TECHNICAL NOTE ON THE ESTIMATION OF INFRASTRUCTURE DEMAND FOR FLOOD CONTROL

"Bridging the Infrastructure Gap in Asia," ADB-JICA Joint Side Event at the 50th Annual Meeting of the ADB Board of Governors

Mikio Ishiwatari
Senior Advisor on Disaster Management and Water Resources Management,
Japan International Cooperation Agency
Kenichi Tsukahara
Professor, Department of Civil Engineering, Kyusyu University

1. Introduction

Each country decides the scale of its investment in flood control based on various factors, such as the scale and frequency of flood disasters, the assets accumulated in areas at risk, and the level of community concern about potential disasters. The experience of selected countries shows that governments allocate budgets for flood control according to historical records of the impact of the most severe disaster on the national economy. Countries can turn a flood disaster from a crisis into an opportunity to expand investment in flood control. The Japanese experience over the last one and half centuries shows that the country has increased flood control budgets every time it has suffered from a major disaster. Experience also shows that budgets for flood control have a positive correlation with urbanization and gross domestic product (GDP) per capita. Based on this experience, investment for flood control in the Philippines is estimated at USD 33-61 billion until 2030. These analyses are useful for estimating the requirements for infrastructure investment for flood control in Asian countries.

2. Relationship between flood control investment and flood damage

Each country decides the scale of its investment in flood control according to the impact of the most severe disaster on the national economy in the past, rather than on the average level of flood damage experienced over time (Table 1). Mega-disasters often become triggers to expand investment in flood control. Japan has repeatedly experienced enormous flood disasters caused by typhoons and heavy rainfall since the Second World War. The economic damage caused accounted for over 10% of national income in 1947 and 1953 for example, and as a result, the Japanese government invested

0.6-1% of GDP for flood control until the mid-1960s to mitigate flood damage. The Netherlands spent 1% of GDP on flood control in 1960 following the catastrophic North Sea flood of 1953. This disaster caused 1,853 casualties and economic damage of some 0.7 billion Euros. Currently, flood damage in the Netherlands and Japan has decreased to 0.02% and 0.06% of GDP, respectively. Yet, these two countries are continuing to make high level of investments of some 0.2% of GDP for flood control. The Netherlands is also increasing its budget for flood control to prepare for potential disasters caused by climate change.

The Philippines, China, UK, and Indonesia have increased their flood control budgets in the past several years as a reaction to the enormous damage from recent disasters. The scale of their investments is also dependent on the magnitude of these disasters. The Philippines and China allocate some 0.4% of GDP, and the maximum economic damage experienced has been 1.3% and 3.5% of GDP, respectively. The UK and Indonesia allocate 0.2 % and 0.06 % of GDP respectively, and the maximum damage experienced has been some 0.2% of GDP. The flood control budget of US Army of Corp Engineers accounts for some 0.01% of GDP. This may seem a low level of investment considering the economic damage of 1% of GDP from Hurricane Katrina in 2005, but it is because only the US federal government budget figures are available; state government budgets are not included.

Table 1: Flood control investment and flood damage in selected countries

Country	Investment % of GDP		Damage % of GDP		Event causing maximum damage	Budget data period
	maxi-mum	mini-mum	maxi-mum	average*		
Netherlands	1.0	0.06	10.6	0.02	1953 High Tide	1960 & 2006-2013
Japan	0.99	0.18	10.2**	0.06	1947 Typhoon	1955-2015
Philippines	0.44	0.06	1.3	0.63	1993 Typhoons	1990-2016
China	0.37	0.15	3.5	0.31	1998 Flood	2000-2015
UK	0.2	0.08	0.2	0.08	2013 Flood	2000-2015
Indonesia	0.06	0.04	0.2	0.1	2007 Flood	2006-2012
USA	0.01	0.01	1.0	0.3	2005 Hurricane	2007-2017

* average annual damage from 1996 to 2015, ** % of National Income.
Sources: Cabinet Office (2015); Darwanto (2012); Department of Budget Management of the Philippines; IMF's World Economic Outlook Database; Japan Institute of Country-ology and Engineering (2011); Kok et. al (2012); Kreft et. al (2015); Ministry of Water Resources of People's Republic of China (yearly); Ministry of Finance of Japan; Office of Civil Defense of the Philippines; Priestley and Allen (2016); Research Center for National Land Development (2006); Statistics Netherlands; U.S. Army Corps of Engineers (yearly); Zhong (2016).

