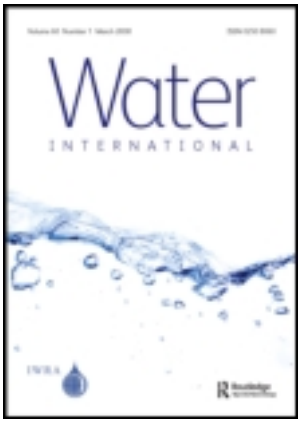

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Jakarta flooding: systems study of socio-technical forces

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Jakarta flooding: systems study of socio-technical forces

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This paper uses tools from systems thinking to address flood problems from multiple perspectives with a case study of flooding in Jakarta, Indonesia, which faces a daunting challenge due to its topography, climate, congested areas and inadequate infrastructure. While it cannot solve flood problems with structural measures alone, Jakarta can incorporate risk management into development strategies and policies, implement an effective early warning system and integrated emergency response programme as well as improve law enforcement; it can also work to develop a culture of resilience through collective strategies, greater public awareness and a flood management information system.

Keywords: urban flooding; developing countries; integrated flood management; socio-technical approach; systems analysis tools

Introduction

Flood disasters, which add greatly to the hardships of low-income people in developing countries, are systemic problems that are linked to social inequality and environmental degradation as well as hydrological conditions. With increasing urbanization and global environmental change, the consequences will worsen unless institutional support systems are improved.

Given the systemic nature of flood disasters, traditional engineering approaches alone will not provide cost-effective and integrated solutions. This paper describes a study that used systems tools to investigate flood management strategies that not only combine structural and non-structural measures, but are also based on an integrated approach with emphasis on community participation and sensitivity to local conditions. The resulting integrated flood management (IFM) approach addresses short and long-term impacts and consequences and offers new thinking to address flood problems that seem intractable.

Conditions in developing countries vary widely, but flood issues are particularly serious in Asia, where environmental conditions have led to disasters from typhoons, monsoons, tsunamis and other extreme rainfall events. The study drew from these experiences in countries such as Bangladesh and Vietnam and focused on Jakarta, Indonesia, as a case study. The analysis showed the links among attractiveness of the city, migration, poverty, lack of community cohesion, overwhelmed infrastructure and management systems and the resulting flood disasters.

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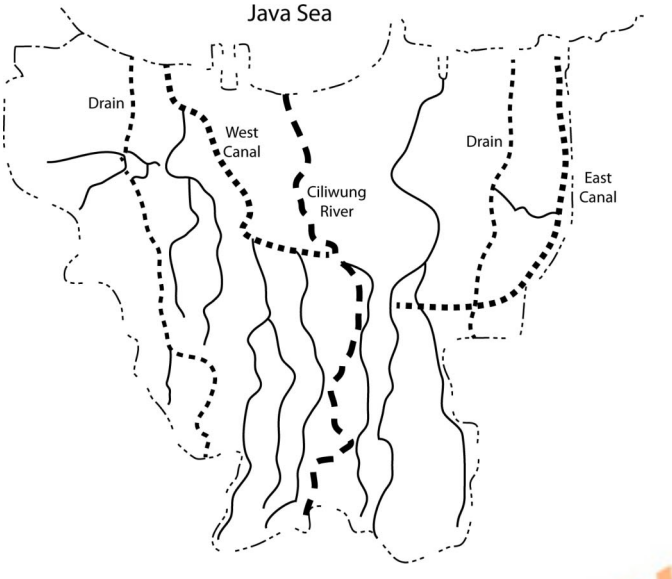

Figure 1. Rivers and drainageways through Jakarta, Indonesia.

Jakarta vulnerability to flooding

Jakarta is the largest city in Indonesia, the national capital and centre of government administration. As shown by Figure 1, it covers an area of 662 square kilometres (255 square miles) and is located on the northwestern coast of Java Island at the mouth of the Ciliwung River. Its northern zones are on plains and the southern parts of the city are hilly. Most of the some 13 rivers flowing through Jakarta flow northwards toward the Java Sea. The Ciliwung River is the largest river and divides the city into its western and eastern principalities.

Jakarta's climate is hot and humid year-round with a daily temperature range of about 25° to 38°C (77°–100°F) and average humidity of 78.4%. Rainfall occurs throughout the year, although it is heaviest from November to May. The wet season rainfall peak is usually in January with average monthly rainfall of 350 mm (14 inches). The average annual precipitation in Jakarta is 1,790 mm (71 inches) (BPS 2007).

