Analysis and Evaluation of the Flood Risk Management Practices in Selected Megacities

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DECLARATION

I hereby declare that "The Analysis and Evaluation of the Flood Risk Management Practices in Selected Megacities" is my own work and efforts. All sources that I have used or quoted have been acknowledged by means of complete references.

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ABSTRACT

Many megacities around the world are facing increasing flood risks, especially within the changing climate. Having a sound and efficient flood risk management system in place is therefore of vital importance. This study selects three megacities – London, Shanghai and Bangkok as case cities, the flood risk management (FRM) practices of which are analysed and evaluated with the aim of examining the strengths and weaknesses of the current FRM practices in megacities. The examination is done through the comparison of the current FRM practices in the three selected megacities and the integrated flood risk management (IFRM) framework and associated indicators and criteria identified from scientific literatures as well as international practice guidelines. A survey in form of questionnaires, together with document examination is used to derive the current FRM practices in the three megacities. Result shows that London has a strong FRM system that fits well to the identified IFRM framework and presents good performance. Shanghai's FRM system is currently functioning due to its high standard of protection through structural measures. Its main weakness lies on the flood risk management process, especially with respect to effective stakeholder collaboration and long-term strategies for coping with future changes. Bangkok has, among the three megacities, the weakest FRM system. Bangkok's weakness lies on both the technical aspect, such as flood hazard analysis, and its flood risk management process. Effective stakeholder participation and collaboration as well as the enforcement of FRM supporting legislations are the two priorities that Bangkok needs to work on regarding its FRM process. The evaluation of the current FRM practices in the selected megacities has demonstrated that the shift from defensive approach to IFRM is still on-going and developing cities/countries usually present greater weakness in their FRM processes.

Keywords

Integrated Flood Risk Management (IFRM), Flood risk management practice, Megacity, London, Shanghai, Bangkok.

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List of Abbreviations

ABI	Association of British Insurers
ADB	Asian Development Bank
ADPC	Asian Disaster Preparedness Center
BMA	Bangkok Metropolitan Administration
BPF	British Property Federation
DEFRA	Department for Environment Food and Rural Affairs
EA	Environment Agency
ESOF	Euroscience Open Forum
EU	European Union
FMMP	Flood Management and Mitigation Programme (Thailand)
FRM	Flood Risk Management
ICE	Institute of Civil Engineers
IFRC	International Federation of Red Cross and Red Crescent Societies
IFRM	Integrated Flood Risk Management
IPCC	Intergovernmental Panel on Climate Change
M-IWRMP	Mekong-Integrated Water Resources Management Project
ONS	Office for National Statistics
PPS 25	Planning Policy 25: Development and Flood Risk
UKCIP	UK Climate Impacts Programme
UNDP	United Nations Development Program
UNDP GRIP	UNDP Global Risk Identification Program
UNISDR	United Nations International Strategy for Disaster Reduction
UNU-EHS	United Nations University – Institute for Environment and Human Security
WMO	World Meteorological Organization

Chapter 1 Introduction

1.1 Background

Flooding has been accompanying the human history since the very first day. The easy access to water and the fertile land resulted from regular flooding has nurtured the development of human species. For a long time, flood was seen as a gift from nature and floodplains were the first choice for settlement. It was never a big problem.

However, with the development of human history, especially the population growth, land use changes (e.g. urbanization, deforestation) and the industrialization, flooding has become an increasingly threatening issue in the last few hundred years.
Today, flood ranks the most frequent among all natural disasters (Jha et al. 2011). Particularly in the past 20 years the number of reported floods has increased significantly, as shown in Figure 1 (EM-DAT 2012).

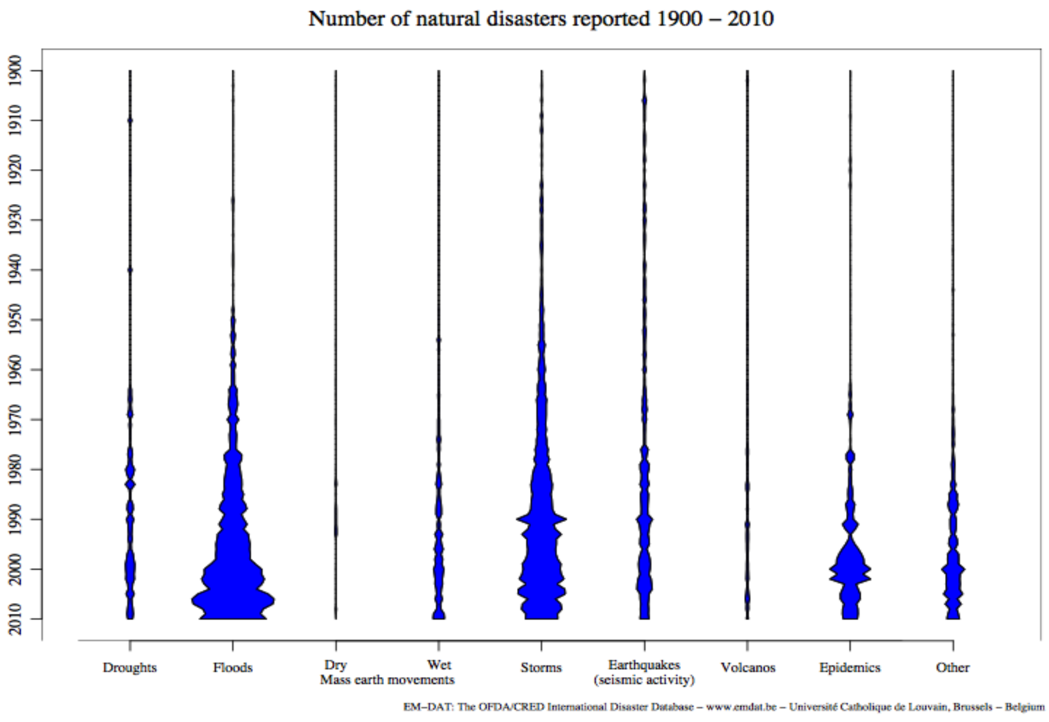

Figure 1. Number of natural disasters reported from 1900 to 2010 (EM-DAT 2012)

According to the International Federation of Red Cross and Red Crescent Societies (IFRC), in the 10 years from 1993 to 2002 flood disasters 'affected more people across the globe (140 million per year on average) than all the other natural or technological disasters put together' (IFRC 2003).

Over the past two years, a series of severe flood events have struck areas across the world. According to the EM-DAT database (EM-DAT 2012), 265 flood events are reported for year 2010 and 2011, of which 98 are in Asia; 72 in Africa; 53 in the Caribbeans, Central, South and North America; 35 in Europe and 7 in the Oceania area.

Among all the land uses that could be affected by flooding, urban settlement is of special risk because of its traditionally high population density and assets value. Flood affects urban settlements of all types, from small villages and mid-sized market towns, to major cities, megacities and metropolitan areas like Sendai, Brisbane, New York, Karachi and Bangkok, all of which have been struck by recent floods (Jha et al. 2011).

Hazardous sites are frequently the ones with the greatest locational advantage for situating human activities, the populations associated with them, and the urban centres in which they are located (Jones et al. 1992). According to the 2006 Euroscience Open Forum (ESOF) in Munich, half of the world's population lives within 200 kilometres of the ocean and 70% of the megacities are along the coast (ESOF, EU 2006).

With the background of climate change, which leads to global sea level rise and more frequent floods in certain areas, many of the megacities around the world are now facing increasing risks concerning coastal and estuarine floods. Megacity, with its distinguished characteristics of very high population density, large sealed surface, high land use values and assets and its very complex social-economical systems, is extremely vulnerable to natural disasters including floods. The very complex systems of megacities are especially troublesome in that a single physical episode of inner flooding can trigger the spread of secondary and tertiary effects on other social systems or organizations, resulting in the collapse of entire systems supporting urban communities (Ikeda et al. 2008).

Once a megacity is hit by destructive flood, the loss of life and economic losses are far more severe than that of small urban settlement or rural areas. Moreover because of their highly complex systems, the recovery and resilience after a flood disaster is often rather difficult as well as time and economically consuming. Therefore, a sound and efficient flood risk management system is of vital importance for megacities.

There are already researches relate to FRM in megacities and metropolitan areas being conducted. Some of them are not focused on flood risk alone but disaster risks in general, such as the research done by Ikeda S. et al. (2008) and Paton D. et al (2001). Others specify their studies on flood risks but mostly focusing either on technical aspects (e.g. Kubal C. et al 2009, Lee J.H.W. et al. 2002 and Dawson R. J. et al. 2011) or decision-making supports (e.g. Cupta A.K. 2011 and Todini E. 1999). Few researches are taken with the sole purpose of examining the current existing FRM practices and how they function. It is with such a background that this thesis is initiated and designed.

1.2 Objectives

This thesis aims at analysing the existing flood risk management (FRM) practices in selected megacities and evaluating them based on the comparison with a conceptual framework of integrated flood risk management (IFRM) as reference. Through scientific research and empirical studies, this thesis intends to answer the following questions:

- How may FRM look like under particular consideration of megacities?
- What are the FRM practices currently adopted in the selected megacities?
- Are there any shortcomings or weaknesses related to the current flood risk management practices and what are possible recommendations for improvements?

1.3 Approach

Three megacities, namely London, Shanghai and Bangkok, are selected as case studies. London is located within the Thames estuary region where tidal flooding and fluvial flooding are major risks. Shanghai is a coastal city along the yellow sea (Pacific Ocean) and has experienced severe damages at its coastal lines in the history. Bangkok, with the Chao Phraya River flowing through the city and the Bay of Bangkok 30 km south of the city centre, has just been hit by destructive flood from late 2011 to the beginning of 2012. All three cities are megacities facing increasing flood risks and are all with functioning flood risk management systems.

