journal, articles, newspaper, book and report that focuses in Malaysia and international experiences regarding floods risk on hospital utility and mitigation measures. Critical infrastructure failure is closely related to critical infrastructure condition. The majority of infrastructure across the United States has been weakened due to aging and declining conditions that make them vulnerable to natural disasters. The American Society of Civil Engineers (ASCE) 2009 Report Card for infrastructure provides average D grade US infrastructure which signifies the need for immediate recovery [18].

There a few studies that have been made relating to the infrastructure of disaster risk reduction. For example, in study by Rinaldi, Peerenboom, & Kelly [29], has proposed a framework that has included six dimensions, type of failures, operating conditions, infrastructure characteristics, the environment, the coupling reaction, the types of relationship of interdependence and behavior to determine the mutual relationship between the infrastructures. Loosemore *et al.* [30,31] exploring Extreme Weather Event (EWE) from a hospital risk management perspectives and Repository, Wales, & Manuscript [32] , explores inter-agency risk to address response hospital to EWE in Australia. While, Carthey [26], explore healthcare endurance strategies at two major hospitals in the Taiwan and UK using semi-structured interviews with emergency officers to explain the strategies preparation to respond to emergencies. Achour *et al.* [13], also explore the key challenges and potential facing health care facilities operating in particular with regard to the supply of utilities in their paper "hospital resilience to natural hazards: classification and performance of utilities". Their finding show that expected to raise awareness of important utility play for the operation of healthcare facilities that potentially lead to improved code and endurance laws. The findings are also expected to compose literature with more information on the availability of healthcare publishing resources. Hiete *et al.* [14], investigates the impact of power outages at hospital in Germany using a qualitative and empirical research approach. The infrastructure network is a highly integrated system that maintains a wide range of community and industry activities and services [18]. In addition, Espada *et al*. [17], presents new approach that examine the vulnerability and critical infrastructure interdepended that uses network theory in the geographic information system (GIS) with a combination of literature and government reports. In study of McGeorge et al. [19], tilted "Modeling the impact of extreme weather events on healthcare infrastructure using rich picture diagrams" has develop a conceptual understanding of the dynamic relationships of hospital facilities before, during and after an extreme weather event. This is an important step in building a sys-

tem model that will help facility managers retain critical healthcare structural method. Rich Picture Diagrams (RPDs) were used to map relationship between critical healthcare infrastructure components such as the base hospital, aged care facilities, remotely located supplies and access roads. The main findings of this research are RPD that has great potential in the development of a soft system model that will help decision makers engage in the design and management of healthcare infrastructure especially in the context of extreme weather event. While Menne & Murray [21], has been developing a framework to manage flood risk with a range of interventions and measures to reduce the impact of human health where this framework addresses primary, secondary and tertiary prevention in their paper titled "Floods in the WHO European Region: health effects and their prevention". While Federal Emergency Management Agency (FEMA) [33], suggests ways to reduce the risk of floods to critical facilities is to relocate critical facilities outside flood plain areas. Study by Plate [34] and Chan [2], suggested selections the best measures to reduce the impact of floods must be considered both of structural and non-structural method.

4. Discussion

The infrastructure network is a highly integrated system that maintains a wide range of community and industry activities and services. Disaster such as floods leads to failure of critical infrastructure ruins, which affect the activities that depend on the infrastructure [18]. The utility failure also impact on the continuity of healthcare services due to external or internal utility system damage. Healthcare is often regarded as a network of buildings and services that collaborate in an efficient manner to provide the public services to community. Healthcare also is one of the most complicated and critical emergency response sources in any country. This is because healthcare has a special importance as a center for handling a large number of injuries that are usually associated with large-scale disasters [35]. Healthcare is usually dependent on the building (e. g. utilities, structural and architectural elements), medical supplies and space, equipment, staff adequacy and availability easy access (e. g. roads). Any damage or interruptions on any of these elements will directly or indirectly affect the continuity of the medical service. Hospital and healthcare also play a major role in public health laboratories, medical precautions and health research centers [36].

Lessons learned from the summer 2007 flooding experiences, disruption of utility supplies including pollution and lack of water supply (no alternative sources), lack of electricity, telecommunications and cancellation of medical services highlight some of the weaknesses faced by most hospitals[35]. The main problem in responding to these challenges is that most health facilities are not built with risks associated with climate change in mind and new design and customization strategies may be needed to ensure that the health infrastructure itself does not pose a risk to effective delivery of health services to residents during extreme weather events. Indeed, numerous studies on climate change emphasize that both mitigation and adaptation strategies are needed to address the effects of climate change that now seem unavoidable regardless of the extent to which mitigation is higher priority. For example, the United Nations Framework Convention on Climate Change (UNFCCC) 2006 state that, until recently, policy makers were focused on reductions, partly because of the concerns that highlight the customization options might reduce immediate for mitigation where mitigation and adaption are not alternative, but both need to be actively pursued and parallel [26]. According to Achour *et al.* [13], to reduce the vulnerability of healthcare utility supply need for a comprehensive strategy for utility resilience such as improving the resilience of utility infrastructure from flood risk and improving of performance of alternative sources.