Like many large cities in developing countries, Jakarta has experienced severe flooding for many years mostly due to heavy rain, clogged pipes and waterways, deforestation, and lack of adequate drainage and flood control systems. The rivers converge in the urban area, and every rainy season they swell quickly and massively.

Also like many large cities, Jakarta struggles with urbanization, which plants the seeds that exacerbate flooding: poverty, inadequate housing, high rates of unemployment, inadequate infrastructure, inadequate health care, lack of services and decreasing environmental quality.

Flood disasters have increased the social and economic vulnerability of Jakarta. Based on the 2008 data released by the Indonesian Central Bureau of Statistics (BPS), Jakarta still has approximately 400,000 residents classified as poor and another 300,000 classified as near poor and vulnerable to external shocks. Many of these people live in slum areas in several parts of Jakarta, which are especially vulnerable to flooding. Most people in Jakarta recognize that flood disasters have caused destruction of private and public infrastructure

and disrupted the fabric of social and economic conditions of many people (Surbakti *et al.* 2010).

Urban development impacts on flooding in Jakarta

Like other large capital cities in developing countries, Jakarta dominates Indonesia's administrative, economic and cultural activities. Over the years, the city has attracted many migrants, and rapid growth has outgrown the capacities of the national and local governments to provide basic needs for its residents. The flood threat to Jakarta is intensified due to its position as a port city on alluvial lowland, which makes it prone to flooding during heavy rainfall. As a result, chronic flooding hits Jakarta every year during the wet season. While this would be difficult enough to manage on its own, the problem is exacerbated by the poorly maintained drainage systems, poor watershed management, deforestation and exploitation of natural resources, and lack of appropriate solid waste disposal, which also decreases the water quality and the capacity of the drainage network.

Jakarta has experienced several major floods in recent years. In late January 2002, a severe flood hit and inundated much of Jakarta, leaving hundreds of thousands homeless. About 15–20% of the city was under water, and thousands of homes were flooded. The flood caused 700 billion rupiah of damage (about US$788 million, with all conversions in this article based on July 2011 exchange rate). The estimates were based on the funds needed to repair or rebuild the ruined infrastructure and did not include the value of damage and losses of individual properties or any indirect damages. At least 200 billion rupiah (US$22 million) was needed to repair roads damaged by the devastating floods.

The major flood that occurred in 2007 is considered the worst in three centuries. It affected 80 separate regions in and around Jakarta, and over 70,000 homes were flooded, resulting in the displacement of some 200,000 people. The death toll reached 68 people, and approximately 190,000 people fell ill due to flood-related illnesses. The flood caused about nine trillion rupiah (US$998 million) in losses (BPS 2007).

Previous studies of Jakarta flooding

Although the problem of flooding in Jakarta has long been recognized, the response has been reactive and flood control measures were usually built only after flooding caused severe damage to constructed facilities. Disaster prevention and mitigation measures were largely concerned with costly technical solutions. Recent studies have shown that traditional engineering measures are insufficient to protect the population from flooding and a sustainable long-term approach for floodplain development is required. This approach should consider socio-economic constraints as well as environmental objectives to mitigate flood impact and to manage the causes of flooding.

The record of structural measures has been reported by several investigators. Siswoko (2005) explained how flood mitigation in Jakarta has relied heavily on structural measures, yet despite massive investments, flooding remains a problem and is getting worse. Moreover, most flood mitigation activities have been carried out by the government with lack of public participation, especially in land acquisition and environmental management. Meanwhile, rapid population growth and lack of law enforcement have contributed to the problem.

Caljouw *et al.* (2004) explained how flood solutions in Jakarta can be based on operational and maintenance measures such as street and waterway cleaning, better solid waste management, removal of obstacles, dredging and improvement of infrastructure capacity.

In addition to physical measures, institutional strengthening can be carried out by technical training, public awareness programmes, law enforcement and early warning and emergency assistance systems. These should be bolstered by long-term improvements through watershed planning and management and the improvement of discharge capacity and retention capacity of streams and floodplains.

These measures will require political responses. Soenarno and Sasongko (2001) emphasized that political reform on the administrative and legal systems is required to improve overall conditions, and these will in time make real achievement in flood damage reduction possible. Marschiavelli (2008) explained how the local government should understand the public's perception of flooding risk in order to address disasters effectively through participation. It is also important to understand coping mechanisms before, during and after flooding so the local government and community can assess and enhance their capacity.

Integrated flood management approach

Given the difficult conditions and the need for both social and technical responses, an integrated approach is required to involve the relevant sectors and communities in a paradigm shift to identify and solve flood problems. It must involve mutual efforts to enhance institutional capacity in local government and empower the total community.

