ESTIMATION OF INFRASTRUCTURE DEMAND FOR FLOOD CONTROL IN MALAYSIA

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1. Introduction

Flood is a common occurrence in Malaysia because of the geographical characteristics of the country that brings abundance of rains during monsoon seasons and also due to convection rains during the hot but humid periods. There are 189 river systems in the country (89 in Peninsular Malaysia, 78 in Sabah and 22 in Sarawak) all flowing directly to the sea (DID, 2003). Of these, 85 are prone to frequent flooding.

Living in such an environment inevitably led to adaptation by the population in terms of lifestyles and flood risks management. A common example is that in the old days, houses are built on stilts in flood prone areas. Crop planting seasons were prudently decided so as to be in time with the rains but avoiding the expected periods of floods. The degree of tolerance to floods was perhaps higher in the old days when agriculture was the main income and affected population was not as large as it now.

As the country's economy transformed into industrialization, the population grew and urbanization expanded rapidly in the plains. Flood developed into a national issue. Although a common occurrence, flood became an issue when it threatens lives, properties and disrupting social and economic activities. Nowadays it is classified as a disaster when it occurs unexpectedly or covers huge areas and affecting a high number of the population and properties.

Since 1920, Malaysia has been experiencing several severe flood events in the year of 1926, 1931, 1947, 1954, 1957, 1963, 1965, 1967,1969, 1971, 1973, 1983, 1988, 2001, 2007, 2009, 2011, 2012 (DID, 2013). From these occurrences, the pattern of heavy rainfall and flood event is getting more frequent. It has been estimated that 10.1% of the total land area of the country is flood prone affecting 5.67 million population. The average annual flood damage was estimated around RM 100 million (USD 25.6 million) in 1980's and has escalated to RM 915 million (USD 234 million) as estimated in National Registry of River Basin study (DID, 2003). Figure 1 shows the flood prone area in Malaysia. Table 1 tabulates the breakdown of the flood prone area, affected population and the average annual damage (at year 2000 price level) according to the states.

Kelantan
- Sungai Kelantan
- Sungai Golok
- Sungai Semerak

Terengganu
- Sungai Besut
- Sungai Dungun
- Sungai Terengganu
- Sungai Kemaman
- Sungai Marang
- Sungai Chalok

Pahang
- Sungai Pahang
- Sungai Kuantan

Johor
- Sungai Benut
- Sungai Johor
- Sungai Batu Pahat
- Sungai Muar

Selangor
- Sungai Langat
- Sungai Buloh
- Sungai Kelang
- Sungai Bernam
- Sg. Selangor

W.Persekutuan KL
- Sungai Klang

Melaka
- Sungai Melaka

Negeri Sembilan
- Sungai Linggi
- Sungai Pahang
- Sungai Muar

Perak
- Sungai Perak
- Sungai Kerian
- Sungai Kurau
- Sungai Slim

Kedah
- Sungai Kedah
- Sungai Muda

Pulau Pinang
- Sungai Juru
- Sungai Muda
- Sungai Pinang
- Sungai Perai
- Sungai Jawi

Perlis
- Sungai Perlis
- Sungai Arau

Sabah
- Sungai Kinabatangan
- Sungai Padas

Sarawak
- Sungai Batang Sadong
- Sg. Sarawak

Figure 1: Location of flood prone area in Malaysia (Mohamed Desa et. al, 2010)

Table 1: Summary of flood conditions in Malaysia (DID, 2003)

State	Flood prone area (km^2)	Affected population (2000 census)	Average annual damage (RM million)
Johor	2,367	290,570	64.00
Kedah	209	117,368	30.20
Kelantan	1,640	714,287	93.32
Melaka	81	27,811	2.29
Negeri Sembilan	129	40,887	3.96
Pahang	6,272	615,128	76.15
Perak	663	275,374	22.64
Perlis	27	12,736	2.75
Pulau Pinang	207	342,254	44.52
Selangor	1,789	669,217	75.76
Terengganu	2,223	425,396	101.58
Sabah	3,284	652,173	140.96
Sarawak	10,896	478,491	157.65
WP Kuala Lumpur	13	157,302	99.30

2. Types, Nature and Causes of Flood in Malaysia

Floods in Malaysia is often broadly categorised as monsoonal, flash or tidal floods. In addition, floods are also describes based on its location, characteristics, the cause and timing as to when it occurs and its duration. The nature of the flood can be described as follows.