Table 2: Japanese flood control budget by decades from the 1880s to the 1930s		
Decade	**Total budget for flood control and rehabilitation (Billion JPY, 1995 prices)**	**Events**
1880s	179.3	1885 major flood in Osaka
1890s	374.3	1896 Major floods throughout the country 1896 Enacted River Law
1900s	518.7	
1910s	831.1	1910 largest flood in Meiji Era 1911 First long-term plan for flood control
1920s	820.4	1921 Second long-term plan for flood control 1923 Great Kanto Earthquake
1930s	1,400.7	Takahashi expansionary financing following the Great Depression 1933 third long-term plan for flood control Increasing military budget
Source: Research Center of National Land Development (2006), modified by the authors.		

3. Trends in Japanese investment for flood control from the late 19th Century

The Japanese experience shows that the country has increased investment in flood control by taking the opportunity to do so after major disasters. Japan has increased flood control budgets through developing legislation, long-term investment plans, and special accounts following major flood disasters during the modernization process from the late 19th century until the mid-20th century. The budget for flood control for each decade increased by eight times from the 1880s to 1930s (Table 2). However, these budgets were less than the economic damage from floods for most of the period before the Second World War (Figure 1).

The national government started projects for flood control in 1885 on the Yodogawa River in Osaka and Kyoto prefectures, following a flood disaster. This flood submerged most of Osaka City, and affected some 270,000 people, resulting in economic damage estimated at 4.4% of the then National Income. Before this disaster local governments had conducted flood control projects, but flood control works in major rivers required high-technology inputs and enormous budgets that local governments could not meet.