The IFM framework has been developed with the aim of maximizing the efficient use of floodplains while minimizing the loss of life from flooding (Global Water Partnership [GWP] and World Meteorological Organization [WMO] 2006a). Conceptually, IFM offers a reorientation of how floods are perceived by society and shifts from the "need to control" approach, based on seeing floods as threats, to the "need to manage" approach, where floods are seen as naturally occurring with some benefits. Our approach for Jakarta is based at least partially on the IFM concept.

Attributes of IFM include a participatory approach involving stakeholders, appropriate roles for a set of actors to ensure coordination and cooperation across institutional and disciplinary boundaries, a firm legal framework, and awareness by organizations and individuals of their roles, responsibilities, rights and powers with respect to flood management (GWP/WMO 2006b).

The IFM approach requires application of systems tools to enable socio-technical solutions.

Application of the systems approach to Jakarta's flooding problems

Systems thinking and its tools provide a method to see the whole picture of flooding and identify the most productive interventions. In the systems approach, the component parts of a *system* can be understood in the context of relationships with each other and with other systems. A socio-technical systems approach recognizes the interactions between human behaviour, social institutions, the environment and physical infrastructure.

The analysis of flooding in Jakarta is too complex for the mathematical modelling that is often used to simulate the behaviour of physical systems. Instead, the present analysis utilizes diagrams to explain how the system elements work and to show how a change in one factor may impact other elements. Diagrammatic tools are useful to study policy issues and they can be used as the starting point for future model efforts that might incorporate social and physical variables.

The main systems tool used is the DPSIR (drivers, pressures, states, impacts and responses) model, which provides an overall view of the dynamics of flooding based on

diagrams and explanatory information. The problem architecture is explained by a process flow diagram. A general feedback model is used to explain how the components of the system and their interactions are identified, as well as how the feedback could alter the initial condition. A causal-loop diagram shows the influences among the elements of the overall system. Together these comprise a conceptual model that describes functionality, explains important components and processes, and identifies how the components and processes are connected. Institutional, technical, socio-economic and financial subsystems are identified.

The DPSIR Model was developed by the European Environmental Agency (2006) as a tool to analyze complex environmental issues. It shows how human activities and external forces (the driving forces) produce pressures that can induce changes (impacts) in the state of biophysical and socio-economic environments. Society then responds to changes in pressures or states with policies and other interventions.

Figure 2 shows the DPSIR framework applied to flood problems in Jakarta. Driving forces such as urbanization add to pressures such as expansion of land uses, which adds to risk. Impacts such as flood damage then elicit responses such as law enforcement.

Figure 3 is derived from the DPSIR model to show the problem architecture and explains how flood hazards result from a combination of physical exposure and human vulnerability to flooding. The problem architecture is arrayed by the subsystems shown.

Figure 4 explains the components of the system and their feedbacks. Inputs include alterations to the hydrologic and hydraulic systems, as well as to the initial geomorphologic and demographic conditions. The initial conditions could be related to natural conditions such as weather and topography or conditions that are driven by engineering, regulations or socio-economic changes. The processes are system behaviours related to flooding and the outputs are the consequences of the processes, which impact the socio-economic and environmental system and provide feedback to alter the initial conditions.