4.1. Resilience of Utility Infrastructure

Floods have disrupted the healthcare system [12]. In the context of climate change that corresponds to the frequency and severity of the disaster, the development of resilient health facilities such as hospital is urgently needed [37]. Resilient health system is one descriptive approach refers to the ability of various institutions, stakeholders, health populations to prepare and respond effectively to the crisis which maintains primary function in times of disaster, experience during the crisis, and use such knowledge to adapt to changing circumstances [38]. The big challenge for implementing this recommendation is the availability of space analysis tool that will help governments, industry and the public to prepare and adapt to climate risks and enhance the resilience of critical infrastructure [17]. Improving resilience of utility requires significant financial. However the on-going financial crisis will make this major challenge and perhaps will require more efficient and effective strategies [13]. For example most hospital are built on floodplains where floods can put pressure on structures that can cause the building to collapse and flood water can damage equipment and services (often located in basements which are prone to flooding) [39]. Several measures could prevent this damage or disruption such as relocating the hospital outside floodplain, relocating the important medical equipment (lifeline) to above grade level flood [20]. Some hospitals dependent on fuel supply to drive the generator. Therefore the supply of fuel should be sufficiently prepared for emergency especially flood. Similarly for the clean water supply must prepare sufficiently. This is because the electricity and water supply is essential utilities [9] . Hospital need to ensure they can provide water and fuel system for the first 72 hours of flooding [23]. In addition, the hospital also needs to upgrade the fuel and water storage on site [20]. The infrastructure Institution of Civil Engineering (ICE) (2010) stated the apparent shortcomings in the country's critical assets is partly due to the lack of integration and collaboration between sectors [13]. Therefore, hospital needs to have good collaboration with other sectors such as fire and rescue departments, water departments and others to get effective and timely assistance [7].

4.1. Performance of Alternative Resources

International organisations such as WHO and PAHO suggest that healthcare facilities have alternative suppliers and duplicate items to provide certain levels of independence from external supply networks [36]. As a result, many hospitals have been equipped with an alternative supply system, which enhances durability and ensures the continuity of healthcare. There are many alternative sources, but the most widely used is the Uninterruptible power supply (UPS) system and the power generator. The UPS system has been used in many facilities around the world (for example in Milton Keynes General Hospital and Matto Public Hospital in Japan). They are charged with commercial power or fuel power generators [13]. Power generator performances have been a major issue in hospital for decades, for example Jones and Mar (1945) states that generator which operating problems are largely due to unsatisfactory cooling. Kobe University Medical College and Hyogo Medical Center not able to use their power generator for fear of overheating as the cooling system relies in the damaged water supply at both facilities. Mechanical failures and dependency on critical infrastructure is element that affects the performance of alternative sources [13]. Therefore, periodic maintenance and testing plays an important role in ensuring the essential equipment such as generator works well especially during emergency [30]. Besides, adoption of less dependent system such as air-cooled power generators could avoid mechanical failure of generator [13].

5. Conclusion

The importance of healthcare infrastructure lies in the essential service they provide all the time. However, their complexity and dependency on external infrastructure make them vulnerable especially in floods. Experience demonstrated that infrastructure have been affected by the increasing number of hazards due to the changing climate such as floods disaster. To reduce these vulnerability, many hospital equipped with an alternative source which aims to provide the necessary supplies especially during an emergency. However, the alternative equipment provided cannot be implemented as expected due to mechanical failure or their dependence on other supplies. It is important to ensure the continuity of hospital services especially during emergency. This is because hospital should always provide their health services especially to critical patients. In order to ensure continuity of hospital services, a study on hospital utilities supplies need to be done to identify the best measures to mitigate flood risk. From the discussion, the risk of floods especially on the hospital utilities supplies can be mitigated through the best identified measures so that hospital could maintain the daily treatment of patients, particularly critical patients. Suggested form study by Achour et al. (2014), developing the right strategy could be the most significant step towards the resilience of healthcare facilities such as improving the resilience of utility infrastructure to natural hazard and improving the performance of alternative sources. This suggestion could be used by researchers as a reference for the studies conducted.

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