Re-framing Infrastructure Investment Decision-Making Processes: A Preliminary Scoping Study for Urban Flood Risk Management in Jakarta, Indonesia

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Jakarta, Indonesia's chronic housing shortage poses multiple challenges for contemporary policy-makers. While it may be in the city's interest to increase the availability of housing, there is limited land to do so. Market pressures, in tandem with government's desire for housing availability, demand consideration of even marginal lands, such as those within floodplains, for development. Increasingly, planning for a flood resilient Jakarta is complicated by a number of factors, including: the city is highly urbanized and land use data is limited; flood management is technically complex, creating potential barriers to engagement for both decision-makers and the public; inherent uncertainty exists throughout modelling efforts, central to management; and risk and liability for infrastructure investments is unclear. These obstacles require localized watershed-level participatory planning to address risks of flooding where possible and reduce the likelihood that informal settlements occur in areas of extreme risk.

This paper presents a preliminary scoping study for determination of an effective participatory planning method to encourage more resilient development. First, the scoping study provides background relevant to the challenges faced in planning for contemporary Jakarta. Second, the study examines the current use of decision-support tools, such as Geographic Information Systems (GIS), in planning for Jakarta. Existing capacity in the use of GIS allows for consideration of the use of an emerging method of community consultation - Multi-Criteria Decision-Making (MCDM) support systems infused with geospatial information - to aid in engagement with the public and improve decision-making outcomes. While these methods have been used in Australia to promote stakeholder engagement in urban intensification, the planned research will be an early introduction of the method to Indonesia. As a consequence of this intervention, it is expected that planning activities will result in a more resilient city, capable of engaging with disaster risk management in a more effective manner.

Key Words: *flood risk management, MCDM, GIS, decision-support tools, participatory planning*

1. INTRODUCTION

Urban populations in both developed and developing countries increasingly dwell in hazardous environments. In the context of this paper, flood risk is defined as the expected value of damage due to flood hazard and vulnerability, including potential damages to socio-economic systems, terrestrial systems (hydrological systems and ecosystems) and exacerbated vulnerability to climate change[1)2)]. Urban encroachment into floodplains

requires localized watershed-level management efforts to address risks of flooding. Similarly, there is uncertainty of risk and liability of these problems since there might not be a clear information related to land use availability. Private developers potentially do not understand about the risk, or there is no other choice instead of using the marginal land. Decision-makers are often asked to consider infrastructural solutions to flood management as buy offs are potentially too costly where land supplies are limited.

This paper presents a preliminary scoping study of a method for increasing engagement in planning for resilient cities, particularly those faced with recurrent extreme flood events. First, the paper summarises background information relevant to problems of housing shortages and flood risk in Jakarta. Then, the paper examines Jakarta's flood risk management infrastructure investments, with particular attention to the incorporation or potential for incorporation of decision-making support tools. The city's existing use of GIS systems is briefly described, establishing that there is sufficient technical expertise to support potential adoption of technology into planning consultation. MCDM is then introduced as a potential tool, with brief exploration of existing applications in other settings, for increasing effectiveness of engagement in planning. Finally, the paper offers guidance for the incorporation of MCDM into future flood plain risk management planning efforts in Jakarta, with particular attention to opportunities and constraints on such incorporation, and how they might be overcome.

2. JAKARTA'S URBANISATION AND FLOOD RISK MANAGEMENT CHALLENGES

This section of the paper is divided into two discussions. First discussion provides an overview of the underlying characteristics of the contemporary Jakarta before moving into description of the city's flood problems.

(1) Characteristics of Contemporary Jakarta

Jakarta is the capital of Indonesia, which has a population of about 9.6 million people in 2010 with total households of about 2.2 million, inhabiting an area of about 661.52 km2[3)4)8)]. This capital city is vulnerable to environmental change due to its location on the northern coast of Java Island as shown in **Fig. 1**. Researcher has listed Central and North Jakarta as the most vulnerable city to climate change in Southeast Asia[6)]. In the northern area Jakarta, about 40 percent of the city is below sea level[7)]. North Jakarta is vulnerable not only to rising sea water, but also flood water from Jakarta's rivers.