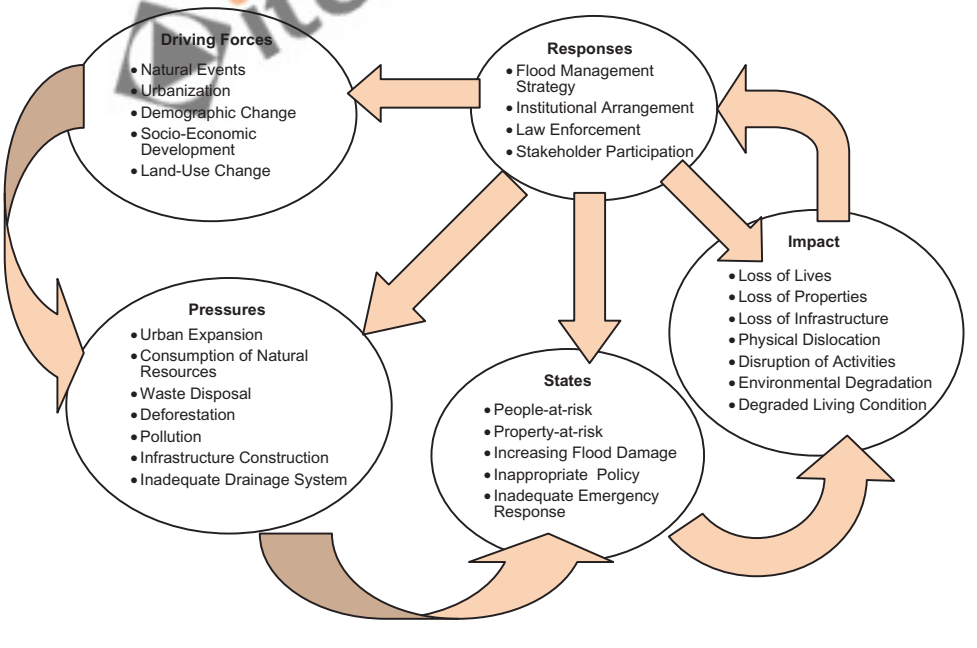

Figure 2. The DPSIR framework for flood problems.

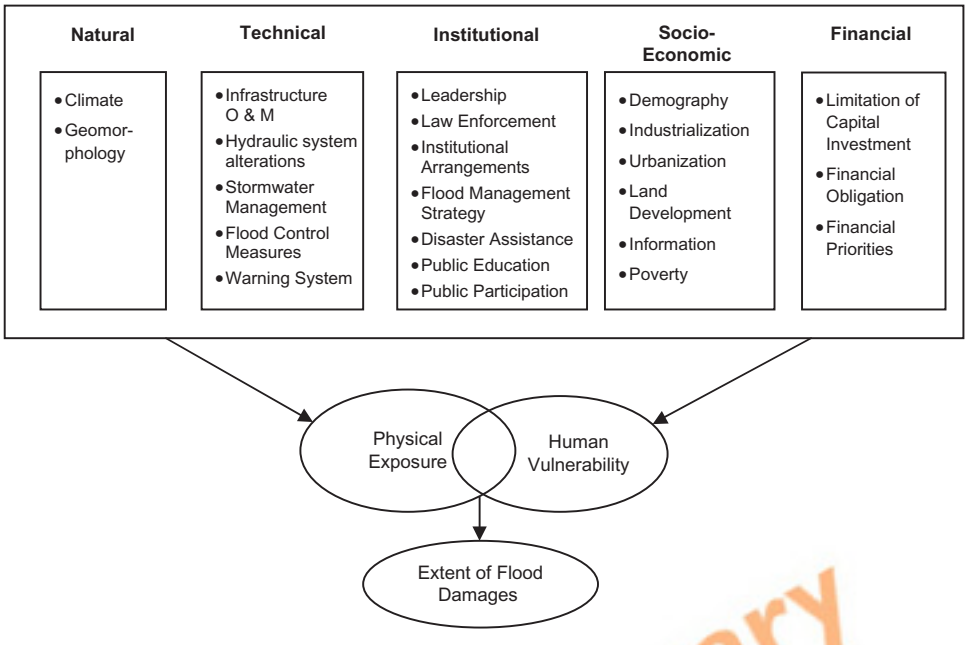

Figure 3. Factors contributing to flood problems in Jakarta.

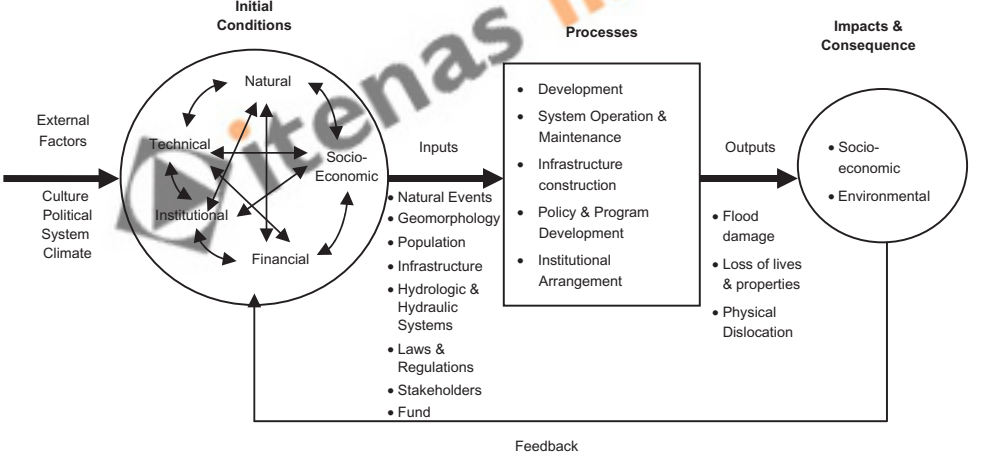

Figure 4. General feedback model.

