A Conceptual Framework of Predictive Analytics Solution for Urban Flood Pattern Occurrences in Kuala Lumpur

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Abstract

Urban flood is a global issue. As the capital city of Malaysia, Kuala Lumpur is one of the city in the world, where a series of occurrences of urban flood have been recorded over the past years. Since the era of Big Data, the possibility to analyse complex data coming from heterogeneous sources to predict and do flood forecasting has been given a different perspective and hope for another way to minimize the impact of flood, especially in urban area. Big Data Analytics (BDA) is one of the key enabler technologies in Malaysia National Policy Revolution Industry 4.0(4iR), hence, urban flood prediction can provide greater value to the Malaysian Government in order to create sustainable development environment for the Malaysian Citizen.

Keywords: *flood prediction, flood pattern, Big Data, urban flood, Kuala Lumpur*

1. Introduction

Urban flood is a global issue. As the capital city of Malaysia, Kuala Lumpur is one of the city in the world, where a series of occurrences of urban flood have been recorded over the past years. Between 1965 to 2016, there are 76 cases of natural disasters recorded in Malaysia including landslide, epidemic, tsunami, mudflows, storm, wildfire and half of that case is related to flood. The impact of the recorded flood includes damage to properties, disruption in social activities and transportation systems, losses in businesses and household assets. Concerned by the impact, in 1971, Federal Government of Malaysia established a Permanent Commission under Flood Control to cope with the issue. The Head of the Commission is Ministry of Agriculture and Department of Irrigation & Drainage (DID) or JPS has been given the mandate to carry out the flood mitigation works (Loi, 1996).

The flood mitigation works involve both structural and non-structural efforts. Structural measures include channel improvement, pumping, flood bypass, flood storage dam, flood detention basins and related works. While, non-structural measures include flood forecasting and warning, flood zoning, flood risk mapping and flood resettlement of the affected population (Jha, Bloch, & Lamond, 2012).

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However due to the complexity of the flood mitigation measures itself, it requires massive studies from many different angles (Bubeck, Botzen, & Aerts, 2012; Tasseff, Bent, & Van Hentenryck, 2019).

Since the era of Big Data, the possibility to analyze complex data coming from heterogeneous sources to predict and do flood forecasting has been given a different perspective and hope for another way to minimize the impact of flood, especially in urban area. Realizing the great benefits of big data analytics in urban flood prediction, this paper aims to discover the issue and cause of the problem, and how big data analytics can be utilized as one of the solutions. Subsequently this will provide greater value to the Malaysian Government in creating a sustainable development environment for the Malaysian Citizen.

2. Research Background

Urban flood is an issue faced by major cities around the world. An urban flood occurs because of a complex combination of meteorological and hydrological extremes, such as extreme precipitation and flows. An urban flood can also be the result of human activities, including unplanned growth and development in floodplains, or from the breach of a dam or an embankment that has failed to protect planned developments (Jha et al., 2012). Among urban flood cases reported were in Wuhan City, China (Cheng, Han, Zhao, & Li, 2019), Turkey (Kumcu), Tanzania (Sakijege, 2019), Sri Lanka, Thailand and Japan (Komolafe, Herath, Avtar, & Vuillaume, 2019)

Urban areas can be flooded by rivers, coastal floods, pluvial and groundwater floods, and artificial system failures. These multiple and complex contributing factors making it the most difficult to predict and the most expensive to recover (compared to rural flood) whenever it occurs (Jha et al., 2012). Urban flood is also a type of natural disaster, can be categorized as external risk, a risk beyond human control and requires a different analytic approach because the probability of occurrence is difficult to foresee by normal approach and strategy(Kaplan & Mikes, 2012).

In Kuala Lumpur, the urban flood is not a strange phenomenon anymore. The vibrant and developing Kuala Lumpur is situated near the confluence of Klang and Gombak River. The rapid urbanization led to a loss of open space and forested land, reducing flood plain, gradual canalization of the rivers and this has led to runoff and peak flow resulting in the increase of flood occurrences in the city (Seang, 2009).