To achieve the above mentioned objectives, firstly a flood risk management framework will be derived based on the review of scientific literatures and international FRM practice guidelines. Then the current flood risk management practices in the selected megacities will be analysed using indicators and criteria from the framework by means of questionnaires to FRM practitioners and professionals. As the third step, results of the empirical work will be evaluated based on comparison with the requirements resulting from the framework to identify strengths and weaknesses. At last, findings will be discussed and recommendations will be derived with regard to better FRM performances. A flowchart of the study approach is shown in Figure 2.

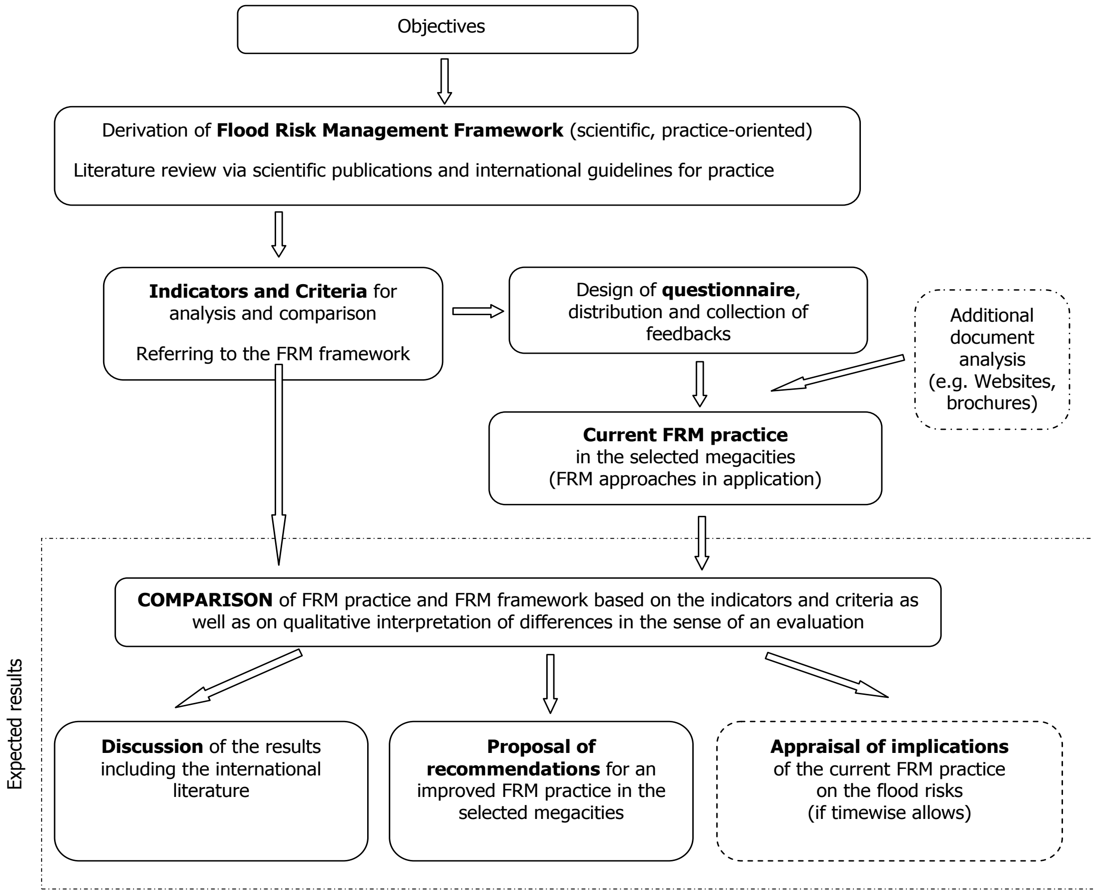

Figure 2. Flowchart - study approach

1.4 Thesis Structure

Following the above stated approach, this thesis consists of 7 chapters.

The first chapter presents briefly the background of the research field, the objectives of the study as well as the approach adopted. The second chapter reviews scientific literatures as well as the practice guidelines concerning integrated flood risk management, from which an IFRM framework for megacities is derived. In the third chapter, information about the case cities (London, Shanghai and Bangkok) is introduced with respect to their geographical locations, social-economic conditions as well as the city's history of flooding. With the background information of the case cities, chapter four moves further to examine and analyse the existing FRM practices in these cities by means of questionnaires to FRM practitioners and professionals with additional information from public sources (e.g. governmental publication, websites). Following the analysis in chapter 4, chapter 5 presents the result of this study, namely the existing FRM practices applied in the three selected megacities and the deviations identified by comparing the IFRM framework with the FRM practices. Recommendations for further improvements are also presented in Chapter 5. Chapter 6 then discusses the result of this study with reference to the theoretical background in Chapter 2. At last, chapter 7 presents the conclusion of this study.

Chapter 2 Framework of Integrated Flood Risk Management (IFRM)

2.1 Overview of Different IFRM Frameworks

Given the fact that flood risks are increasing world widely, both the scientific community and the international organisations have put much effort into the issue of how to manage flood risks in a more effective and efficient manner. As a result, the concept of Integrated Flood Risk Management (IFRM) is raised and different IFRM frameworks have been proposed accordingly.

This sub-chapter gives an overview of the evolvement of IFRM as concept and introduces different frameworks proposed by the scientific community as well as the international organisations.

2.1.1 Basic Terms and Concepts of IFRM

A number of researches have been done with the aim of understanding what flood risk is and how the flood risk system operates. Hereby, the most commonly accepted definitions are addressed.

According to Crichton (1999) ***risk*** is the probability of a loss, which depends on three elements – hazard, vulnerability, and exposure. If any of these three elements in risk increases or decreases, the risk increases or decreases respectively.

Flood risk is then understood as the probability of negative consequences due to floods and can only be reduced to a tolerable level. To be more specific, flood risk can be expressed as follows (Schanze 2006, Schanze 2009, WMO and GWP 2008):

Flood risk = Flood hazard * (exposure) * flood vulnerability*, whereof*
*Vulnerability = value/function * susceptibility * coping capacity.*

Hazard is a physical event, phenomenon or human activity with the potential result in harm (Schanze 2011). Tywissen (2005) has compared different definitions of hazard and concluded that one important feature of hazard is that it has the notion of probability, or a likelihood of occurring. It is a threat that has potential to cause severe adverse effects.

Flood hazard is defined as the exceedance probability of potentially damaging flood situations in a given area and within a specified period of time (Merz 2007). It depends on flood magnitudes such as flood depth, velocity and duration (Tingsanchali

2011).

Vulnerability is a measure of the potential for loss of the physical, economic and social value of a given site. It is a product of the interaction of susceptibility and resilience within the system (McFadden 2001). It can be expressed in terms of functional relationships between expected damages regarding all elements at risk and the susceptibility and exposure characteristics of the affected system, referring to the whole range of possible (Messner and Meyer 2006). Vulnerability is a dynamic, intrinsic feature of any community (or household, region, state, infrastructure or any other element at risk) that comprises a multitude of component. The extent to which it is revealed is determined by the severity of the event (Tywissen, 2005).
Flood vulnerability refers to the characteristic of a system that describes its potential to be harmed. It can be considered as a combination of value or function, susceptibility and coping capacity. Flood vulnerability covers social, economic, ecological and institutional aspects (Schanze 2011).

Based on the Source-Pathway-Receptor model developed by the Institute of Civil Engineers (ICE 2001), a modified Source-Pathway-Receptor-Consequences (SPRC) model (Figure 3) (e.g. Couldby 2008, Schanze 2006) is commonly adopted to understand the flood risk system and the link among its processes.

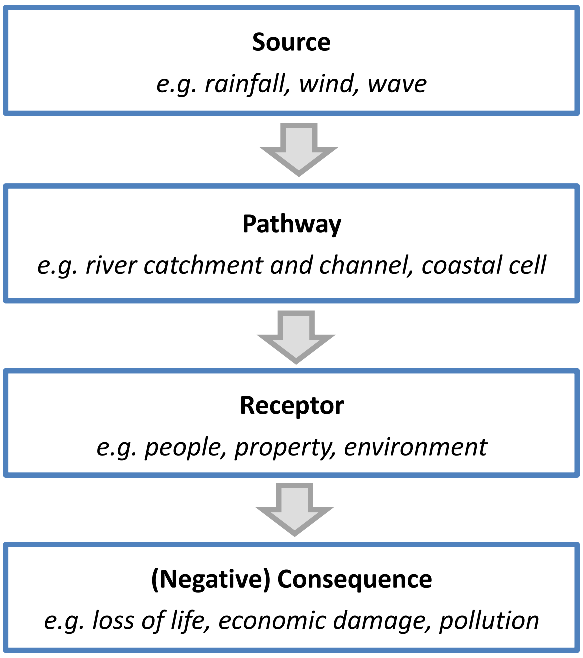

Figure 3. Source-Pathway-Receptor-Consequence model (ICE 2001 modified, Schanze 2006)

The source of a flood is usually an extreme meteorological event. Such as the heavy rainfall that triggered the 2002 Elbe flood in Czech Republic and Dresden in Germany. The global climate change can affect flood extremes by alteration of meteorological conditions and meteorological events.

Pathway is the route that a hazard takes to reach the receptors. A pathway must exist for a hazard to be realized. It could be a river catchment or a megacity that situated on flood plains. Human interventions in river basins, such as river training, loss of flood plains and the retention capacity, the increase of impervious surfaces, large changes of land cover and intensified land use, in particular for the development of settlements, have direct impact on flood risks.
Receptor refers to the entity that maybe harmed, such as people, property or the environment
(Negative) Consequence is the impact such as economic, social or environmental damage that may result from a flood. It may be expressed quantitatively (e.g. monetary value), by category (e.g. high, medium, low) or descriptively.
(Source: FLOODmaster)

While traditional defensive approaches intervene mainly in the *Pathway* process by introducing structural measures, the integrated flood risk management considers the entire flood risk system and the interaction among each process (SPRC), including the uncertainties that the system incorporates. As one example of the needs for integrated flood risk management, the IFRM takes into account for climate change and change of land-use, which are gradual processes that require slow but continuous adaptation (UFM 2006).