A causal-loop diagram is a systems tool used at different stages of the analysis to conceptualize and communicate the problem structure. Widely used in systems applications, it consists of sets of nodes representing the variables, which are connected with arrows to show how the variables affect each other (Kim 1999). A plus (+) sign indicates a positive correlation, while a minus (−) sign indicates a negative one. Figure 5 shows the causal-loop diagram for Jakarta with the technical, institutional, socio-economic and financial subsystems outlined.

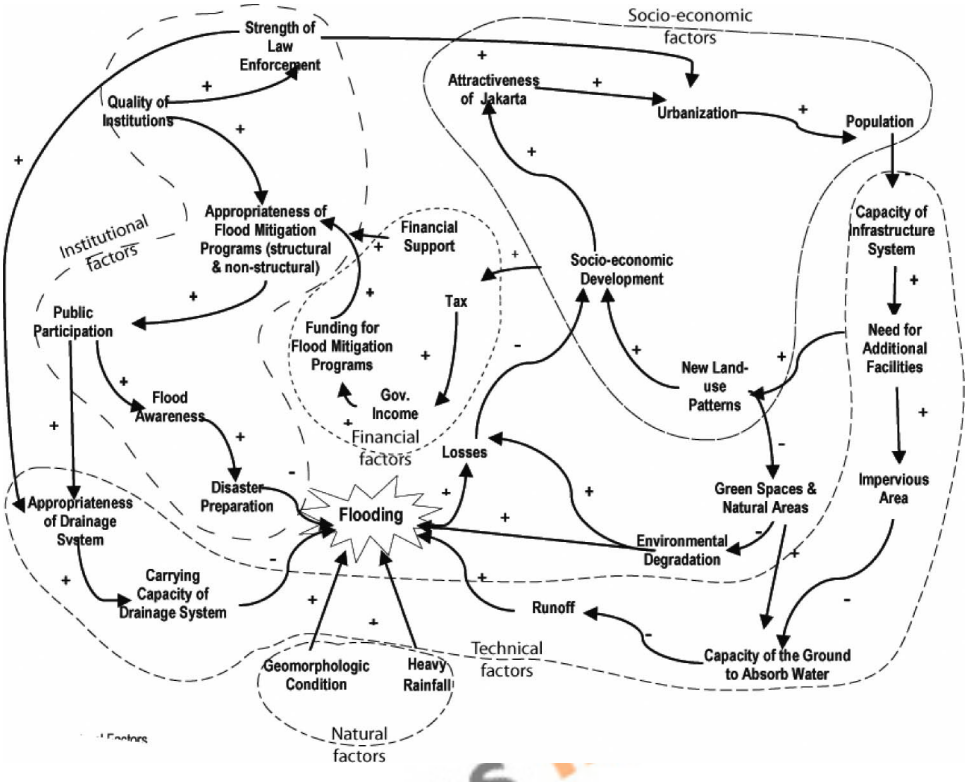

Figure 5. The causal-loop diagram for flood problem in Jakarta.

Analysis of the Jakarta case study

As explained earlier, Jakarta's flood problems are caused by inadequate public services for flood protection and drainage systems that have not kept pace with population growth. The large area below sea level, and legal and illegal developments, have decreased the infiltration capacity of the catchment area. Given these problems, the inadequate drainage and flood control systems are overwhelmed by heavy rain. After a long period of slow responses, it has been recognized that a broader approach is needed that includes better law enforcement, public participation and active stakeholder roles in flood management.

Table 1 shows existing flood mitigation activities in Jakarta. The table illustrates the structural and nonstructural measures that are supposed to take place to mitigate flood damage in the city.

The study sought to use surveys and interviews to test these activities to see how effective they are and to use the results to draw conclusions from the systems model.

Survey and interviews

To provide a better understanding of the flood-related problems in Jakarta, interviews were conducted with the local government, academicians, researchers, consultants, non-governmental organizations and citizen communities. The survey was based on questionnaires for communities in the municipalities of North, South, Center, West

Table 1. Flood mitigation activities in Jakarta.