a) River floods

River flooding is a natural process and part of hydrological cycle of rainfall, surface and groundwater flow and storage (Madani et. al., 2007). Floods occur whenever the capacity of the river is unable to cope with the volume of water generated by rainfall. The floods vary considerably in size and duration with prolonged rain falling over wide areas, the resultant surface waters flow into a network of ditches, streams and tributaries. The volume of water increases as it flows downstream and combines with flows from other channels. Floods occur when the flow is beyond the capacity that can be contained in the river channel.

b) Regional floods

Regional floods are also river floods but the events cover a wide area or region. This is typical in large river basins such as Kelantan River, Terengganu River and Pahang River. In large flood plains with extensive river system, flooding can occur over a considerable period after the rainfall stops as it takes time for the large volumes of water to drain out from the catchment. In some cases, floods occur in dry weather conditions (no rains) on the downstream of the catchment. This is due to the heavy rains on the upstream area (usually hilly area) that located away from the flood event location. Regional floods usually occur during monsoon seasons.

c) Localised floods

This types of flood usually occurs at the low lying areas and often sensitive to small amount of rains as the natural drainage is difficult. Usually floods last only for a few hour. However, there are also areas that remain flooded for up to month or more and well after the floods in the surrounded area receded. In this case, the flood water removal is mostly dependent on evaporation. One such area is in Buloh Kasap, Segamat, Johor.

d) Coastal floods

Coastal floods are those that occur on the coastal plains. There are two causes of coastal floods. One is the tidal effects causing sea water to flow inland and spill over the low lying area. The problem is intensified when high volume of river flows from inland meets the tide as it moves inland. More so when the level of the river flow is lower than the tide level. Example of this type of coastal flood is at Kampung Kapar in Selangor. River flow in the sea also obstructed when the coastal wave surges occur. Example of severe coastal flood is tsunami of December 2014 that affected the coasts of Langkawi Island, Penang Island and Kuala Muda in Kedah.

e) Urban floods

Urban flood are those in built up areas such as in cities, townships, commercial and residential areas. Urban floods affect more people and properties per unit area compared to those in agriculture and rural areas. The impact on traffic and services extends well beyond the physical location of the flood occurrence itself. Urban flood can be more damaging and life threatening with roads becoming swift flowing channels, basement flooded and uncovered drains, bridges and crossings usually camouflaged by the flood waters.

f) Flash floods

A flood that rises and falls rapidly with little or no advance warning is called flash flood. Flash floods usually result from intense rainfall over relatively small area. Flooding is usually due to intense local storms. This mostly happen in urban settings. The flood depths can be relatively shallow (100 mm or so) but there are cases of some being up to 2 metres depth but lasting less than 1 hour. In most cases, the impacts is not as severe as larger floods but, in urban areas such as Kuala Lumpur, it can become very disruptive to the daily routine of the urbanites.

The causes of floods can be categorized into two; natural and human induced. Malaysia is a tropical country receives an average annual rainfall of 2500 mm, making it one of the countries with the heaviest rainfall in the world and is thus prone to monsoonal and flash flood. The temperature does not have significant seasonal change and it is always hot and stable between 29/30 °C. There is an increase between March and August 38 °C then low down to around 23 °C. Precipitation from the northeast monsoon (NEM) starts in November and ends in February, while the southwest monsoon (SWM) brings rain from May to August. The NEM brings heavy precipitation in the east coast of Peninsular Malaysia and in the northeast of the East Malaysia region as a result of orography, while the SWM brings relatively less precipitation, particularly in the west coast of PM because of the shield provided by Indonesia.

By contrast, the two inter-monsoon seasons, i.e., from March to April and from September to October, bring heavy precipitation that normally occurs as convective rain. Thus, the increase of flood frequency in Malaysia can be attributed to heavy rainfall, effects of climate change and rapid urbanisation (Khalid and Shafiai, 2015).

Land use changes without due consideration for drainage needs is also the main human induced floods in the country. The Klang Valley flood issue in 1960s is a good example where urbanization resulted in more hard surface cover and therefore higher surface runoff during rains. The drainage infrastructure during that time cannot cater the increased runoff. This land used changes is believed to cause the big Kuala Lumpur flood in 1971.

Other human factor is poor design of bridges and culvert and operational requirements of structures such as dams and dam failures. In 1883, the dam upstream of Kuala Kubu town in Selangor collapsed and destroyed the town and many lives were lost.

3. Scenario of Floods in Malaysia

Roseli (1999) concluded that converting land use from agriculture to urban area increase the runoff rate by two-fold. The frequency of flood also increased yearly since 2010 until 2016 (DOSM, 2017) for most states in Malaysia as shown Figure 2.