2.1.2 From Defensive Approach to IFRM

Nowadays the ‘integrated’ approach is widely accepted as the preferred form of knowledge acquisition and strategy building for environmental management (McFadden et al. 2009). Such an integrated strategy approach usually facilitates the development of a management process which allows a combination of long-term goals, aims and measures each to be continuously aligned with the changing physical and societal context (McFadden et al. 2009). In the field of managing flood risks this approach is reflected in the shift from the traditional defensive approaches towards an integrated flood risk management (IFRM).

The traditional defensive approaches focus greatly on the flood defence system, especially the structural devices, such as building up dams and dikes, straightening the channel by river training or setting up flood protection walls. Such approaches involve setting up a design flood event (e.g. return period 100 years) and providing flood alleviation measures that are appropriate for this predicted magnitude of flood. It usually achieves sufficient protection within the relevant designed magnitude, since the degree of risk within is considered. However, when a flood event is greater than designed such approaches may fail in protection because the impact of great-than-design event is not taken into account for in the design process, which is sometimes the case (e.g. 2002 Elbe flood in Germany). This is especially disturbing with the background of global climate change which results in more intensified floods in certain areas. With defensive approaches, the only way to overcome the above situation is by setting up a higher design flood (e.g. return period of 500 years or even higher). However, protection of extreme flood events is very expensive and is often too costly for the affected community to burden. In addition, the traditional defensive approaches often do not address the uncertainties. There is a wide range of factors that can give rise to uncertainties, from environmental loading to structural performance of defences. Unless these uncertainties are identified and addressed, designs will be vulnerable (ICE 2001). According to Ganoulis (2009), the global efficiency of a flood defence system based only on structural measures has proven to be unsatisfactory. The Asian Development Bank (ADB 2003) admits that large and costly structural interventions have only contributed to lulling people into a false sense of security through ‘encouraged unimpeded development in areas where devastating floods will nevertheless inevitably occur’ (ADPC 2005).

Shift from defensive approaches to integrated flood risk management is therefore widely acknowledged in both scientific communities and in practice. Along with this shift is the understanding that absolute protection is both unachievable and unsustainable because of high costs and inherent uncertainties (Schanz, 2006). Integrated flood risk management, on the other hand, incorporates the uncertainties by acknowledging that uncertainties cannot be completely avoided and focuses on ‘living with tolerable/acceptable risks’ instead of trying full protection.

Integrated Flood Risk Management deals with a wide array of issues and tasks ranging from the prediction of flood hazards, through their societal consequences to measures and instruments for risk reduction (Schanze 2006). It is a comprehensive approach where equal emphasis is placed on mitigation, preparedness, relief and recovery through the involvement of all relevant sectors and stakeholders with the overall goal to reduce flood risks (ADPC and UNDP 2005) and it has to be considered within the contexts of both sustainable water management (ACC/ISGWR 1992) and sustainable development (DE Bruijn et al. 2007).

According WMO (2009), *Integrated Flood Risk Management* takes a participatory, cross-sectoral and transparent approach to decision-making. The defining characteristic of IFRM is integration, expressed simultaneously in different forms: an appropriate mix of strategies, carefully selected points of interventions, and appropriate types of interventions (structural or non-structural, short- or long-term).

Hutter (2006) studied flood risk management strategies from a process perspective and defined flood risk management strategy as a consistent combination of long-term goals, aims, and measures, as well as process patterns that is continuously aligned with the societal context.

A widely used frame for flood risk management is the disaster management cycle (Figure 4), which clearly shows that flood risk management encompasses a wide range of activities and measures, ranging from the traditional flood defence measures, such as dikes and dams, to spatial planning, early warning, evacuation and reconstruction (Deltares 2010).

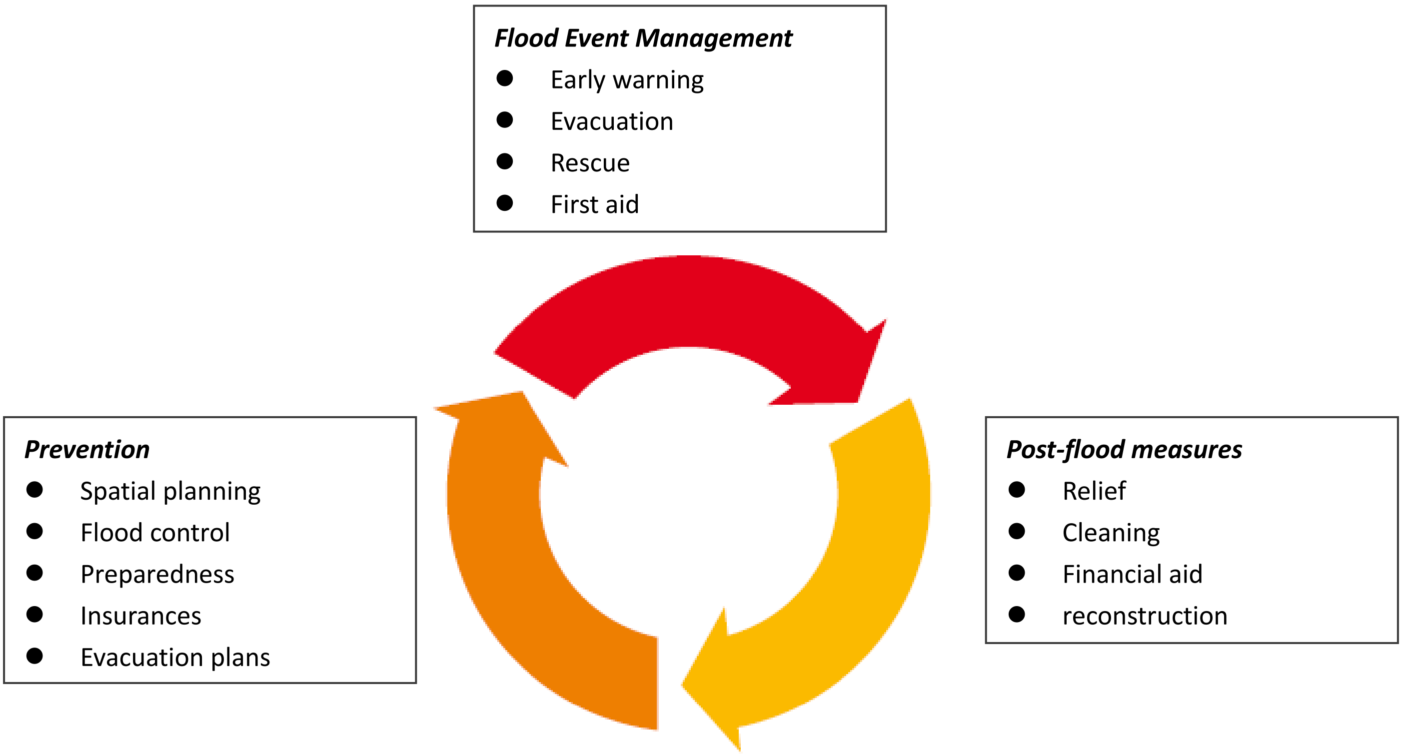

Figure 4. Flood risk in disaster management cycle (Deltares 2010)

As integrated flood risk management being widely accepted as the state-of-art methodology, a number of attempts towards integrated approaches have been taken to manage flood risks, such as the THESUS project (Zanuttigh 2011) in Europe, the UFM (Urban Flood Management) project in Hamburg, London and Dordrecht (UFM 2006) as well as the Thames Estuary 2100 Project (TE 2100) in the greater London area.

The THESUS project, funded by the European Commission and consists of 31 partner institutes, will examine the application of innovative combined coastal mitigation and adaptation technologies generally aiming at delivering a safe (or low-risk) coast for human use/development and healthy coastal habitats as sea levels rise and climate changes. The primary objective is to provide an integrated methodology for planning sustainable defence strategies for the management of coastal erosion and flooding which addresses technical, social, economic and environmental aspects (THESUS homepage).

The UFM project is a joint action between London (Thames Gateway), Hamburg and Dordrecht that aims at developing sound urban flood management strategies. Under the UFM project, an integrated urban flood management plan and possibly a flood resilient master plan will be created for real development projects in flood prone areas (UFM website).

The TE 2100 project was established by the Environmental Agency of UK (EA) in 2002 to develop a flood management plan for London and the Thames Estuary that is risk based, takes into account existing and future assets, is sustainable, includes the needs of stakeholders and addresses the issues in the context of a changing climate and varying socio-economic conditions that may develop over the next 100 years (Environmental Agency 2009).

However, though the IFRM concept has been widely acknowledged and some attempts of integrated approaches have been taken, traditional defence measures still dominate in flood protection practices. Several international organizations have issued publications and guidelines encouraging the application of IFRM (World Bank 2012, WMO 2009, ADPC and UNDP 2005, EU Floods Directive 2007), which gives hope to actual adoption and wide practice of IFRM.

2.1.3 Different IFRM Frameworks

There are a few modules/frameworks of IFRM being developed in the past decade (e.g. Nachtnebel 2007, Plate 2007, DE Bruijn et al. 2007, Schanze 2009). Despite the various perspectives that the scientists looked into from, all modules/frameworks inevitably addressed one same concept: cross-sectoral solutions, which involves not just technical but also social, economic as well as environmental aspects.

Examples of different IFRM frameworks proposed by the scientific community as well as the international organisations are as follows.

Schanze (2009) has developed a basic framework for flood risk management (Figure 5), where three tasks with specific components are used for structuring the flood risk management activities. The three main tasks are:

- Risk analysis,
- Risk evaluation and
- Risk reduction.