Type of measures	Phase		
	Before	During	After
Structural measures	• Planning flood control projects • River improvement (dredging, widening channel and diversion) • Building flood control projects • Drainage pump placements	• Emergency flood control works	• Rehabilitation and reconstruction of affected facilities • Evaluation of flood control performance • Revision of flood control plan
Non-structural measures	• Spatial planning • Rainfall monitoring • Flood forecasting • Flood hazard mapping • Early warning system • Logistical planning • Public education and training • SOP planning • Assign shelter and evacuation route • Network establishment among agencies • Designating rescue team • Soil conservation • Flood proofing	• Monitoring of flood water levels and flood control facilities • Dissemination of flood warning • Designation of shelter and rescue team • Evacuation of people from inundated areas • Search and rescue of missing people • Resources mobilization • Distribution of food, drinking water, medical supplies • Collecting flood information	• Providing medical care and counselling • Returning displaced people • Cleaning up vital public facilities • Assessment of flood impacts • Inventory of number of victims and damages • Report and evaluation of the event • Maintenance of public infrastructure

and East Jakarta to gather information about current local conditions and the concerns and needs of the residents. About 350 questionnaires were distributed between 10 February and 11 March 2008. The questionnaire generated 181 responses from community residents, university staff, business and public offices, and the general public for a response rate of 51.7%.

The results of the survey and interviews showed the following opinions and status of awareness:

- Most respondents thought that natural and technical factors were the primary causes of flooding in Jakarta. Only 29.5% of the respondents believed that the dense population also contributed to the problem.
- Most of the respondents (58.9%) did not receive any warning. Only about 12% of the respondents heard flood warnings on local radio or television, and 18.9% witnessed them with their own eyes.
- About 40% of the respondents have knowledge about flood regulation policies for the Jakarta area. Most of them are East Jakarta respondents.
- Only 18.9% of the respondents indicated that their communities have some kind of flood mitigation programme. About 37% did not know about the programme, and 44.2% indicated that there is no flood mitigation programme in their neighbourhoods.
- Almost half of the respondents had not taken any action to make their homes flood-resistant, but they expressed great concern about reducing flood risk in their area. Most (78.9%) expressed interest in making their homes more resistant to flood hazard.
- Most (75.1%) of the respondents have not participated in any flood mitigation programme. About 56% expressed interest in participating.
- There is a lack of trust in the government. Only 15% of the respondents believed that the government has allocated funds appropriately to solve the flood problems.
- About 21% of the respondents believed that the local government has been responsive to solve the problem, while 67.4% of the respondents thought otherwise. Only 1.7% of the respondents felt that the local government had helped their community to a great extent. More than half of the total respondents (57.5%) stated that the government did not much help them during flood events.

Analysis and findings

By combining the theoretical analysis based on systems studies with the results of the survey and interviews, it is clear that serious and unsolved problems are caused by inadequate technical systems and institutional arrangements, leading to a great deal of suffering. Table 2 shows the summary of the major problems as well as causes and impacts of flooding in Jakarta for each of the subsystems in the systems study.

The causal-loop diagram (Figure 5) shows how the technical, institutional, socio-economic and financial aspects of the problem are related to each other, and it leads into the DPSIR framework (Figure 6), which describes the driving forces, pressures, states, impacts and responses for each aspect. Figure 6 presents the information contained in Table 2, with examples of the elements that belong at the different stages and levels of the analysis.

Table 2. Summary of major problems, causes and impacts of flooding in Jakarta.

Element	Major problems	Causes	Impacts
Technical	• Inadequate infrastructure system • Inadequate drainage system • Inadequate flood warning system	• Urbanization • Population growth • Poor city planning • Lack of maintenance • Outdated infrastructure • Low understanding of the Early Warning System (EWS) • Weak link to the flood affected community • Poor emergency management	• Additional infrastructure construction • Decreased infiltration capacity • Increased runoff • Decreased water retention • Decreased carrying capacity • Low trust in the EWS • Warnings not received by the communities in a timely manner
Institutional	• Fragmented institutions • Poor law enforcement • Low trust in the government	• Inadequate/weak governance • Lack of coordination among agencies • Low understanding of flood risk • Lack of transparency	• Unclear policies • Ambiguous and overlapping roles, responsibilities • Lack of disaster awareness • Lack of public participation • Lack of actions and commitment of both the community and the government
Socio-Economic	• Urbanization	• Attractiveness of Jakarta • Socio-economic motivation • Poverty	• Rapid population growth • Land use change • Illegal settlement • Socio-economic development • Environmental degradation
Financial	• Limited budget for flood mitigation activities	• Global economy • Developing country • Financial priority	• Inability of the local government to solve flooding problem in Jakarta