Fig. 1 Map of Jakarta, Indonesia[8)]

Jakarta is also a magnet for people looking for better living conditions. 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[9)]. These include poor people who came to Jakarta. There are also slum areas in several parts of Jakarta where many of these are at risk from flooding, one must first obtain information on the environmental conditions of Jakarta[10)]. Strong and sustained

growth in Jakarta's population and economy have resulted in a vast increase in the urbanized area and land use change. In 2010, the population of Jakarta Metropolitan Area has already reached 27.9 million[11]. **Table 1** presents data on the scale and speed of population growth in Jakarta.

Table 1 Population Growth of Jakarta Metropolitan Area (JMR) According to 2010 Census[11]

DKI Jakarta (Special Territory of Jakarta) with area about 660 km^2			**Jakarta Metropolitan Region (Jakarta, Bogor, Tangerang, Bekasi) with area about 7,500km^2**		
Year	**Population ('000)**	**Mean density ('000/km^2)**	**Year**	**Population ('000)**	**Mean density ('000/km^2)**
1971	4,579	6.9	1971	8,374	1.1
1980	6,503	9.9	1980	11,485	1.5
1990	8,259	12.5	1990	17,105	2.3
1995	9,113	13.8	2000	20,438	2.7
2000	8,389	12.7	2010	27,940	3.7
2005	8,864	13.4			
2010	9,588	14.5			

(2) Jakarta's flood problems

Jakarta is located in a deltaic plain of 13 natural rivers and more than 1,400 km of man-made waterways. Naturally, Jakarta's site is highly prone to flooding from water draining through the city from the hills in the south, and also from coastal tidal flooding such as that experienced in 1996, 2002, 2007 and 2013[3)7)10)]. Severe floods took place in Jakarta which at times inundated more than half of the city mostly due to heavy rain, clogged pipes and waterways, deforestation, and inadequate drainage and flood control systems[9)]. **Table 2** summarizes historic flood events and their impacts on the city, while **Fig. 2** indicates the extent of flooding associated with the 1996, 2002, and 2007 events and gives indications of infrastructure investments and policies to address flood risk.

Table 2 Floods Hazard Summary from 1996-2013

Flood Event	**Rainfall Intensity**	**Inundation Area**	**Evacuees**	**Deaths**	**Economic Impacts**
1996	288.7 mm[12)]	unknown	30,000[12)]	10[12)]	US$100M[12)]
2002	361.7 mm[12)]	330 km^2[12)]	380,000[12)]	22[12)]	US$180M[12)]
2007	401.5 mm[12)]	400 km^2[12)]	590,000[14)]	79[14)]	US$998M[9)]
2013	125.0 mm[12)]	> 400 km^2[12)]	18,000[14)]	15[14)]	US$ 2000M[13)]

Economic impacts presented are as a consequence of flooding and include loss of property and businesses, and do not include impacts which are difficult to cost such as spread of illness and loss of life and loss of access to clean water. Depending on the severity of the flood, there can also be effect traffic circulation, business activity, damage to property, power outages, displacement, and spread of disease. Population growth and land subsidence of around 10 cm per year are further aggravating the situation[8)].

Jakarta is exposed to multiple hazards both natural and compounded by climate change and other man-made factors. These exacerbated impacts of flooding which caused very high human and economic costs on the city. The floods of February 2007 were the worst in the history of the Indonesian capital[3)4)]. About 70 percent of the urban area was affected. Seventy nine people died and a total of 400,000 people were affected. Floodwaters destroyed one hundred houses located in informal settlements[3)4)9)]. The flood caused about US$998 million in total losses[9)].