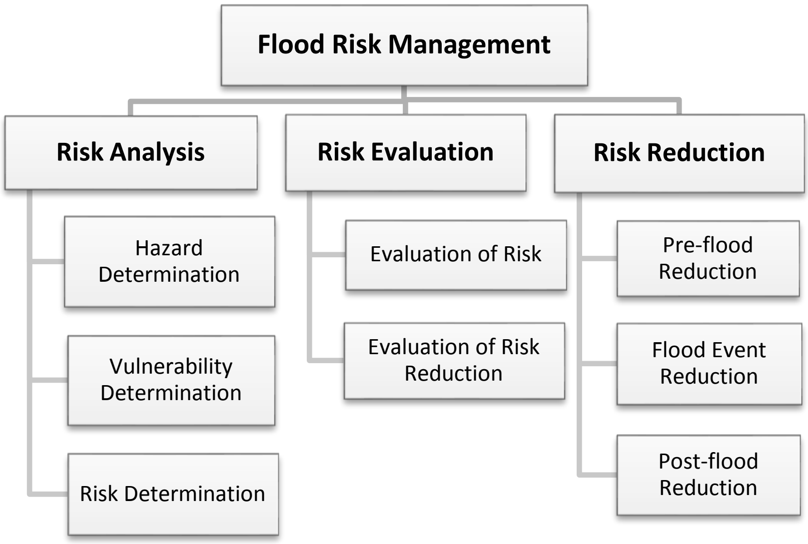

Figure 5. Tasks and components of flood risk management (Schanze 2009)

Nachtnebel (2007) has developed an IFRM framework based on the understanding that the entire river basin has to be the basic planning unit, further a sensible combination of measures should be identified comprising spatial planning, structural engineering and institutional development, and finally that the public should be involved at several levels of decision making and as an actor. His approach is closely related to the sequence of actions including prevention, response and aftercare of flood events, as shown in Figure 6 (Nachtnebel 2007).

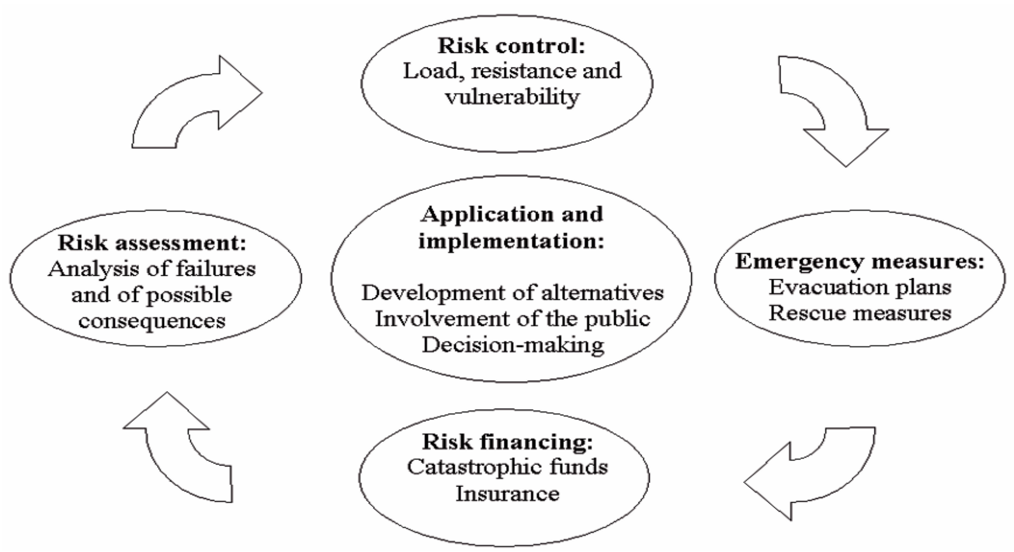

Figure 6. Main modules of IFRM by Nachtnebel (2007)

DE Bruijn et al. (2007) developed a framework for flood risk management from a system's perspective (Figure 7) based on the idea that the purpose of FRM is to create a balance between, and thus be able to manage, the socio-economic and physical characteristics of the system and the rainfall or peak discharge entering the system.

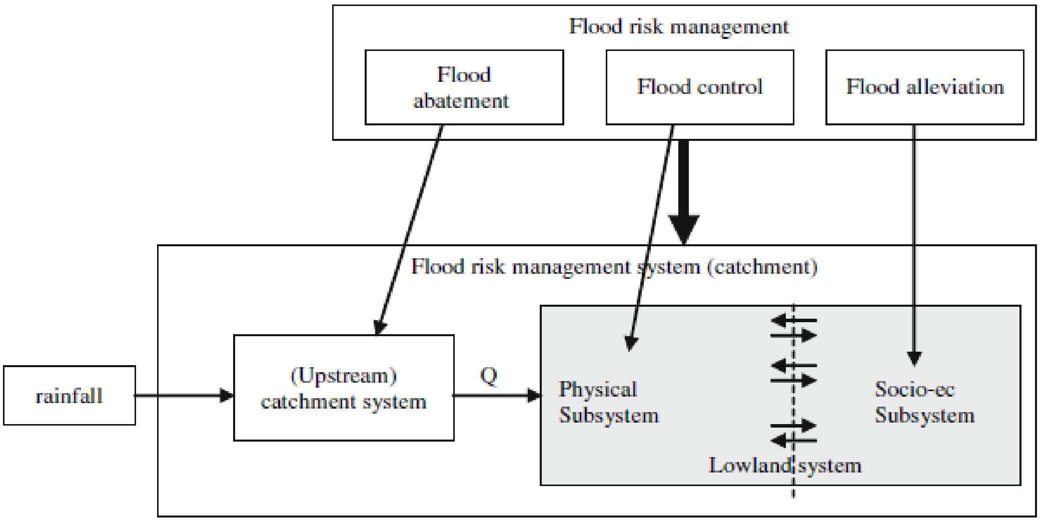

Figure 7. Flood risk management from a system perspective by De Bruijn et al. (2007)

The Institute of Civil Engineers (ICE 2001) has proposed a FRM matrix (Figure 8) where all important processes/tasks of a holistic approach to flood risk management are addressed to better facilitate the design and development of an integrated flood risk management system.

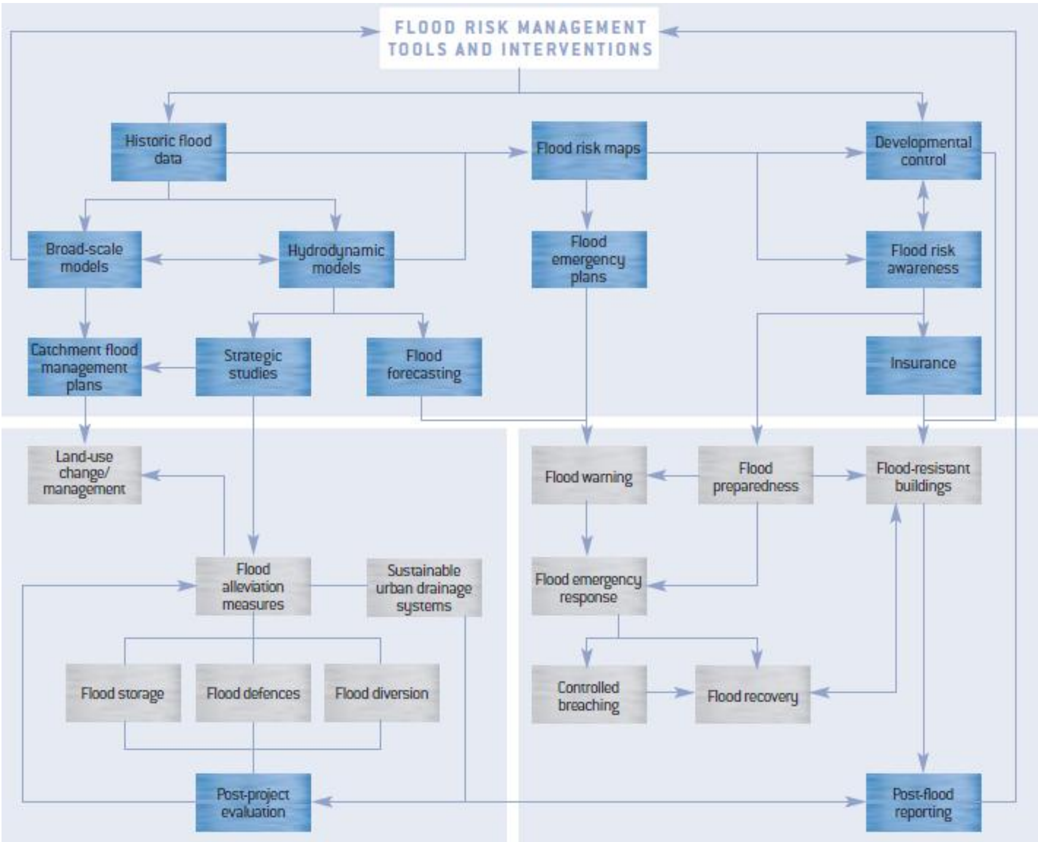

Figure 8. Matrix of flood risk management by ICE (2001)

Despite the various perspectives, all modules/frameworks inevitably addressed one same concept: cross-sectoral solutions, which involves not just technical but also social, economic as well as environmental aspects.

2.2 Selected Framework of IFRM

This study adopts the framework developed by Schanze (2009), where three tasks with specific components are used for structuring the flood risk management activities. The three main tasks are:

- Risk analysis,
- Risk evaluation and
- Risk reduction.

Each of the main tasks consists of several sub-tasks, which can be expressed as Figure 5. Linking the FRM tasks and components with decision making process and considering the interactions among these tasks and components, a basic framework of Flood Risk Management can be obtained as Figure 9 (Schanze 2009).