Recently, the urban flood is has become a growing a serious natural disaster. The impact of the urban flood can be catastrophic damage to the local economy. Hence, a quick and efficient disaster management flood mitigation measures have been programmed to cater this issue. Flood mitigation is a site-specific discipline, institutionalized through local governments and founded on integrated, multidisciplinary consideration of various concepts, measures, and technique. It aims towards flooding control solutions that satisfy the requirements of environmental and economic sustainability (Bubeck et al., 2012). It requires public participation based on the ongoing development of public awareness as well as on the evaluation of the past experience. This includes structural measures such as preservation of unsealed areas, preservation of natural ponds, inducing groundwater recharge and greening of unsealed areas (Kryžanowski, Brilly, Rusjan, & Schnabl, 2014); meanwhile for non-structural measures includes district plan, land use control, water circulation plan, open area preservation and green buffer and zone development (Kang, Lee, & Lee, 2009).

Disaster Management is characterized by complexity, urgency, and uncertainty. It is crucial for participating organizations to have a fast though smooth and effective decision-making process (Kapucu & Garayev, 2011). Decision making related to natural disaster should be fast and in timely manner. However, for the government this could be the opposite due to complexity of parties involves. The multi-layers of government agencies governance seems to hinder the quick action to be taken (Gang-Hoon Kim, 2014). This may result in huge losses, slow search and rescue efforts and making it harder to recover in the impacted area.

Fast forward to 2014, Malaysia Government has given a mandate to Malaysian Administrative Modernization and Management Planning Unit (MAMPU) to lead the Public Sector Big Data Analytics initiatives. This has given a space to explore the opportunities of big data analytics implementation on natural disaster management and prevention. The previous study also has suggested the untapped area on the utilization of big data analytics in flood disaster domain (Zakaria & Rashid, 2017). This is also in line with Malaysia National Policy on Industry 4.0 (Industry4WRD) which was introduced in 2018 by the Ministry of International Trade and Industry (MITI), Big Data Analytics has become one of the enabling technologies listed in the policy. This positive national strategy alignment can be exploited by providing a holistic approach in predicting urban flash flood in the era of Big Data and Industry 4.0.

3. Research Methodology

In order to identify the root causes of the urban flood in Kuala Lumpur, this study performs a literature analysis based on the Ishikawa diagram. It is a fishbone diagram, also called a cause and effect diagram is a visualization tool for categorizing the potential causes of a problem in order to identify its root causes (Ishikawa, 1990). The Ishikawa diagram is proved to be one of the effective methods to understand the issues from multiple perspectives and has been applied in similar natural disaster study by (Nygård & Broen, 2018). Figure 1 shows the Ishikawa diagram

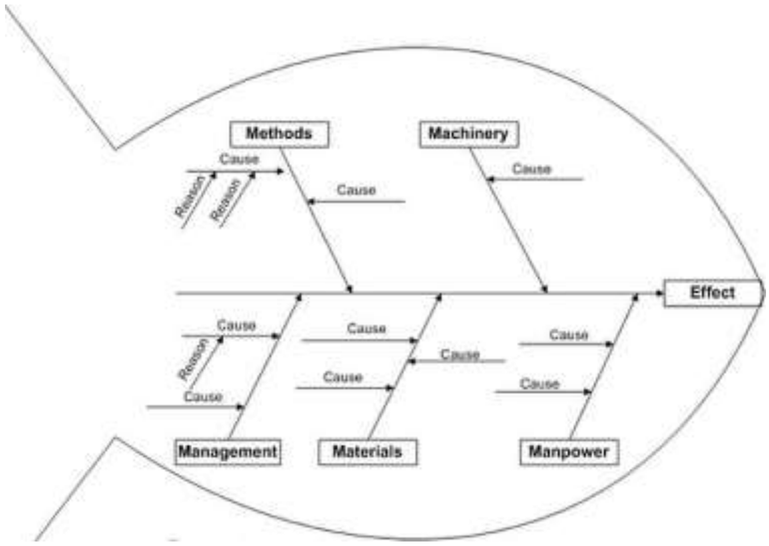

Figure 1: The Ishikawa Diagram (Ishikawa, 1990)