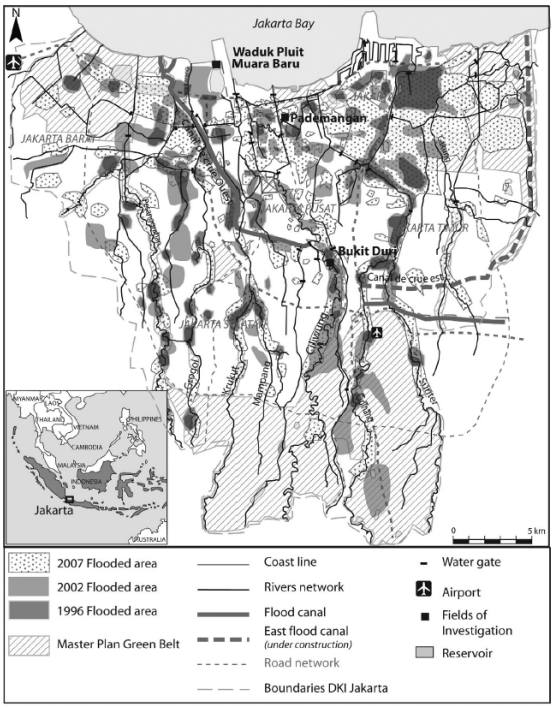

Fig. 2 Flood Map of Jakarta[3)]

In brief, the scope of damage shows how vulnerable the communities living in Jakarta are. Five-year flood has become a crucial threat for Jakarta as capital city. This is challenging all of the decision makers to be more critical to flooding. Regarding this shortcoming, Jakarta's response to flood need to be well understood. The next section describes the existing Jakarta's response to flood.

3. EXISTING JAKARTA'S RESPONSE TO FLOOD

This section explores the existing solutions to flood, including structural and non-structural measures, as supportive information to the next section. This section illustrates the flood response to build an understanding of flood risk management infrastructure investments of Jakarta.

In many regions, encroachment as well as development in flood prone areas increasingly affects the damage potential[1)]. Related with this shortcoming, assessment of the solution to flood hazard is only indicative since the performance of the technological options is associated to a large extent with case specific characteristics and cannot be easily generalized[15)]. Researcher argues that floods are best managed within the context of the natural environment in which they originate rather than the administrative area in which they occur[2)].

Regarding Jakarta's flood, for decades, flood prevention and mitigation measures were emphasized with protection based on costly technical measures, which proven not enough as exemplified by the January 2013 floods. 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. Moreover, most flood mitigation activities have been carried out by the government with incorporation of public participation, especially in land acquisition and environmental management. Meanwhile, rapid population

growth and incorporation of law enforcement have contributed to the problem. Jakarta Government focuses on natural hazard strategies rather than reducing vulnerability.

While adaptation policy is developed at national level, differences in physical environment, land use and population make the task of implementing adaptation strategies a task best carried out at regional and local scale[16]. This result in arising of urban flood risk management options varying from technical options to non-technical options or communication strategies[17][18].

In 2010, the Province Planning Agency (*Badan Perencanaan Pembangunan Daerah*) in coordination with Province Department of Public Works (*Dinas Pekerjaan Umum*) initiated a master plan for flood mitigation in Daerah Khusus Ibukota (DKI) Jakarta[8]. This master plan consists of several structural measures, including: drainage improvement, river improvement, improvement of retention ponds, coastal defense and road protection. In order to mainstream risk reduction, the government is incorporating those activities and projects into the long-term spatial plans, the most recent of which is Jakarta's plan for 2010–2030. This master plan outlines the long term vision of Jakarta and highlights three key principles, including: focusing on growth management, metropolitan area functional based planning (including Jakarta, Bogor, Depok, Tangerang, Bekasi, Puncak, Cianjur) and paradigm shift from 'stakeholders' to 'shareholders'.