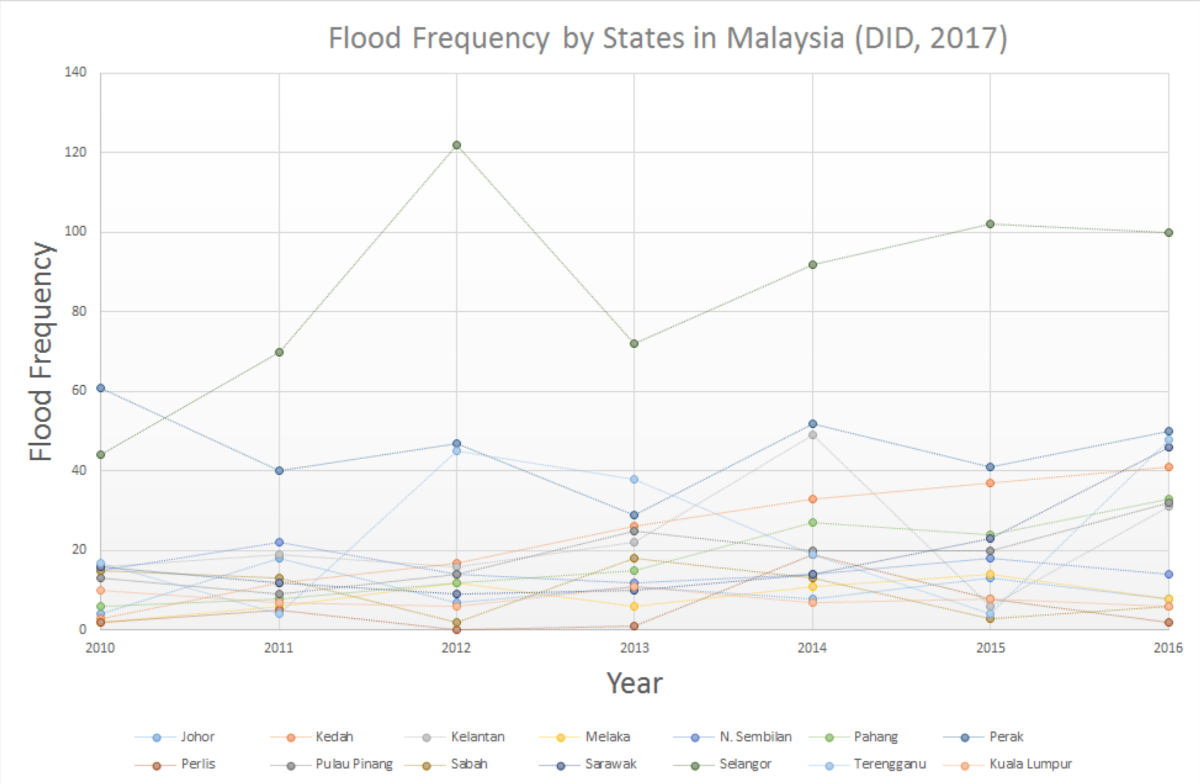

Figure 2: Flood frequency in Malaysia (2010-2016)

Shah et. al., (2017) summarize an official flood loss estimates for selected and major flood events in Malaysia. According to the recent records indicate that the worst flood disasters occurred in December 2014 in Kelantan, Pahang, Terengganu and Sabah which generated many victims and caused severe destruction of properties. On top of that, the strategic states and urban area such as Selangor and Penang, and Kuala Lumpur, the capital of Malaysia, have been also affected by floods every year and government has to spend so much effort and budget in order to assist its citizens in recovery and re-build infrastructure after disaster. The recent Penang flash flood in 2017 shocks the nation with its severe impacts and losses although the state has been hit by frequent flash floods since 2013.

4. Flood Mitigation in Malaysia

The Department of Irrigation and Drainage (DID) is the lead Government agency responsible for flood management in Malaysia. DID at Federal Level are responsible for policy planning for flood mitigation, drainage works, irrigation works and river conservancy if it involves rivers (eg. flood caused by river overspill). The State/District DID implements project and operates the flood control structures after completion. Local authority may also carry out their own drainage improvements to alleviate flash flood and mostly maintain the local drainage system. The 1971 floods is the turning point where flood mitigation was added to DID's function. The Government took several positive steps to deal with the flood problem. Among these were:

a) Establishment of the Permanent Flood Control Commission
b) Establishment of flood disaster relief machinery
c) Carrying out of river basin studies and preparation of drainage master plans for major towns
d) Implementation of structural and non-structural measures
e) Setting up flood forecasting systems
f) Setting up nation-wide network of hydrological and flood data collections stations

To mitigate measures of flood disaster i.e. structural and non-structural, the Government of Malaysia has spent more than RM 3 billion on structural measures to mitigate flooding since 1970's until now. However, this figure is still insufficient and this amount will keep on accumulate due to the increasing project cost and flooded areas. Moreover, structural measures are time consuming which involves physical works such as construction of dams, channel improvement, river diversion, embankment and levee to keep floods away from people. Thus, the non-structural measure such as flood-forecasting and warning systems is preferred to reduce the future flood effects as it can help a responsible authority to plan an effective emergency response towards flood. In addition, it can also strengthening the society to manage the impacts and threats of floods (Shah et. al, 2017).