To suit with the flood mitigation issues, this study adapted the diagram and introduced new categories namely process, technology, economic, people and social which is formed while doing the literature analysis. Alongside it, this study applied the 5W1H Method in order to have a clear picture of how to tackle this issue. 5W1H (who, what, where, when, why, how) is a method of asking questions about a process or a problem taken up for improvement. Four of the W's (who, what, where, when) and the one H is used to comprehend for details, analyze inferences and judgment to get to the fundamental facts and guide statements to get to the abstraction. The detailed results are discussed in the following section.

4. Findings and Analysis

Many researchers have done significant work on predicting and trend analysis of flood occurrences. With the availability to analyze complex data and better computing power technology in the era of Big Data Analytics, more analysis is expected to be done and perfecting the previous work which is not possible using traditional data processing. From the literature, there is a very close relationship between floods, and rapid development and urbanization (Sani & Rindam, 2011). If development processes are not done in a sustainable approach, it would result in higher likelihood for flood occurrences. For the purpose of flood forecasting and river monitoring in the Klang Valley, the Department of Irrigation & Drainage (DID) has developed the Integrated Flood Forecasting and River Monitoring System (IFFRM).

By analyzing trend using time series and historical data provided by DID, correlation of the amount of rainfall and number of flood incidents can be studied and the results showed a weak relationship between amount of rainfall and number of flood incidents. This study indicates that flood incidents do not happen just because of rainfall. There are also other contributing factors such as tidal rivers, climate change, temperature, altitude, drainage and terrain changes(Mohamed, Ismail, Ismail, Adnan, & Raji, 2014).

Not only that, advancement in the tool to analyze complex data such as hydroclimate data can accelerate the process of data computation (Abdullah, Ibrahim, & Zulkifli, 2017). The advancement of technology of big data analytics has also accelerated in early prediction of flood. From 5 hours of early flood prediction to 3 hours earlier water level prediction using the same algorithm Neural Network Autoregressive with Exogenous Input (NNARX) Structure can be made(Adnan, Samad, Zain, & Ruslan, 2014) (Ruslan, Samad, & Adnan, 2015) and by using big data analytics advanced analysis from collection of data sources like sensors or satellite data can make the process of prediction faster, thus, provide a timely information to the related parties for further action and implementation plan strategy execution.

The analysis is shown in the Ishikawa Diagram as per Figure 2 and Table 1.