Table 3 summarizes large-scale infrastructure projects, including Jakarta Coastal Defense that protects coastal neighborhoods from tidal surges, and the East and West Flood Canals. The Jakarta Coastal Defense has been presented to the Jakarta government as a feasibility study. East and West Flood Canals are the largest and most ambitious projects for Jakarta in terms of flood management, but the smaller secondary and tertiary systems are still under-managed and inadequate. The largest infrastructural project on water management of the recent years is the East Flood Canals, completed in 2011 at a cost of 4.9 trillion IDR (US$500 million)[8]. Another important planned project is World Bank funded Jakarta Urgent Flood Mitigation Project, in which 13 canals in Jakarta will be dredged, costing US$150 million[8].

Table 3 Large-Scale Environmental Infrastructure Investments in City of Jakarta's Annual Budget[7]

	2009	**2010**
Flood control		
East flood canal	US$93.13M	US$60.35M
Drainage and river dredging	US$10.80M	US$11.42M
Dam, polder, and catchment area development	US$0.62M	US$40.61M
TOTAL	US$104.55M	US$112.38M
Pollution containment		
Open green space development	US$15.91M	US$77.24M
Climate change adaptation		
Sea Wall	US$2.24M	US$5.59M

Although technical measures continue to dominate, there have been more investments in non-structural measures, including: awareness raising, law enforcement, upper watershed planning and management, early warning system, spatial use control and urbanization control. Those existing flood's solutions mentioned above provided information related to how Jakarta government addressed flooding problem as a critical obstacle. However, there is no information related to decision-support tools used in the decision-making process. The next section examines decision-support tools to urban flood risk management infrastructure investments in Jakarta.

4. EXISTING & POTENTIAL USE OF DECISION SUPPORT TOOLS

This section examines the existing decision-support methods to urban flood risk management infrastructure investments. This section is divided into three discussions, including: current use of GIS in communicating flood risk, opportunities for use of MCDM tools in the decision-making process, and challenges to the use of decision-support tools to increase city's resilience. The discussion of this section is evaluated based on theory relevant to decision-support tools to effectively improve participatory planning in urban flood risk infrastructure investments.

(1) Current use of GIS in communicating flood risk

To move on overcoming technical complex related to urban flood risk options, implementing spatial analysis might be very useful. A spatial analysis consists of at least two elements, including: action and location, which can be specified explicitly or implicitly[19]. GIS is one of the spatial analysis tools. This includes the visualizations of predicted hydrographs, ensembles, or zones of flood inundation and the interpretation of the predictions in terms of flood warning and planning maps[20].

Jakarta has spatial information which is located in several agencies, not only at the provincial level, but also at national level. The GIS is mainly used for urban planning (creating land use map), unfortunately it is not integrated yet with the other social and economic data in one system. Therefore, it is not easy to superimpose the map with other information to allow spatial or intersectional analysis. There is also an incorporation of information in terms of types and depth of scale related to flood which is available in Jakarta. The incorporation of available data also makes it difficult to conduct any meaningful assessment of the climactic conditions in Jakarta, such as long time series data on rainfall, baseline data on tides and the daily measurement of temperatures [20].

Therefore, there are a lot of efforts that must be done in relations to preparing Jakarta to cope with flooding. There is a need to collect baseline information on factors related to flood and constructing appropriate indicators to assess the impact of flood[20][21]. There are also plenty of opportunities to conduct research stemming from the availability of the data in providing GIS information base to support adaptation policy, such as defining the need of data or information and the appropriate systems application to support the information.

Flood risk management plan that integrates the GIS and MCDM might show comprehensive information including hydrologic models, flood information systems, social-environmental databases, and flood mitigation and adaptation action for decision makers[19][21]. The opportunities for use of MCDM tool in decision-making process of Jakarta flood response is examined in the next discussion.

(2) Opportunities for use of MCDM tools to improve decision-making processes

Human reasoning and decision-making is very often based on uncertainty embedded in natural language[22]. MCDM is a collection of methodologies to compare and select multiple alternatives that involve disproportional attributes[21]. MCDM is useful not only for improving coordination among governments, Non Governmental Organisation (NGO), and community but also for modelling the flood preferences of those decision-makers.