Figure 3 shows the allocated amount by the Government for flood mitigation measures since 1971 to 2020 (Shah et. al., 2017). This shows the Government is committed in mitigating floods in Malaysia.

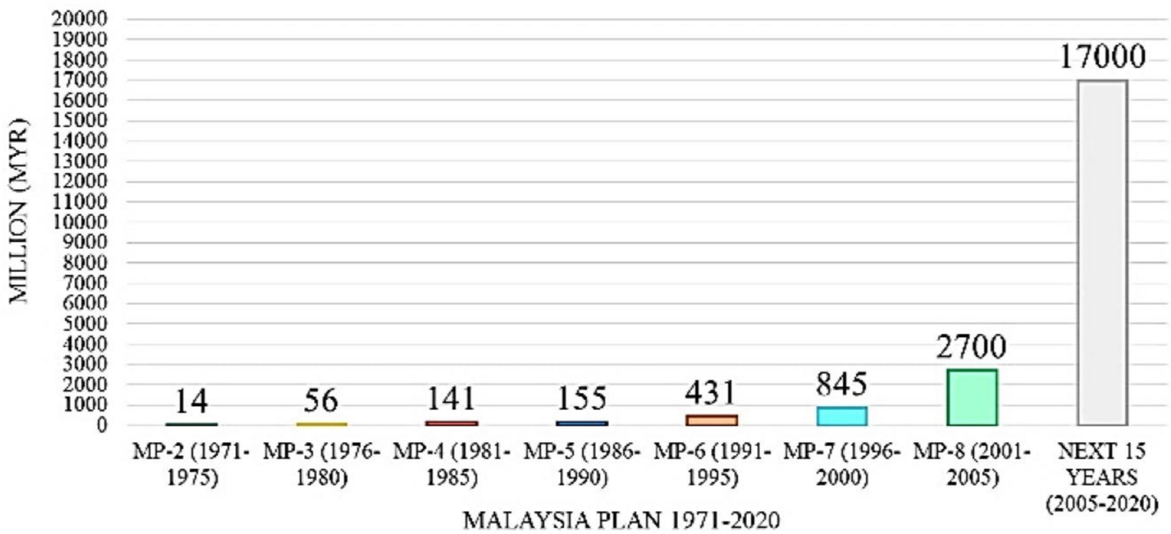

Figure 3: Budget allocation for flood mitigation projects under Malaysia Plan (Shah et. al., 2017)

5. Methodology

This study mainly focusing on data collection through secondary sources from:

a) DID flood report for all states
b) DID annual flood report
c) Annual national budget

d) Journal articles
e) Thesis

The method used to estimate the investment on flooding is multiple regression model (best fit curve).

The allocation of flood mitigation include the following activity:-

a) Flood control infrastructure plan
b) Drainage system
c) Early warning system
d) Hydrological data

The allocation of flood mitigation and estimated damage loss due to flood are inflated using 2015 as base year of Consumer Price Index (CPI). The equation of inflated price is:-

$$MYR\ inflated\ in\ 2015 = MYR\ in\ current\ year \times \frac{Average\ CPI\ in\ 2015}{Average\ CPI\ in\ current\ year}$$

The average of CPI for Malaysia is obtained from Bank Negara Malaysia and World Bank Group (Appendix A).

For this study, it is assumed that the exchange rate between US Dollar and Ringgit Malaysia is USD 1 to MYR 3.91.

6. Data Analysis and Results:

Based on literature review and data collection, trends in flood disaster risk reduction budgets were gathered and obtained from DID annual flood reports. These budgets were allocated for DID to mitigate floods. Figure 4 shows the total budget (blue) in yearly and the total damage loss due to floods (red) in million USD from 1991 until 2018.