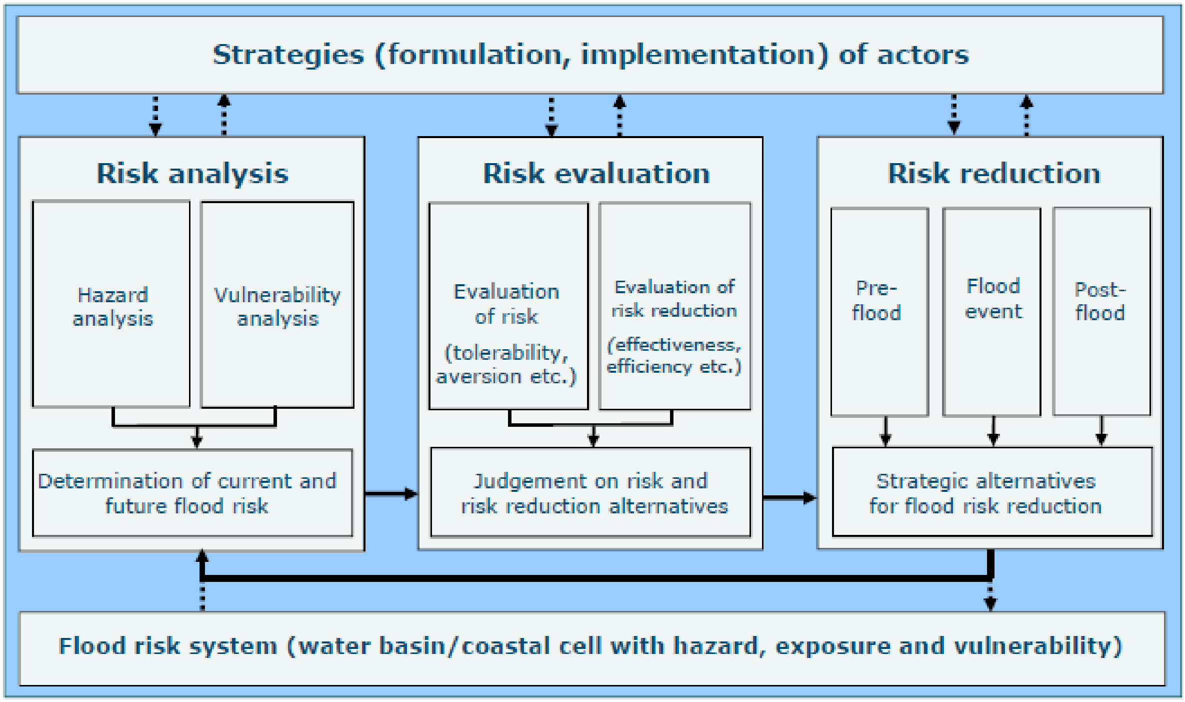

Figure 9. Basic framework of flood risk management (Schanze 2009)

As important and enlightening as the scientific research is, it is sometimes difficult to put the advanced research result into practice due to various reasons such as the transfer of knowledge, cost of certain application or the lack of capacity. On the other hand, practice guidelines and scientific research may focus on or address different aspects or issues because of their intrinsic nature. Therefore, some available IFRM practice guidelines issued by well-known international organisations are also examined here to help orient the IFRM framework into practice.

The practice guidelines being examined are:
Cities and Flooding – A Guide to Integrated Urban Flood Risk Management for the 21st Century, by **World Bank** (2012),
Integrated Flood Management – Concept Paper, by **World Meteorological Organization (WMO)** (2009),
EU Flood Directive, by **European Union** (2007),
Urban Flood Management, by **WMO** (2006),
Integrated Flood Risk Management in Asia, by **Asian Disaster Preparedness Center (ADPC)** (2005),
Hyogo Framework for Action 2005 -2015- Building the Resilience of Nations and Communities to Disasters, by **International Strategy for Disaster Reduction (ISDR)** (2005).

2.2.1 Risk Analysis

Risk analysis provides information on previous, current and future flood risks (Schanze 2006). It involves mainly 2 tasks – hazard analysis and vulnerability analysis. Main result of the risk analysis is flood risk maps.

a. Flood hazard analysis

Two aspects of flood hazard analysis are of importance and have drawn much attention – hydraulic modeling of flood behaviors and the associated uncertainty analysis.

Hydraulic modeling

Application of hydraulic modeling tools to simulate flow characteristics in the investigated area has become an indispensable component of modern flood management (Musall et al. 2011). Hydraulic modeling is an important element of establishing a robust flood forecasting framework, and simulation results from hydraulic models can be used to produce inundation maps which enable the community officials or the general public to have a direct idea of the risks they may be facing (Gilles et al. 2010).

As an advanced and commonly adopted group of hydraulic models, the hydrodynamic numeric models (HM models) do not just balance the input and output variables of precipitation, evaporation and discharge, they also additionally consider spatial high resolution information about the terrain (e.g. roughness), which is needed for detailed predictions of hydraulic processes within the area of interest (Musall et al. 2011).

As for urban flooding, one-dimensional HM models are unable to resolve complex floodplain flow fields and require post-processing to produce realistic flood extents, while two-dimensional HM models are unable to model structural elements that may produce upper-critical or pressurized flow conditions (Gilles et al. 2010). Recent urban flood modeling efforts have been focused on dynamically coupling of one- and two- dimensional models to avoid such limitations (Frank et al. 2001, Patro et al. 2009). According to Syme et al. (2004), in urban areas, fully 2D modeling offers a major step forward in the prediction of flood extents through superior representation of the complex hydraulic processes. Additional benefits include velocity and flood hazard mapping at a much finer resolution and greater accuracy. For hydraulic features that are poorly represented by the 2D domain (e.g. pipe works, narrow waterways, etc.) 2D and1D coupling models offer a near complete solution.

In recent years, efforts have also been made in the integration of hydraulic models into GIS-based tools to better facilitate the flood risk analysis results, such as visualising the results in an easy-to-read format for decision makers and other stakeholders who do not have much knowledge about flood risks. According to Musall et al. (2009), using such a GIS integrated application module even users without consolidated hydraulic background could run HN calculations and immediately visualise the results in GIS, which can be superimposed afterwards with other geo-referenced data (e.g. topographical maps or aerial images). Such a system can contain at least the following functions (Musall et al. 2009):

- Execution of hydraulic models
- Visualisation of calculation results
- Automated freeboard analysis along dikes
- Automated inundation analysis of relevant structural facilities (e.g. dike gates)
- Superimposition with other flood relevant information
- Risk analysis of protected areas.

It is recommended that appropriate hydrodynamic numeric (HM) models, especially 2D or 2D/1D coupling models to be selected for hydraulic modeling based on the environment of the areas in concern. In addition, a GIS integrated application module (e.g. GIS user interface) is highly recommended.

Uncertainty analysis

Ideally, a flood risk analysis should take into account all relevant flooding scenarios, their associated probabilities and possible damages as well as a thorough investigation of the uncertainties associated with the risk analysis (Apel et al. 2004). Merz et al. (2008) argue that uncertainty considerations (1) improve flood risk analyses, (2) help to confirm or falsify risk analyses, and (3) support decision-making for flood risk mitigation. It helps to identify the weak points of a flood risk analysis and guides the efforts for assembling further information and data that are supposed to be most valuable for constraining the uncertainty and therefore to improve the risk estimate.

Two types of uncertainties shall be distinguished: *aleatory* and *epistemic* uncertainty (Merz et al. 2008, Schanze 2006). *Aleatory uncertainty* refers to the fact that quantities are inherently variable over time, space or subjects and objects, while *epistemic uncertainty* results from the limited knowledge of the elements and processes of the flood risk system (Schanze 2006). It is important to understand that epistemic uncertainty can be reduced whereas aleatory uncertainty is not reducible (Merz 2008).

There are a few methods available for quantifying the uncertainties (e.g. Monte Carlo Simulation). However, when complex hydraulic models are performed, especially those of the hydraulic models estimating inundated areas, incorporation of these models in Monte Carlo based uncertainty analysis is restricted since only a few scenarios can be simulated (Merz et al. 2008).

Apel et al. (2004) developed a simplified model system, where models can either be embedded in a Monte Carlo framework or considered in scenario calculations for uncertainty analysis. The model system was successfully implemented to the Lower Rhine River in Germany where it produced flood risk estimates with associated uncertainty bands (Apel et al. 2008).

In general, uncertainties shall not be regarded as completely irreducible and uncertainty analysis shall be incorporated into the flood risk analysis process to derive more explicit and accurate risk information.

b. Vulnerability analysis

One state-of-art technique for vulnerability analysis is the adoption of mulitcriteria that considers not just economic but also social and environmental/ecological aspects.

Multicriteria (social, economic, environmental /ecologic)

Though there are various studies that suggest the use of multicriteria to assess, map and manage the economic, social and ecological dimension of flood risk in an integrated manner, the application of such multicriteria approaches for an integrated assessment of flood vulnerability is relatively rare (Scheuer et al. 2011).

Kienberger et al. (2009) has developed a spatial multicriteria approach for integrated assessment and mapping of susceptibility and adaptive capacity indicators based on the Geon[1] concept introduced by Lang (2008). This approach is successfully implemented in the Salzach Catchment in Austria. Kienberger (2012) has used this spatial approach to model vulnerability in Mozambique at district level, where he proposed a set of indicators that allow the modeling of vulnerability in a data-scarce environment. The concept and workflow of this spatial multicriteria approach are expressed as Figure 10.

Data availability is of vital importance for the spatial multicriteria. It determines

[1] Geon concept is used to describe generic spatial objects that are homogenous in terms of changing spatial phenomena under the influence of, and partly controlled by, policy actions (Kienberger et al., 2009).

directly the accuracy of such approach and highlights the need for the identification of basic data needs for vulnerability assessments and its continuous availability over different time periods (Kienberger 2012).