The government's policy should focus on reducing structural vulnerability. However, the official policy of Jakarta government to face flooding does not address the deep causes of vulnerability but rather emphasizes natural hazards. It focuses on technical measures to control floods and public awareness campaigns to enhance low perception of risk. In many ways, Jakarta government is only beginning to comprehensively measure and understand the city's key vulnerabilities to become climate-resilient and to anticipate potential disasters.

It is crucial to integrate community-based planning and local coping mechanisms and knowledge into the official urban flood risk management system. However, incorporation of coordination between the decision-makers has been challenging. There are several factors influencing the decision-making in the planning processes, as can be seen in **Fig. 3**, which might be barriers to decision-makers to gain a consensus plan that is implementable. Therefore, NGO may play significant roles to aid communities and community-level governments to educate individual citizens, families, and community leaders to prepare for damaging flood events.

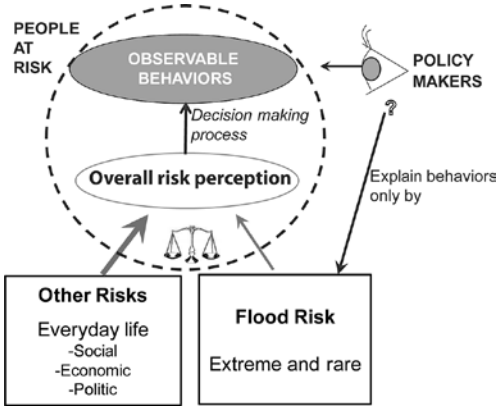

Fig. 3 Factors influencing decision-making process of flood response in Jakarta[3)]

However, integrating climate change adaptation and education into planning for social services and community awareness is new for Jakarta government. It has only been in 2011 that DKI Jakarta has been engaging with local NGOs and other organizations and funders to develop and understand community resilience specifically toward risk management related to climate change. Regarding those difficulties relevant to coordination and community engagement in the planning process, MCDM has the potential to improve collaborative decision-making process by providing a flexible problem-solving environment where those involved in collaborative tasks can explore, understand, and redefine a decision problem. This method, which was integrated with geo-spatial technologies, has been used as stakeholder engagement tools in urban planning and development in Australia[23)]. This allows transfer of knowledge about flood processes. The use of this decision-support tool for flood risk management can help to facilitate coordination among flood agencies, organizations, and affected citizens in the floodplain.

(3) Challenges to the use of decision-support tools to improve resilience

Many countries have enacted environmental regulations that require a comprehensive multiple criteria analysis as a part of water resources planning and management. While the flood risk management process has been extensively discussed at the national and international levels, more effort is needed to examine the preferences, needs, and 'changing value systems' of actors involved in the flood management process[20)].

However, benefits from urban flood risk management infrastructure investment to society might not optimal. There might be technical or engineering solutions, structural and non-structural, to overcome flooding issues but the implementation could be inappropriate. As a result, those solutions could not be optimalised so that the city as well as the society is challenging the flood impacts. These shortcomings were face by Jakarta, which is exposed to multiple hazards both natural and compounded by climate change and other man-made factors. The following **Table 4** summarizes challenges to the use of decision-support tools in improving Jakarta's resilience.

Regarding Jakarta's flood solutions, there is no uniform or agreed upon format for risk assessment or investment decision-making. Many stakeholders consider this as an obstacle that hampering development. One measure that can be taken is standardization. Most agencies, excluding Department of Spatial Planning and Provincial Government of DKI Jakarta, do not have expertise in how to apply geospatial information. On one hand, although Jakarta government has several large-scale infrastructural projects as well as master plans related to flood risk management, there is incorporation coordination amongst decision makers as mentioned above. In addition, people do not understand the risk of flooding so that the public awareness to contribute in flood resolution has not been optimally realized. This shortcoming might result in ineffective governmental projects and planning because each stakeholder, including Jakarta citizens, is playing an important role.