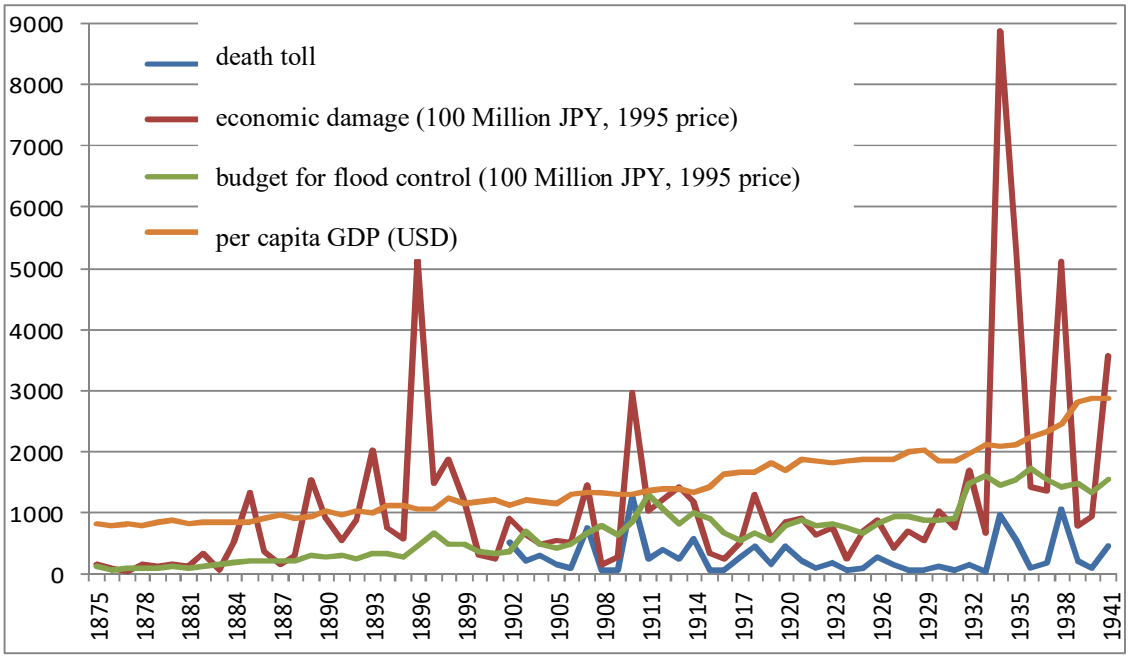

Figure 1: Investment for flood control before the Second World War

Source: Research Center of National Land Development (2006), The Maddison-Project, http://www.ggdc.net/maddison/maddison-project/home.htm, 2013 version.

A River Law was enacted to mitigate flood damage in 1896 when flood disasters impacted on communities throughout the country. This law stipulated that the national government could conduct flood control works covering multiple prefectures, while prefectural governments were in principle responsible for flood disaster management.

The government formulated the first long-term plan for flood control in 1911, recognizing the necessity for long-term commitment to flood control. Flood disasters in 1911 left some 2500 people dead or missing, and economic damage accounted for 3.6% of National Income. The long-term plan covered works in 50 major river basins for 18 years. Also, the government created a special account to manage financing that included shares by local government, and loan programs from postal savings.

However, the government could not always secure budgets for flood control because of inflation in the 1910s, rehabilitation efforts following the Great Kanto Earthquake in 1923, and the impact of the Great Depression in 1929. Furthermore, in the 1930s, the government allocated the major portion of the national budget for military expansion instead of public works. Because of limited investment in flood control the country suffered from serious floods following the Second World War. Annual economic damage from the floods was between 1 and 10 % of National Income from 1946 until 1959 (Figure 2).