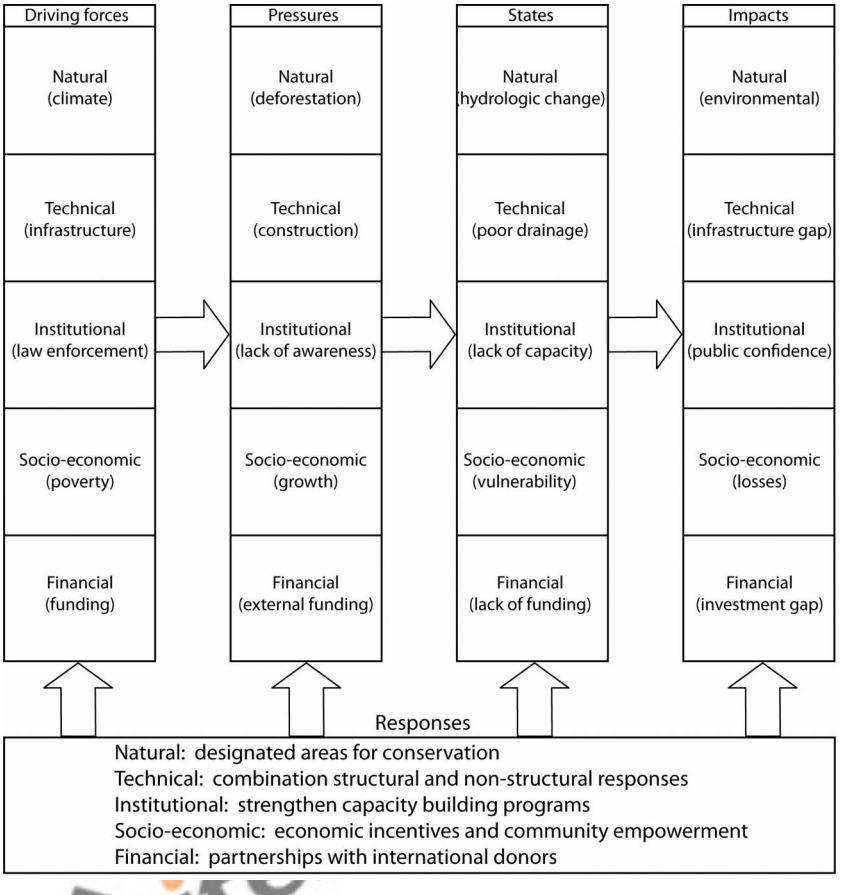

Figure 6. DPSIR framework and examples for flood problem in Jakarta.

Use of these tools enables us to perform a gap analysis and identify the major issues and responses in the technical, institutional, socio-economic and financial categories (Table 3). This creates a long list of responses and policy interventions that are needed, and which could be used for policy setting, programme development and/or new legislation.

Summary and conclusions

While it is generally known that flooding problems in Jakarta are beyond the capacity of technical solutions alone, the study showed details of how technical, institutional, socio-economic and financial subsystems of the urban area are inter-related to influence flood consequences. Policy studies of flooding in cities like Jakarta must recognize that integrated approaches are required to reduce the risk and mitigate the effects of flooding in complex socio-technical situations. The flood management system should be integrated with other urban subsystems, which display dynamic inter-sectoral behaviours.

Specific conclusions about Jakarta flooding, which may be useful to apply in other situations, are:

(1) The flood problem in Jakarta is caused not only by natural events but also by human activities that increase the risk of flooding and offer possibilities for non-structural

Table 3. Summary of major issues, gaps and responses.

Element	Major issues and gaps	Responses/policy intervention
Technical	Heavy reliance on structural solutions. There is a need to shift to non-structural solutions.	• Adopt both structural and non-structural measures • Promote collective flood strategies • Build culture of resilience
	Outdated and inadequate infrastructure system. There is a need to improve structures without damaging the environment.	• Rehabilitate and improve infrastructures • Integrate flood management into development planning • Develop policy for risk assessment • Control urbanization and population growth • Protect critical public infrastructures
	Inadequate drainage system O&M. There is a need to improve the system and educate people to maintain their environment.	• Establish technical training • Develop maintenance schedule • Improve solid waste management • Enhance law enforcement • Establish awareness programme
	Current Early Warning System does not yet reach community-at-risk in timely manner. There is a need to develop reliable EWS.	• Establish flood management information system • Prepare disaster map and vulnerability profile • Establish risk assessment at different levels and scales • Improve communication among stakeholders • Establish and maintain reliable EWS
Institutional	Fragmented institutions. Poor law enforcement exacerbates flood problem.	• Improve institutions for flood management • Publish and implement relevant policies and guidelines • Improve law enforcement
	Low trust in the government. Flood disaster management needs good governance and strong leadership.	• Enhance political will from the government • Improve law enforcement • Improve accountability and transparency • Improve communication with communities and agencies

(*Continued*)

Table 3. (Continued)