In the context of flood risk management, much of what is labelled as 'adaptation' could just be described as 'good practice'[24)]. However, adaptation is limited by awareness and understanding of both methods of adaptation and of risks. Effective engagement in decision-making requires access to information, technical literacy,

institutional flexibility and permeability, as well as a desire for increased resilience. Similarly, the probability that research will deliver benefits to society further increases when decision makers have reasonable expectations of what types of information science can provide, and when they are able to apply and evaluate scientific research[25].

Table 4 Challenges to the Use of Decision-Support Tools[8]

Decision-Support Tools	**Challenges**
GIS	Sharing data with other agencies is not common practice. This could be due to the fact that geospatial data is mainly used on project basis. IT and GIS capacity is not available within most of the agencies. It is critical that both the technical tools and the political relationships are developed to support better management and sharing of data amongst the government stakeholders.
MCDM	The urban investment decision-making process in Jakarta is part of a complex a budgeting process stretching across multiple levels of government. It is important to distinguish stakeholders with an investment decision-making role versus technical data or information providers.

In the case of Jakarta, decision-support tools in flood risk management infrastructure investments of Jakarta need to be enhanced. Jakarta government has implemented decision-support tool but has not fully addressed the information clarity to transfer knowledge and to facilitate coordination amongst decision makers. 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.

5. CONCLUSION

In brief, the success of urban flood risk management infrastructure investment implementation depends on how the problems as well as the options could be comprehensible by the decision makers. The Jakarta Spatial Plan 2030 integrating current and future climate change vulnerabilities within broader government policy aims and implementation programmes. It outlines a long-term vision for the city, but explicitly looks to integrate different scales, policy fields and institutions in the short term.

Although many laws and regulations are in place in Jakarta to deal with flood-related issues, to date participatory planning in terms of urban flood risk management infrastructure investments is limited. There are barriers challenging government's institution to manage data and activities relevant to flooding. This challenge may due to the incorporation of capacity to develop a participatory approach, from local to regional level. 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. In this context, transparency and clarity of technical analysis to communication to decision makers are very important. Decision-makers should be able to understand the public's perception of flood risk in order to address disasters effectively through participation approach using decision-support tools, which potential to gain an implementable planning.

This paper suggests that policies and investments should be based on improved information, an understanding of community actions and adaptive capacities. Collaboration with the administrations of neighboring provinces, as well as with the local communities as active participants and partners is crucial to the success of long-term action. Therefore, capacity building should be emphasized at every level. The using of decision-support tools potentially effective in improving urban flood risk management infrastructure investments towards participatory approach. There is a significant learning curve in terms of first thoroughly understanding, and then communicating, how climate change affects Jakarta.