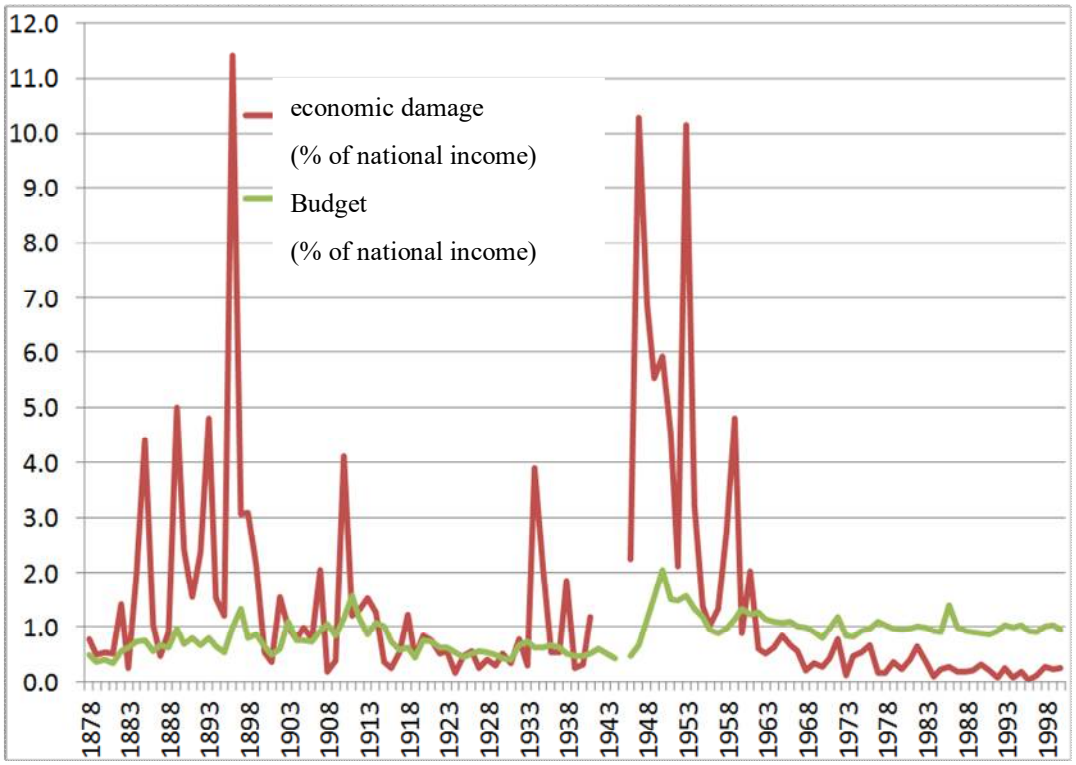

Figure 2: Trend of flood damage and flood control budget (1878-2000)

Source: Research Center or National Land Development (2006).

Because of the intensive budget allocation, economic damage substantially decreased to 0.1% of National Income. Following a serious of serious flooding in the 1940s and 1950s the government increased the flood control budget accordingly, to about 1% of National Income (more than the cost of flood damage in most years), until now to protect the assets increasingly accumulating in risk areas. This budget level shows a positive correlation with urbanization and GDP per capita (Figure 3). Tsukahara and Kachi (2016) estimated the annual benefit from flood control investment at over 6 trillion JPY, or 55 billion USD, in the mid-1990s. This was almost double the budget for flood control.

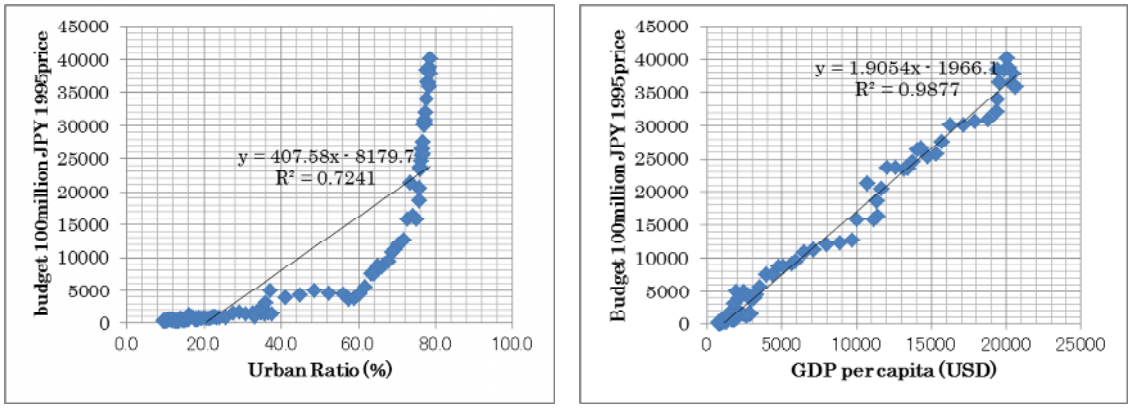

Figure 3: Relationship between budget for flood control and (a) urban ratio (1893-2000) and (b) per capita GDP (1875-2000)
Source: Research Center of National Land Development (2006), The Maddison-Project, http://www.ggdc.net/maddison/maddison-project/home.htm, 2013 version, Statistical Bureau of Japan.

4. The Philippines is increasing investment on flood control.

The Philippines is rapidly increasing its national budget for flood control following a serious of typhoon disasters in recent years. The government increased the budget by 10 times from 2008 to 2016 (Figure 4). Typhoons Ondoy and Pepeng caused serious floods and landslides in Metro Manila and Luzon Island in September and October 2009. The total economic damage was estimated at PhP38 billion, or 0.5% of GDP. Following 2009, several typhoons continuously caused serious damage. In particular, Typhoon Yolanda caused a high tide disaster in the Leyte Islands, resulting in economic damage of PhP95 billion, or 0.8% of GDP.