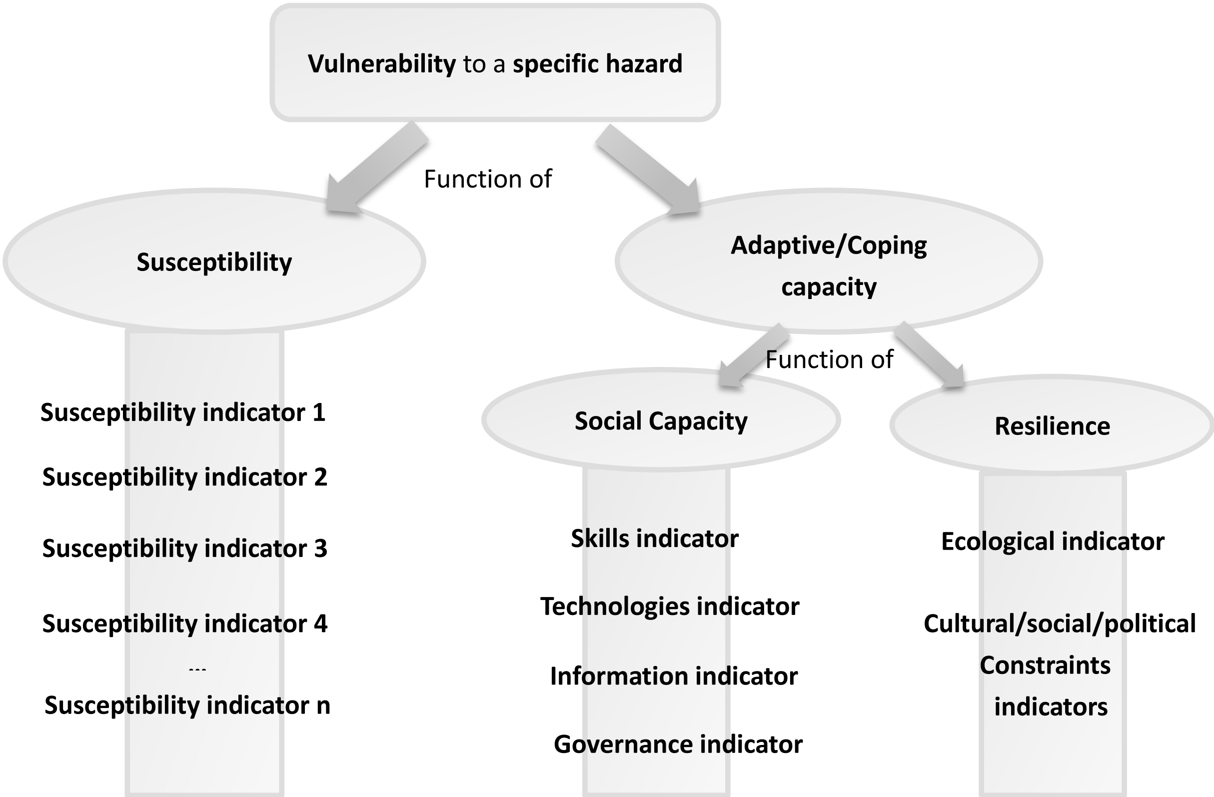

Figure 10. The concept of the spatial multicriteria approach by Kienberger et al. (2009)

Following the approach demonstrated by Kienberger et al. (2009), Scheuer et al. (2011) presented an approach to modeling and mapping multicriteria flood vulnerability in cities and have it tested in the city of Leipzig, Germany. This approach addressed especially the coping/adaptive capacity with respect to the economic and social dimension (Table 1).

Table 1. Criteria covering the urban coping capacity (Scheuer et al., 2011)

Flood risk dimension	Evaluation criteria	Subcriteria	Element of coping	Spatial unit	Coping unit
Economic	Wealth	Income	High income households	Area	%
			Share of unemployment	Area	%
Social	Population	Health care	Hospital beds	Area	Number
			Doctors	Area	Number
		Age	Young people	Area	%
		Support	Social networks*	Household	Probability (0…1)
	Accessibility	Transport	Stops of public	Area	0/1

		transport		
	Shopping	Supermarkets	Area	0/1

*The social networks *SN* base on a household type distribution dataset for Leipzig and was calculated according to the following formula:
$SN = \{H1 \times 0.6) + (H2 \times 0.8) + (H3 \times 0.1) + (H4 \times 0.2) + (H5 \times 0.9) + (H6 \times 0.4) + (H7 \times 0.6)$, where H1 are young singles, H2 you cohabitation households, H3 elderly singles, H4 elderly cohabitation households, H5 families with dependent children, H6 single-parent families and H7 flat sharers.

It is recommended that a multicriteria approach, which covers all three dimensions (social, economic and environmental/ecological) shall be considered and adopted with regard to vulnerability analysis.

Risk mapping

As a product of risk analysis, flood risk maps play a very important role in the development of flood risk management strategies. It is usually shown in a static and 2-dimenstional format (Schanze 2006, Merz et al. 2007) and can serve, among others, at least the following several purposes (Merz et al. 2007):

- Raising awareness among people at risk and decision makers,
- Providing information for land-use planning and urban development, investment planning and priority setting,
- Helping to assess the feasibility of structural and non-structural flood control measures,
- Serving as base for deriving flood insurance premiums,
- Allowing disaster managers to prepare for emergency situations.

Despite the various understanding of risk mapping concept, risk maps can be grouped generally into 3 types:

- Flood hazard maps – contain information on flood probability, water depth, flow velocity etc. (e.g. inundation maps); for a single or several flood scenarios.
- Flood vulnerability maps – contain information about the effect of flooding on society, economy as well as the natural environment/ecology; for a single or several flood scenarios. E.g. maps of flooded buildings and infrastructures.
- Flood risk maps – combination of flood hazard maps and vulnerability maps; sometimes also include information of expected monetary damage; for a single or several flood scenarios.

Another special type of flood risk maps is the dynamic flood mapping for *real-time flood forecasting and warning systems*. These maps provide information on ongoing flood events with the aim of enhancing the lead time for preparatory activities (e.g. reservoir control, evacuation etc.) (Schanze 2006). They mainly consist of meteorological and hydrological modeling (Cluckie and Hajjam 2001, Schanze 2006).

Currently, flood risk maps usually have 1:2000 to 1:20000 in local scale (Merz et al. 2007) and are mostly in printed or digital formats. More flexible, interactive and web-based risk map systems do partly exist and are in further development (Schanze

2006).

Flood risk mapping is an essential step and an important product of the flood risk management approach. It is indispensable especially for decision-makers and the local communities to understand the risks they're facing. Therefore sound and proper flood risk maps shall always be included in the FRM framework and it is also recommended that the risk maps to be opened to all stakeholders including the public and local communities.

2.2.2 Risk Evaluation

Flood risk evaluation can be seen as the procedure to evaluate the level of risk that one may face, e.g. if the risk is acceptable/tolerable, if the risk level is high or low etc. However, the result of flood risk evaluation can be quite different in various societal or cultural contexts. This is due to that individuals with different social and cultural background usually perceive and weigh risks differently. Shen (2010) has done a thorough study on flood risk perception and communication in different cultural contexts (Germany and China). As important as risk perception and risk weighing are, their difference in various societal and cultural contexts are not the focus of this study.

Recently a new and widely acknowledged concept for risk evaluation within risk management is the ALARP principle – as low as reasonable practicable (e.g. Melcher 2001, Aven 2010). This concept has also been accepted by the field of flood risk management (e.g. Schanze 2006, THESUS Project). The concept of ALARP can be expressed as Figure 11 (FLOODsite Consortium 2009, Melchers 2001, HSE of UK, 1992).

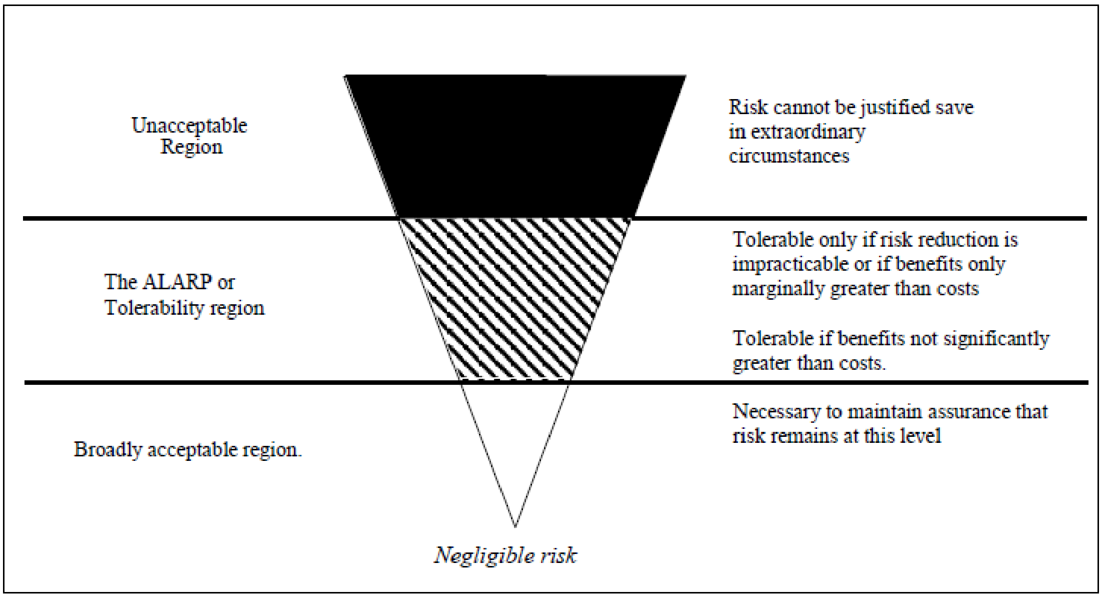

Figure 11. Level of risk and ALARP (FLOODsite Consortium 2009)

Based on the ALARP principle, it is commonly agreed that risk evaluation needs to include both 'costs' (risks) and 'benefits' of use (opportunities) (Schanze 2006). Hereby, 'costs' should cover both the negative consequences and the efforts for risk reduction (Schanze 2006). Cost-benefit analysis is a relatively easy and direct step for risk evaluation. When full cost-benefit analysis cannot be conducted, sometimes a cost-effectiveness analysis that compares the cost and the effects of actions can be used instead.