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REFERENCES

1) Kundzewicz, Z. W., Hirabayashi, Y., & Kanae, S.: River floods in the changing climate-observations and projections. *Water Resources Management, 24*(11), 2633-2646, 2010.
2) Lamond, J. : *Flood hazards: Impacts and responses for the built environment.* Hoboken: CRC Press, 2011.
3) Texier, P.: Floods in Jakarta: when the extreme reveals daily structural constraints and mismanagement. Disaster Management and Prevention, 17, 358–372, 2008.
4) Ward, P. J., Pauw, W. P., van Buuren, M. W., and Marfai, M. A. : Governance of flood risk management in a time of climate change: the cases of Jakarta and Rotterdam, Environmental Politics, DOI:10.1080/09644016.2012.683155, 2012
5) Prasad, Neeraj; Ranghieri, Federica; Shah, Fatima; Trohanis, Zoe; Kessler, Earl; Sinha, Ravi : *Climate resilient cities : a primer on reducing vulnerabilities to disasters*. Washington D.C. - The World Bank, 2009.
6) Yusuf, A. A., and Francisco, H.: "Climate change vulnerability mapping for Southeast Asia." *Economy and Environment Program for Southeast Asia*, 2009.
7) Dickson, Eric; Baker, Judy L.; Hoornweg, Daniel; Tiwari, Asmita: Urban risk assessments: understanding disaster and climate risk in cities. Urban development series. Washington D.C. - The World Bank. 2012.
8) World Bank: Tools for building urban resilience: integrating risk information into investment decisions pilot cities report - Jakarta and Can Tho. Washington D.C. - The World Bank, 2011.
9) Akmalah, E. and Grigg, N. S.: Jakarta flooding: systems study of socio technical forces, Water International, 36:6, 733-747, 2011.
10) Surbakti, I.M., Idroes, I.C., Simarmata, H.A., and Firman, T. : Jakarta City Report : Information related to climate change in Jakarta City, Workshops of Climate Change Vulnerability Assessment and Urban Development Planning for Asian Coastal Cities, Rose Garden Sampran Riverside, Nakorn Pathom, Thailand, 22 – 28 August, 2010.
11) Abidin, H. Z., Andreas, H., Gumilar, I., Fukuda, Y., Pohan, Y. E., & Deguchi, T. : Land subsidence of Jakarta (Indonesia) and its relation with urban development. Natural hazards, 59(3), 1753-1771, 2011.
12) Sagala, S., Lassa, J.A., Yasaditama, H. and Hudalah, D. : The evolution of risk and vulnerability in Greater Jakarta: contesting government policy in dealing with a megacity's exposure to flooding, 2013.
13) http://www.antaranews.com/en/news/87013/jakarta-may-suffer-rp20-trillion-in-losses-due-to-flood-governor
14) http://www.republika.co.id/berita/nasional/umum/13/01/20/mgwpka-banjir-2007-lebih-parah-ketimbang-2013
15) Makropoulos, C. K., & Butler, D. : Distributed water infrastructure for sustainable communities. *Water Resources Management, 24*(11), 2795-2816. doi: http://dx.doi.org/10.1007/s11269-010-9580-5, . 2010.
16) Foley, A. M.: Uncertainty in regional climate modeling: A review. *Progress in Physical Geography, 34*(5), 647-670. doi: http://dx.doi.org/10.1177/0309133310375654, 2010.
17) de Graaf, R., van de Giesen, N., & van de Ven, F. : Alternative water management options to reduce vulnerability for climate change in the Netherlands. Natural Hazards, 51(3), 407-422. doi: http://dx.doi.org/10.1007/s11069-007-9184-4, 2009.
18) Wright, J. M.: Chapter 7, Flood damage reduction strategies and tools. Floodplain management: principles and current practices (pp. 7.1-7.17). Knoxville: The University of Tennessee Press, 2007.
19) Malczewski, J.: GIS-based multicriteria decision analysis: a survey of the literature. *International Journal of Geographical Information Science, 20*(7), 703-726. doi: 10.1080/13658810600661508, 2006.
20) Faulkner, H., Parker, D., Green, C., & Beven, K. : Developing a translational discourse to communicate uncertainty in flood risk between science and the practitioner. *Ambio, 36*(8), 692-703. doi: 10.1579/0044-7447(2007)36[692:datdtc]2.0.co;2, 2007.
21) Levy, J. K.: Multiple criteria decision making and decision support systems for flood risk management. *Stochastic Environmental Research and Risk Assessment, 19*(6), 438-447. doi: 10.1007/s00477-005-0009-2, 2005.
22) Constantino, N., d'Amato, M., & Pellegrino, R.: A real options and fuzzy delphi-based approach for appraising the effect of an urban infrastructure on surrounding lands. *Fuzzy Economic Review, 14*(2), 3-16, 2009.
23) Glackin, S.: Redeveloping the grey fields with envision: using participatory support systems to reduce urban sprawl in Australia. *European Journal of Geography, 3(3),* 6-22. 2012.
24) Wilby, R. L., & Keenan, R.: Adapting to flood risk under climate change. *Progress in Physical Geography, 36*(3), 348-378.doi: http://dx.doi.org/10.1177/0309133312438908, 2012.
25) Sarewitz D, Pielke JRA: The neglected heart of science policy: reconciling supply of and demand for science. *Environmental Science and Policy, 10*: 5–16, 2007.