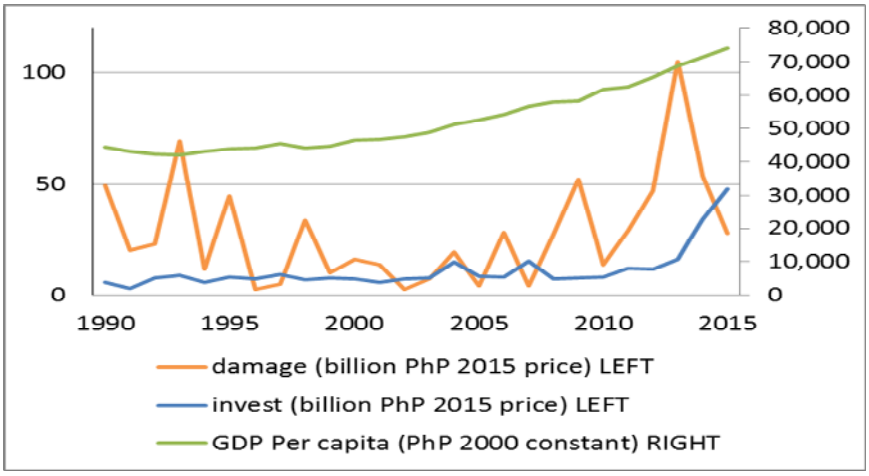

Figure 4: Trends of flood damage, flood control budget, and GDP per capita in the Philippines
Source: Department of Budget Management of the Philippines and ADB.

The demand for flood control investment was estimated at USD 33-61 billion, or PhP1.5-2.8 trillion from 2016 until 2030 by applying two methods: (a) increasing budgets at the same pace as GDP growth as a lower estimation, and (b) using the results of a multiple regression model as an upper estimation (Figure 5). This investment scale is equivalent with 0.45 to 1.08% of GDP in 2030. The upper estimation of 61 billion USD is almost double of the lower estimation of 32 billion USD because it is based on the recent rapid growth in the actual budgets.

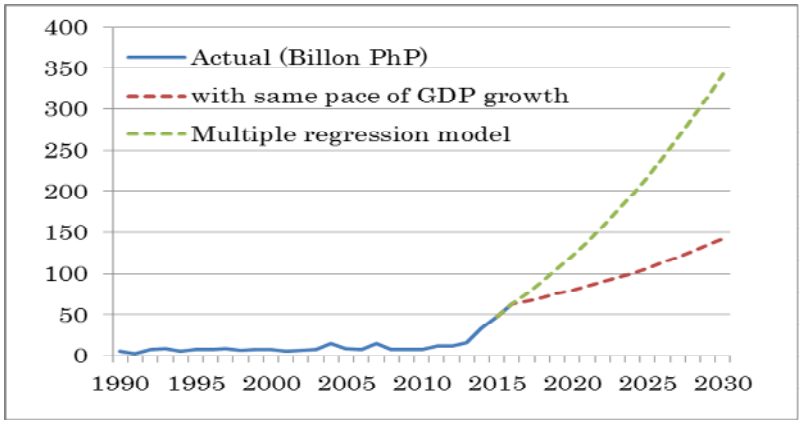

Figure 5: Estimate of infrastructure investment for flood control in the Philippines
Source: Department of Budget Management of Philippines, and the authors.

Urbanization, growth of GDP per capita, and budget of previous year are used as explanatory variables for the regression model. The ADB uses several variables, including lagged values of the infrastructure stock, GDP per capita, shares of agriculture and industrial value-added in GDP, the urbanization rate, and population density, to estimate infrastructure investment. Among these variables, the budgeted amounts for flood control are correlated with changes in urbanization, GDP per capita, and previous year's budget. Urbanization increases the potential for flood damage. For example, while the built-up area increased by 50% from 2008 to 2015 in Davao city, the area at risk increased by more than 200% (Figure 6). The R^2 value for the regression model used here is 0.909, and the adjusted R^2 value is 0.896.