From the figure, huge damage were recorded in 1996 where floods were brought by Tropical Strom Greg in Keningau resulting huge damage. In 2006 and 2007, enormous flood in Malaysia flood disaster history stroked four states in Peninsular Malaysia; Johor, Pahang, Melaka and Negeri Sembilan resulting in huge damage approximately 400 million USD. And last but not least was the Yellow Flood that hit Kelantan, Terengganu and Pahang in 2014 resulting in approximately 732 million USD damage loss. It is the worst monsoon flood that affecting east coast of Peninsular Malaysia, especially Kelantan where 540,000 people were affected. Figure 5 shows the 2014 flood situation in Kelantan.

The national allocation for flood mitigation is at the lowest during the period of 1997 until 1999 as Malaysia was affected by the Asian Financial Crisis. After the crisis, Malaysia regained back financially in 2000 and invested SMART tunnel project to solve Kuala Lumpur flood problem. The budget fluctuated slightly before increased again from 2007 until 2010 where flood mitigation projects took place in north (Kedah) and south of Peninsular Malaysia (Johor, Pahang, Melaka and Negeri Sembilan) after the enormous flood in 2007. The national allocation however did not increase after the worst ever recorded 2014 flood event. It is believed that more allocation were given to aid the response and preparedness phase.

Figure 6 shows the investment estimation of flood mitigation in Malaysia from 2020-2030. The estimation is produced by using regression equation using 2014-2019 data. It is observed that the commitment shown by current government to invest in flood mitigation becomes significant and it is foresee the demand for allocation will be high despite Malaysia is still stabilizing back its financial situation.

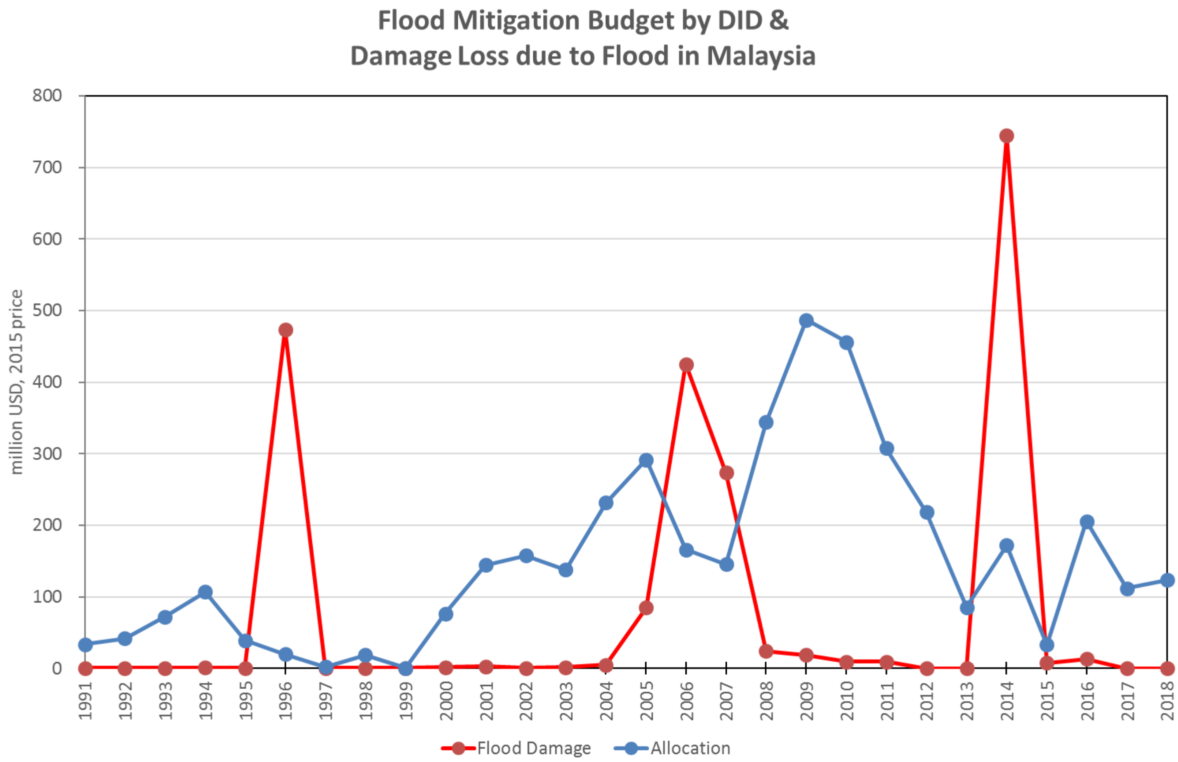

Figure 4: Flood mitigation budget and damage loss due to flood in Malaysia from year 1991 - 2018

Figure 5: Situation of flood in Kelantan 2014 flood where major infrastructure such as bridge collapsed during the flood.