However, within the integrated approach some aspects might not be easily monetized, especially social and environmental/ecological risks (Meyer 2007), e.g. flooding caused environmental/ecological degradation. This is where the multicriteria evaluation (MCE) steps into stage. MCE considers indicators with different units (fuzzy system) and therefore include flood risks that is difficult to be measured in monetary terms. As the FLOODsite Consortium (2009) defines, MCE presents the opportunity to measure the consequences of an activity in terms of different units and to leave the final weighing of criteria to the decision-makers or to a stakeholder meeting.

Typical methods of MCE are, for example, Compromise Programming (CP), Multi-Attribute Utility Theory (MAUT) and Analytic Hierarchy Process (AHP). In recent researches the AHP approach is greatly investigated in the field of flood risk management or even larger watershed management (e.g. Chen et al. 2011, Sinha R. et al. 2008, Wang et al. 2011, Biswas et al. 2012).

It is recommended that a thorough cost-benefit/cost-effectiveness analysis shall be taken at the stage of risk evaluation so that the decision makers and the stakeholders could have a clear view of the risk they face. For intangible risks, a multicriteria evaluation approach shall be taken to cover the whole spectrum of risks.

2.2.3 Risk Reduction

If risks have been evaluated as not tolerable, measures and instruments shall be applied for risk reduction (Schanze 2006). Hereby (Olfert 2007),

Measures are physically tangible interventions which cause effects directly through their existence. These include all kinds of flood control and defence works, traditionally called structural measures such as dams, dikes or river training. But here also belong the more recent approaches such as land management techniques, river rehabilitation, mobile defences, and different types of flood proofing or evacuation measures.

Instruments are interventions which cause effects indirectly by shaping the scope for action or by improving risk perception and preparedness of stakeholders including land users. Examples are land use regulations, financial incentives, flood warning or hazard maps.

Depending when the risk reduction efforts take place, risk reduction can be divided into 3 groups - pre-flood risk reduction, flood event management and post-flood risk reduction. Each group has its own measures and instruments that can be applied to reduce flood risk.

Pre-flood risk reduction
Measures: traditional structural defence facilities (dams, dikes, flood proofing buildings), land management techniques (less sealed surface by introducing more green area), river rehabilitation, etc.
Instruments: flood insurance, preparedness of the local community, spatial planning, etc.

Flood event management
Measurements: flood control measures (operation of reservoirs to control the discharge and water level, pumping systems in urban areas), flood proofing buildings, emergency evacuation (governmental aid, community self-aid, third party aid), etc.
Instruments: flood early warning system, emergency plan, etc.

Post-flood risk reduction
Measures: reconstruction of buildings and other facilities
Instruments: financial aid for recovery, recovery and resilience plan.

Usually, more than one set of measures and instruments can be taken for reducing certain flood risk. This is especially true with regard to pre-flood risk reduction efforts. Therefore, there are often alternative sets of risk reduction activities available for decision makers to choose. In such cases, appropriate evaluation of these alternative sets should be taken and presented to the decision makers and sometimes other stakeholders. Such evaluation is usually taken within the flood risk evaluation process.

Instead of focusing fully on flood defensive measures (traditional structural measures), a variety of risk reduction measures and instruments shall be combined together as a set to reduce risk from various angles and perspectives.

2.2.4 Flood Risk Management Process

Management of the flood risk system requires further consideration of the linkages among the tasks and components introduced in the framework (Figure 9) as well as their application by representatives of the society (Schanze, 2006). The tasks and components in the framework are often done by various actors involved in the FRM system (e.g. the meteorological department, flood risk managment authority, water authority etc.) and the decisions (e.g. flood risk reduction options) are taken by the decision makers. However, as stated in the previous chapters, societal context and behaviours could have strong influence on the actors and decision makers, which in turn determines the actions and decisions to be taken and their implementations. For example, Chinese decision makers are more likely to look for technical solutions and favour the traditional structural defense measures, while German decision makers would prefer a combined set of measures and instruments (Shen 2010). In this aspect, actors and decision makers will sometimes need the support from scientists and experts from the FRM field.

The links among each task and component as well as the interaction between the tasks and the decision making/development process have also led to a new research area – the strategies for flood risk management. Hutter (2006) defined strategy as such: a strategy for flood risk management is defined as a consistent combination of long-term goals, aims, and measures, as well as process patterns that is continuously aligned with the societal context. Within this multidimensional definition, two issues have raised increasing concern – the integration of spatial planning into FRM and the consideration of future climate change.

Spatial planning

Spatial planning is increasingly regarded as one of the important instruments in disaster risk reduction. In the field of flood risk management, spatial planning regulates land use in flood-prone areas and ensures that the development of new settlements and industries be kept out of the main risk zones (Böhm et al. 2004).

As England's Planning Policy Statement 25 (PPS 25, Development and Flood Risk) states, the aims of planning policy on development and flood risk are to ensure that flood risk is taken into account at all stages in the planning process to avoid inappropriate development in areas at risk of flooding and to direct development away from areas at highest risk. Where new development is, exceptionally, necessary in such areas, policy aims to make it safe without increasing flood risk elsewhere and where possible, reducing flood risk overall.

Spatial planning, as one of the sustainable risk reduction instruments, have already been implemented in a few projects, such as the joint ELLA[2] project by Germany and Czech Republic and the IRMA-SPONGE[3] project in Europe.

Climate Change

Climate change and the related sea level rise are generally regarded as one of the main reasons to reconsider flood risk management policies for the future (Klijn et al. 2012). Climate change could result in more frequent weather extremes including extreme precipitations or more intensified rainfalls in certain areas (e.g. ICE 2001, Ntelekos et al. 2010) and lead to increasing flood risks.

To cope with the possible climate change consequences, many researches have been

[2] ELLA Project, http://www.ella-interreg.org/
[3] IRMA-SPONGE Project, http://www.irma-sponge.org/

taken with scenario-based considerations that take into account the plausible futures. These scenario developments are usually based on the Intergovernmental Panel on Climate Change (IPCC[4]) predictions and involve meteorological and hydraulic modeling followed by subsequent flood risk assessment. By doing so, the possible flood risks for different plausible futures could be evaluated and assessed and decision makers could then adjust their flood risk management policies accordingly.

It is recommended that spatial planning shall be integrated into the FRM practice especially as one of the risk reduction instruments. Climate change considerations shall be taken into account to ensure that uncertainties of plausible futures are considered and incorporated in to the FRM practice.

In addition to what have been already discussed, the international guidelines also focus greatly on the perspective of legal, institutional and governance arrangements, which is also a challenge that many developing countries are facing in terms of disaster risk management.

The important aspects addressed by the international guidelines are summarized as follows:

- Strong legal support
- Inter-institutional coordination and stakeholder participation
- Capacity-building
- Integration of risk management into development plans
- Adaptive management

Strong legal support

To have clear and objective FRM polices, supporting legislation and regulations are a prerequisite. The policy stipulations require an appropriate legislative framework defining the rights, powers and obligations of the concerned institutions and floodplain occupants (WMO 2009). World Bank (2012) also agrees that clarity of responsibility for constructing and running flood risk programs is critical. ADPC (2005) stated similar concept and also addressed that it is important to place the responsibilities not only into the hands of decision-makers, and planners, but also the general public.

Inter-institutional coordination and stakeholder participation

Flood risk management involves usually several stakeholders. Be it governmental authorities, non-profit organisations (NGOs) or simply the general public and local communities, all are somehow part of the whole flood risk management plan. Because of the different functions and priorities that the various stakeholders hold, the coordination and cooperation across their functional and administrative boundaries becomes critical. Developing effective institutions is vital to overcoming the real

[4] IPCC. http://www.ipcc.ch/

challenges of managing flood risk (World Bank 2012). The stakeholder participation system shall also include mechanisms for consensus-building and conflict management (WMO 2009). The development and strengthening of institutions, mechanisms and capacities shall be executed at all levels, in particular at the community level that can systematically contribute to building resilience to hazards (ISDR 2005).

In addition, the World Bank (2012) and WMO (2009) especially acknowledged the important roles of banks and insurance sectors for their sharing of flood risks as well as their contribution in risk mitigation, which are not yet considered as options in some developing countries.

Capacity building

Knowledge transfer and capacity building is seen as a key element to the successful implementation of flood risk management as well. As WMO (2009) stated, effective stakeholder involvement requires a capacity-building effort to ensure that stakeholders operate from a sound and relevant knowledge base and are supported by expert advice. Information related to flood emergency preparedness and response should be shared as public goods. The World Bank (2012) suggested continuous communication to raise awareness and reinforce preparedness, especially using recovery after a flooding as an opportunity to build capacity at the community level. The Hyogo Framework (ISDR 2005) also suggested the use knowledge, innovation and education to build a culture of safety and resilience at all levels.

Integration of flood risk management into development plans

The integration of flood risk management into development plans is of special interests and vital importance for urban areas, including megacities. As the World Bank (2012) stated, rapid urbanization requires the integration of flood risk management into regular urban planning and governance. It requires incorporating land use, shelter, infrastructure and services. The Hyogo Framework (ISDR 2005) also acknowledged the integration of disaster risk considerations into sustainable development policies, planning and programming at all levels as a key element for effective disaster risk management.

Adaptive management and review of the FRM plans and strategies

Adaptive management involves planning, acting, monitoring and evaluating applied strategies, and incorporating new knowledge as it becomes available into management approaches (WMO 2009). With adaptive management, the flood risk management strategies and plans are periodically reviewed and assessed, and if applicable updated, to ensure that the effectiveness as well as the efficiency of the FRM plans and strategies. The EU flood directive (2007) regulated that the elements of flood risk management plans should be periodically reviewed and if necessary updated. The World Bank (2012) also pointed out that a monitoring program shall be established to ensure the measures and instruments having the ability to perform the required standards and prevents failure as well as provides learning for the future.