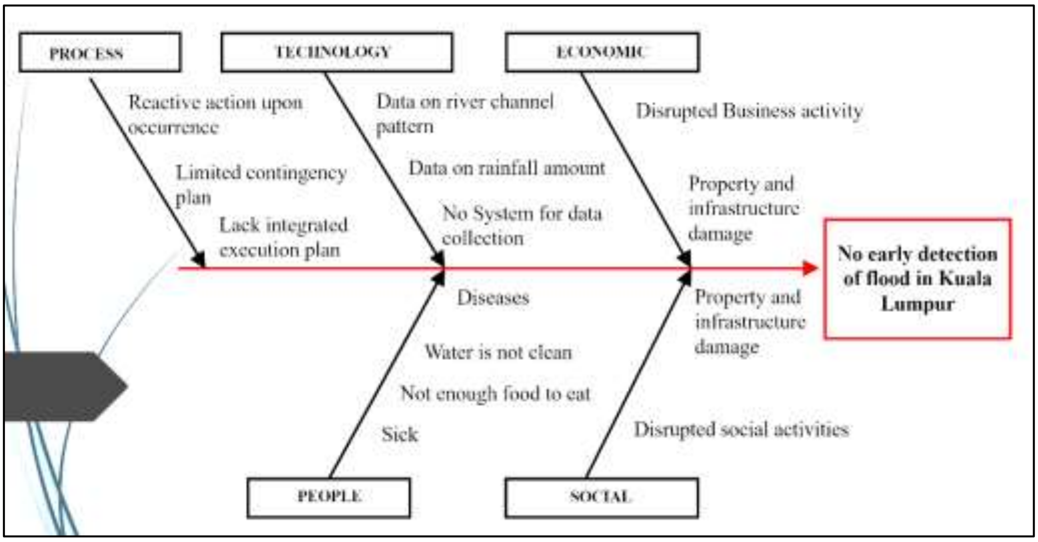

Figure 2: Ishikawa Diagram for Flood Mitigation Issue and Impact Analysis

Table 1: Detail Analysis of Urban Flood Issues and Impacts

Category	Description
Solution	• To apply big data analytic method: Descriptive and predictive analysis on the **flood pattern occurrences** to predict and avoid the damage caused by the flood.
Stakeholders	• Stakeholders can curate better planning and decision for example in terms of the execution plan, town planning as well as strategic planning on what type of building structures can sustain the condition in long term
Planet/Environment	• The surrounding area will have a stronger earth structure (no landslide, no property cracks) • Surrounding rivers will not have murky water

	• Waterborne diseases can be avoided
Social /People	• Social activities and events may be held with ease
Profit /Economy	• Business and economy within the vicinity will survive and thrive due to strategic area and market positioning within the area • Value of the land and property within the area can sustain market depreciation value • The insurance company can re-evaluate the option to include flood in the city (KL) as one of the available coverage for property and vehicle. Additional raider for insurance will cost more thus, increase revenue to the insurance company

Meanwhile, the 5W1H analysis for the urban flood issues and its possible solution is shown in Table 2.

Table 2: Using 5W 1H Method to identify the urban flood issue and possible solution

5W 1H Method	
What	City Flood → Uncertainties of the occurrence → Reduce Damage Impact
Who	People → Surrounding citizen, Business owners
Where	City Area → Kuala Lumpur
When	Throughout the year
Why	The impact of the flood is more costly compared to the rural areas
How	Analysis → Prediction of the possible occurrence of the **flood pattern**

From the findings, this study proposed a conceptual framework to show the issue, cause, proposed solution (by using the big data analytics approach) and the predicted impact to the people, social, environment and economy. Figure 3 describes the conceptual framework of this study.