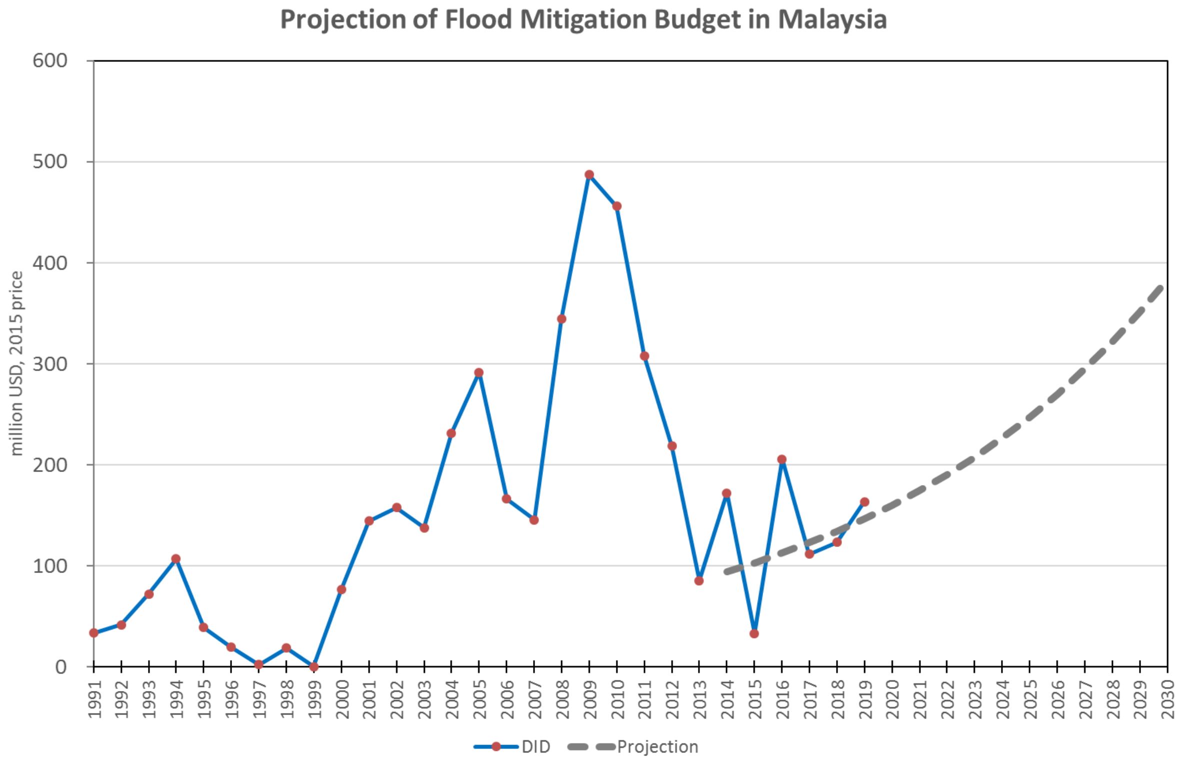

Figure 6: Investment estimation of flood mitigation in Malaysia from 2020-2030

Figures 7 and 8 illustrate the number of casualties due to flood disaster and number of affected people by flood since year 1967 to 2017. The higher number of casualties was recorded in 1996 where Sabah was hit by Tropical Storm Greg. For the number of affected people due to flood, monsoon flood in that affecting east coast area in 1967 is the highest followed by 2014 monsoon flood.