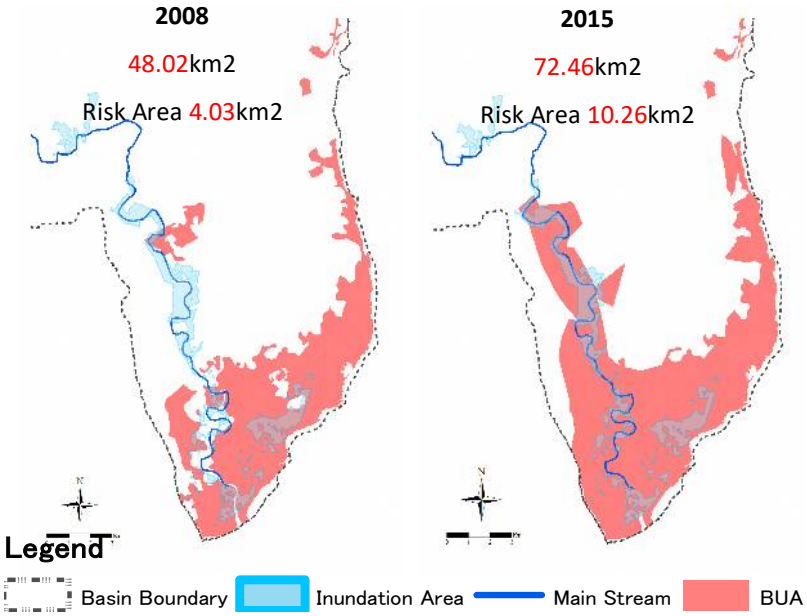

Figure 6: Change of risk area in Davao

Source: JICA (2008), Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community.

The investment will pay off. Figure 7 shows the results of the economic analysis of investment using the upper estimation model. At the early stage of investment, the cost exceeds the benefit. However, as per capita GDP grows, the benefit exceeds the cost because the asset density of the protected area increases. The balance (benefit minus cost) accumulation becomes positive in 2025. The ratio of benefit per cost until 2030 is estimated at 1.92. Total benefit is assumed from the average benefit of the flood control projects recently planned in the Philippines.

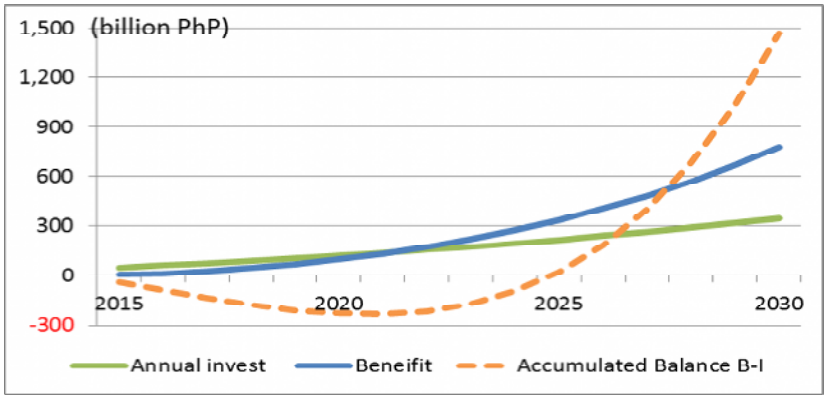

Figure 7: Benefit of investment

Source: The Authors.

5. Conclusion

The relationship between flood control budgets and the level of flood damage was examined in Japan and selected countries in this note. These countries decide on the scale of their flood control investment based on the disaster that had most impact on the national economy in the past. Japan and some other countries have turned these disasters from crises into opportunities for expanding this type of investment. Demand for flood control infrastructure in the Philippines is estimated at 32-61 billion USD using multiple regression analysis and the growth of GDP. The investment will pay off, since the asset value in risk areas will increase because of urbanization and economic growth. This estimation shows a continuous rapid increase of the budget. Financing arrangements and strengthening the implementation capacity for flood control are challenges.

As the next step, the level of the investment in the infrastructure required for flood control will be estimated for other Asian countries. Policy recommendations on how to secure the enormous financial resources for flood control infrastructure in these countries will be examined.

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