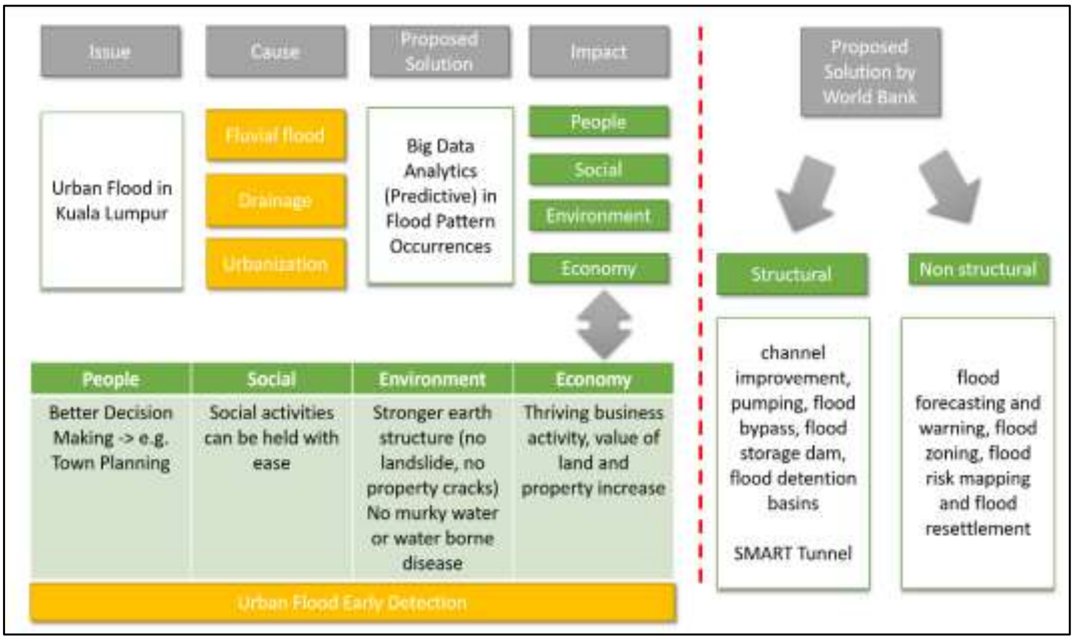

Figure 3: The conceptual framework of the issue, cause, solution and impact of big data analytics solution to urban flood

In Malaysia, there are two types of floods. One is monsoon flood and the other is flash flood or in this case, urban flood. The issue to be overcome is urban flood occurrences in Kuala Lumpur. The notable key variables of the occurrences are fluvial flood, drainage blockage and also urbanization(Tariqur Rahman Bhuiyan, Mohammad Imam Hasan Reza, Er Ah Choy, & Pereira, 2018). For fluvial flood, data collected by DID and DID only started to collect the data starting from 2000. The data is then updated again in10 years once. For drainage, data is collected by KL Municipal Council or DBKL. DBKL only started to collect flash flood data from 2010. The proposed solution to these causes is by using Predictive Analytics in Flood Pattern Occurrences.

Several impacts can be identified by having a good flood pattern prediction. The biggest impact factor is People. People involve around stakeholders where it can enable them to make better decision in various area regarding flood including better town planning and flood prevention programs. The second impact is on Social. Daily activities and events can be held with ease without any disruption and sudden cancellation. The third is Environment. Stronger earth structure without soil erosion, landslide and also cracks can be improved. No murky waters, as well as water borne diseases, can be carried out from the flash flood. Last is Economy. The economy in surrounding area will be thriving and land and property value can be appreciated if flood is no longer the issue.

However, the above solution is only in the nonstructural part. Suggestion from World Bank extensive study has mentioned that both structural and nonstructural measures are equally important for an integrated solution, preventing and mitigating flood. Therefore, when designing for flood mitigation plan, both measures need to be taken into considerations.

5. Conclusion and Future Work

Urban flood pattern prediction is still in the early stage of evaluating interdependent variables as contributing factors which is crucial in determining correlation and relationship between them. Even though in Malaysia, big data analytics has just starting to sprout ever since 2014 mandate, data collection on river basins and water level by DID all these years, has been helping researchers to continue analysis from the time series and historical data collected. Collaboration on data sharing like this has helped researchers a lot in conducting prediction using machine learning algorithm. This indicates that collaboration between parties such as government agencies, researchers and private sectors can expedite the formulation of the prediction model. In future, hopefully, the prediction model can be perfected and become a major breakthrough in predicting urban flood pattern in Kuala Lumpur.

The roles of the integrated method from structural and nonstructural measures can confront the issues in a more realistic and holistic way. Therefore, integration with various parties can construct a better framework to overcome urban flood in Kuala Lumpur and provide sustainable development environment for the surrounding area.

Early detection in urban flood is still at the beginning phase in Malaysia. More research needs to be conducted on this issue to provide a better prediction model to the urban flood in Kuala Lumpur. The government may help in providing more research grant to universities and related agencies for a more concerted effort. Although the effort so far has inclined to more structural measures like building the SMART Tunnel in Kuala Lumpur, nonstructural method is also important and has equivalent precedence especially in assisting flood prediction.

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