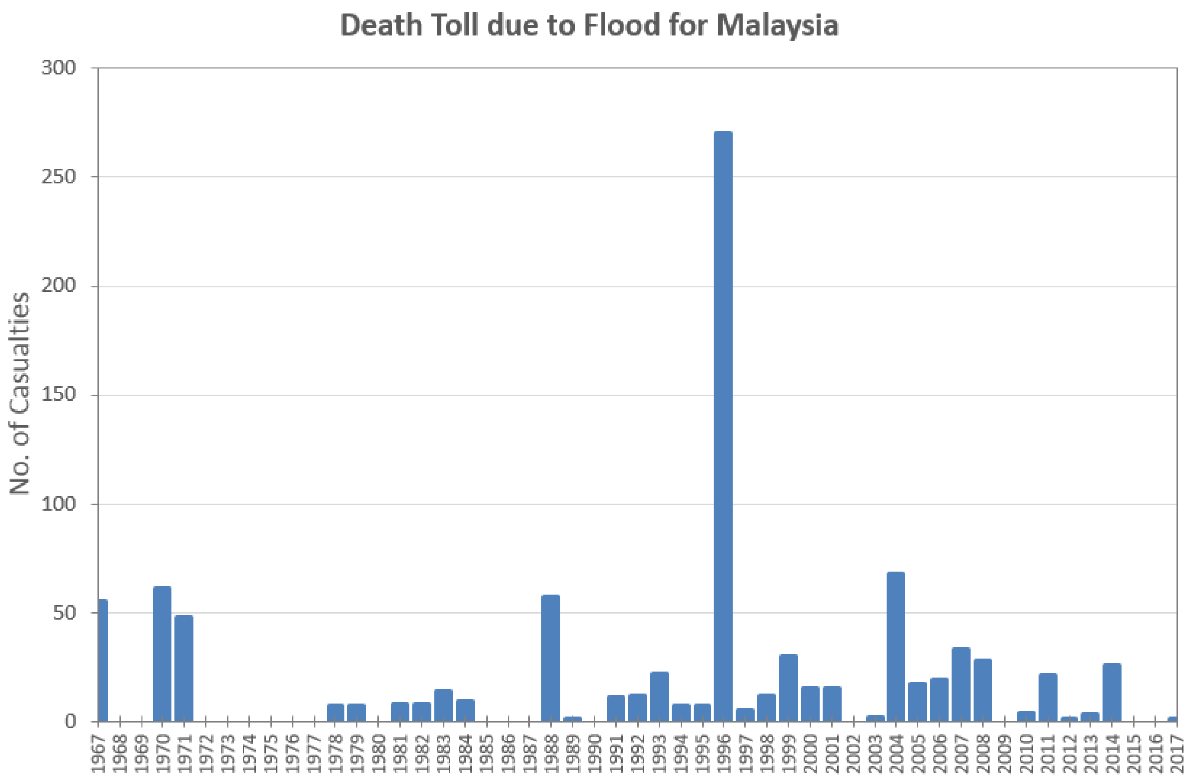

Figure 7: Death toll due to flood disaster in Malaysia (1967 – 2017)

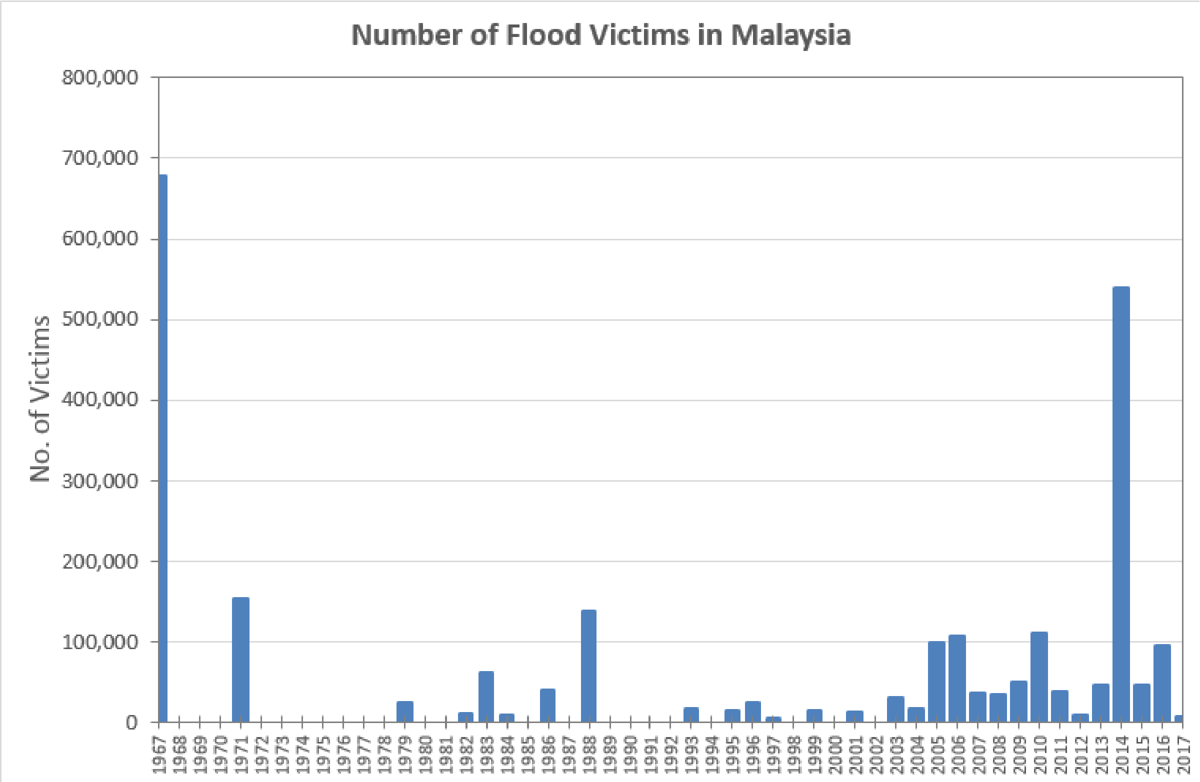

Figure 8: Number of flood victims (1967 – 2017)