Element	Major issues and gaps	Responses/policy intervention
	Flood disaster awareness of flood risk is low resulting in inadequate capacity. Polices and mechanisms to address this issue are needed.	• Develop and disseminate relevant flood information • Develop/improve public education • Develop programmes on disaster preparedness training • Support stakeholders for flood mitigation programmes
	Level of public participation is low.	• Develop an integrated emergency response • Develop system for stakeholders' analysis • Develop legal and institutional framework • Develop mechanism to engage active participation • Systematically involve community in flood mitigation
Socio-Economic	Poor spatial planning. There is a need to alleviate poverty, control urbanization and avoid policies that will increase attractiveness of the city.	• Prepare and enhance land use maps • Improve land use planning • Develop system to update land use planning • Control urbanization and population growth • Develop strategies for poverty alleviation
	Inadequate mechanism to integrate flood issues with development planning.	• Incorporate flood disaster risk management into existing development strategies and policies • Create supportive policies and provide incentives
Financial	Limited budget for implementing flood mitigation programmes.	• Improve resources allocation for flood management • Develop sustainable funding mechanism • Promote alternative funding for mitigation programmes • Develop a system to distribute funds to communities and develop a monitoring mechanism.

improvements. Urbanization, lack of drainage capacity and inadequate system operation and maintenance exacerbate the problem; socio-cultural factors such as solid waste management are also important contributors.

(2) Economic development in developing country situations such as in Jakarta is accompanied by urbanization with rising demand for housing, water, sewerage and other urban services. Problems in meeting these demands may be compounded by poor spatial planning, poor public policy and ineffective law enforcement.

(3) Previous and current mitigation efforts fail to reach their targets due to: lack of awareness of disaster risk to communities living in flood prone areas; lack of direct participation from communities; cultures not conducive for effective integrated flood management; lack of dissemination of information; and lack of financial support.

(4) An integrated approach to flood risk assessment would consider a broad range of solutions with a mix of structural and non-structural measures. The prevailing precautionary approach for flood reduction measures without considering full flood risk is inadequate. Integrated long-term flood risk management can be more effective.

(5) An effective legal framework is required to provide a clear sense of direction with firm signals about changing culture. For practical reasons it may not be feasible to implement immediate reforms in the context of inadequate institutions, especially law enforcement. In the meantime, joint action of the community is required.

(6) The major challenges for flood management are socio-technical, such as strengthening coordination and cooperation among all stakeholders to support preparedness of institutions and communities. Community participation is an essential element to address local needs, engage people in flood disaster preparedness and build a culture of safety and sustainable development.

(7) While it is not possible or feasible to totally eliminate the flood risk, it should be recognized that floods also have some positive impacts. The challenge is to manage them as part of natural occurrences and take advantage of the beneficial aspects. This is in line with current thinking and the concept of integrated flood management, which shifts away from fighting floods towards managing risk and integrating flood control with other urban systems. In Jakarta, where most of the communities are adjusting to flooding, the approach should be focused on community resilience rather than costly total flood control. By increasing people's resilience to flood hazards, such an approach will enable people to live and cope with floods at the same time that improvements are made in other sectors.

In the final analysis, control of flooding is a daunting challenge in fast-growing megacities. Jakarta is a special challenge because much of its area is below sea level and is subject to heavy rainfall and increasing runoff from urbanization. With so many illegal residents and other problems of urbanization, the city will be hard-pressed to respond systemically to flood threats, but it can implement low-cost measures that engage the residents while seeking larger-scale solutions and the capacity to build and maintain new infrastructure.

In the future, a mix of structural and non-structural measures will be required. Appropriate structural measures have a place in a comprehensive strategy, and they must be maintained and improved. It is important to integrate flood management into development planning and to begin to gain ground on the problems of development in the catchment areas and of land use in the city. Planning for mitigation should be based on a disaster map and vulnerability profile with risk assessment at different levels and scales. Measures to

control urbanization and population growth would help greatly. The city should incorporate flood risk management into existing development strategies and policies. An effective and reliable early warning system would enable residents to adjust better to flooding if coupled with an integrated emergency response programme.

In 2007, Indonesia passed a Disaster Management Law (No. 24/2007), but implementation must be phased in over many years. Meanwhile, the local government should enforce current laws and enable people to manage their immediate environments. Lack of effective empowerment of the community and inadequate local institutional capacity building, coupled with lack of coordination and financial capability, have been major problems.

Effective law enforcement with improved solid waste management would reduce clogging of drainage systems. Most importantly, a culture of resilience must be developed through collective flood strategies, greater public awareness and a flood management information system. All of these strategies will require the government to approach the flood problem on a more systematic basis.

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