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Appendix A

Consumer Price Index for Malaysia

Year	Consumer Price Index (2015 = 100)	Year	Consumer Price Index (2015 = 100)
1960	18.89	1990	50.37
1961	18.86	1991	52.57
1962	18.88	1992	55.07
1963	19.47	1993	57.02
1964	19.39	1994	59.14
1965	19.37	1995	61.19
1966	19.55	1996	63.32
1967	20.45	1997	65.01
1968	20.42	1998	68.43
1969	20.33	1999	70.31
1970	20.71	2000	71.39
1971	21.04	2001	72.40
1972	21.72	2002	73.71
1973	24.02	2003	74.51
1974	28.18	2004	75.57
1975	29.44	2005	77.82
1976	30.22	2006	80.63
1977	31.66	2007	82.26
1978	33.20	2008	86.74
1979	34.42	2009	87.24
1980	36.71	2010	88.66
1981	40.28	2011	91.48
1982	42.62	2012	93.00
1983	44.20	2013	94.95
1984	45.92	2014	97.94
1985	46.08	2015	100.00
1986	46.42	2016	102.09
1987	46.55	2017	106.04
1988	47.74	2018	107.01
1989	49.09	2019	106.84

Source: Bank Negara Malaysia and World Bank Group

Appendix B

List of Flood Events and Damages in Malaysia

Year	State	Population Affected		Damage (2015 prices)	
		Evacuated	Casualties	RM million	USD million
1967		678,000[1]	55[2]	690.98[1]	176.72
1970		N/A	61[2]	N/A	N/A
1971		153,000[1]	48[2]	311.82[1]	79.75
1978		N/A	7[4]	N/A	N/A
1979		23,898[1]	7[2]	N/A	N/A
1981		N/A	8[2]	0.03	0.01
1982		9,893[1]	8[2]	N/A	N/A
1983		60,807[1]	14[2]	N/A	N/A
1984		8,400[1]	9[3]	35.60[1]	9.11
1986		40,698[1]	N/A	13.50[3]	3.45
1987		N/A	N/A	7.39[3]	1.89
1988		137,755[1]	57[1]	57.87[1]	N/A
1989		N/A	1[2]	0.15[4]	0.04
1990		N/A	N/A	2.12[3]	0.54
1991		N/A	11[5]	3.15[3]	0.81
1992		N/A	12[1]	2.22[3]	0.57
1993		17,000[1]	22[1]	2.73[3]	0.70
1994		N/A	7[4]	4.20[3]	1.07
1995		14,900[1]	7[2]	2.53[3]	0.65
1996		24,000[1]	270[9]	1,852.50[2]	473.79
1997		5,321[1]	5[1]	1.46[3]	0.37
1998		N/A	12[5]	2.45[3]	0.63
1999		15,500[1]	30[5]	2.82[3]	0.72
2000		N/A	15[2]	7.12[3]	1.82
2001		13,195[1]	15[2]	12.03[3]	3.08
2002		N/A	N/A	1.98[3]	0.51
2003		31,046[1]	2[3]	7.67[3]	1.96
2004		17,080[1]	68[2]	19.49[3]	4.99
2005		99,405[1]	17[6]	331.61[6]	84.81
2006		107,000[1]	19[6]	1,663.34[6]	425.41
2007		36,143[1]	33[6]	1,069.43[6]	273.51
2008		34,015[4]	28[2]	95.52[2]	24.43
2009		50,157[4]	N/A	74.58[4]	19.08
2010		111,323[4]	4[2]	37.40[2]	9.56
2011		38,446[4]	21[8]	36.55[4]	9.35
2012		9,038[4]	1[4]	N/A	N/A
2013		46,906[4]	3[4]	N/A	N/A
2014		206,386[4]	26[4]	2,911.00[7]	744.50
2015		46,011[4]	N/A	30.43[4]	7.78
2016		95,929[4]	0[4]	52.13[4]	13.33
2017		7,033[4]	1[4]	N/A	N/A

Source:

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