2.3 IFRM Framework with Indicators and Criteria

In order to facilitate the analysis and evaluation of the flood risk management practices in the selected megacities, a set of FRM framework indicators and criteria is proposed (Table 2). Indicators and criteria are identified on the basis of review of scientific literature and practice guidelines issued by international organizations, as explained in chapter 2.2.

Indicators are the components of which a well-functioning FRM framework should consist. Criteria refer to the techniques and/or approaches through which a specific indicator should be achieved.

The analysis of the FRM practices in the selected megacities will adopt these indicators as benchmarks, meaning a functioning FRM approach would fulfill these indicators. The criteria will help facilitate the evaluation of the FRM practice by examining the techniques and approaches used to achieve the indicators. In general, state-of-art techniques or approaches suggest better FRM performance.

Table 2. Proposed indicators and criteria for the IFRM framework

FRM tasks	Indicators	Criteria	
Risk Analysis	Return period for hazard analysis Hydraulic modeling Uncertainty analysis	A series of return periods (e.g.50 yrs, 100 yrs, 200 yrs, ect.). 1D, 2D or 1D/2D coupled. Shall be included (e.g. Monte Carlo simulation, scenarios calculation, etc.).	
	Vulnerability analysis	Multicriteria that cover social, economic and environmental/ecological dimensions, instead of 'only economic considerations'.	
	Vulnerability, hazard and risk mapping	Vulnerability maps, hazard maps, risk maps in place; Possibly also dynamic flood mapping for real-time flood forecasting.	
	Availability of the maps	Paper copies at authorities, brochures and/or websites, etc.; Easy access for the public.	
Risk Evaluation	Return period for design level	100 yrs, 200 yrs, or higher.	
	Risk evaluation (also consideration of the efficiency of risk reduction activities)	At least cost-benefit analysis and/or cost-efficiency analysis, better multicriteria evaluation (MCE).	
Risk Reduction	Risk reduction activities	Combination of measures and instruments.	
	Pre-flood risk reduction activities	*Measures*	*Instruments*
		Structural defence (e.g. dikes and walls);	Spatial planning with focus on flood risk reduction;
		Flood proof buildings;	Preparedness of local community;
		Land management techniques.	Flood early warning; Flood insurance.
	Flood event management	*Measures*	*Instruments*
		Flood control measures (e.g. urban pumping);	Emergency plan/ evacuation plan;
		Emergency evacuation (governmental aid, community self-aid, third party aid).	Real-time flood forecasting and warning.
	Post-flood reduction activities	*Measures*	*Instruments*
		Reconstruction and resilience measures;	Financial subsidy for relief and recovery;

		Recovery and resilience plan.
	Relief funding	Governmental budget, insurance, tax increase etc.
Flood Risk Management Process	Legal support	Clear definition of responsibilities. Appropriate legislative framework supporting FRM.
	Stakeholder participation	Relevant sectors involved (e.g. water authority, spatial planning authority and insurance sectors etc.).
	Stakeholder collaboration	Platform for effective collaboration in place.
	Capacity building	Trainings and education of stakeholders.
	Public and local community involvement	Effective involvement (e.g. through brochures, media, workshops, hearing, etc.).
	Climate change and societal changes	Climate change adaptation; Long-term plans and strategies.
	Integration of FRM into development plans and strategies	Consideration of flood risk into spatial planning, urban planning as well as development strategies.
	Adaptive management	Monitor and periodical evaluation of FRM plans and strategies; Update of FRM plans and strategies.

Chapter 3 Case Study Cities

This study selects three megacities that are facing increasing flood risks as case study. The three megacities are: London, Shanghai and Bangkok.

3.1 London

London, as the capital city of England and the United Kingdom, is the largest metropolitan area in UK and one of the largest urban zones in Europe. London is one of the largest cities in the developed world in terms of its built-up area, and is the most populous city in Europe, with over 7 million residents. It is also one of the European Union's most densely settle areas (ONS UK 2007). Besides, London is a leading global city with strengths in arts, commerce, finance, tourism and transport etc., which are contributing to its prominence (Institute for Urban Strategies 2010, Wikipedia 2012a).

With part of London lies within the Thames tidal floodplain (Figure 12, Figure 13), the London area has long been accompanied by flooding. The earliest written record of flooding along the Thames Estuary dates back to 1099 form the Anglo Saxon Chronicle and numerous floods have been recorded since then (Lavery et al. 2005). The last devastating flood in 1953 has acted as a catalyst for construction of the current system of River Thames tidal defences (Lavery et al. 2005).

Currently the tidal defence system comprise the Thames Barrier, 185 miles of floodwalls , 35 major gates and over 400 minor gates that protect London from tidal surges (Dawson et al. 2011). However, the flood risk is increasing within the changing climate. According to Dawson et al. (2011), under the trend of global warming London is expected to experience faster relative sea rise which, coupled with storm surges, will heighten the risk of surge flooding in the tidal Thames. The problem could be further aggravated by extreme river flows. The median flow and 100 year return period flow are ~350m^3/s and ~550m^3/s respectively but over the next century, increased amounts of rainfall are predicted over the Thames river catchment which could lead to changes in extreme river flows (Reynard, 2003). The current standard of protection provided is generally at least 1: 1000 years and the current design standard has an allowance for sea level rise to the year 2030 (McFadden et al. 2009).

To assure the Thames Estuary and London's capability of coping the increasing flood risks beyond 2030, the UK environment Agency has set up the Thames Estuary 2100 (TE 2100) project which is an integrated approach for managing the flood risks within the region.

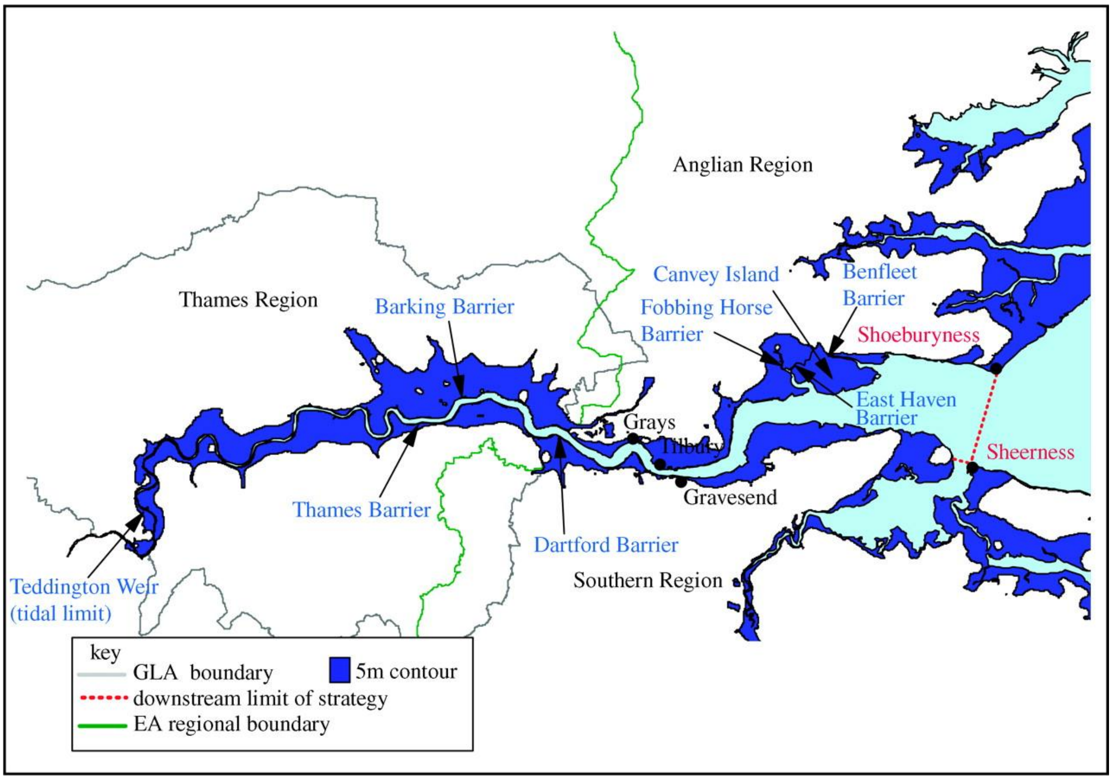

Figure 12. The defended Thames tidal floodplain (Lavery et al. 2005)

Figure 13. Location of the municipality of London[5]

[5] Map available at: http://londonairconnections.com/extras.html

3.2 Shanghai

Shanghai is the largest city of the People's Republic of China. With its population over 23 million[6] in 2010, it ranks one of the most densely settled cities in the world. As the commercial and financial center of China, Shanghai is also a global city with influence in commerce, culture, finance and transport etc. (Wikipedia 2012b). It is a major financial center[7] and the busiest container port in the world[8].

Sits on the Yangtze River Delta on China's eastern coast, the municipality as a whole consists of a peninsula between the Yangtze and Hangzhou Bay, Chongming island and a number of smaller islands (Wikepedia 2012b). Huangpu River, a tributary of the Yangtze River, runs through central Shanghai and finally reaches the sea (Figure 14). Central Shanghai has quite low elevation. Most of the city center has an elevation below 4.0 m and the lowest area below 2.0 m. Being a peninsula with such an elevation and a major river running through the city make Shanghai quite prone to flooding.

Shanghai subjects to frequent flooding due to its geographical location as well as the impact of periodical typhoons. In the recent history, two severe flooding, in 1949 and 1962 respectively, has struck Shanghai causing serious damage to the city. The 1962 flood has caused loss of 49 lives. The most recent severe flooding happened in 1997, which was equivalent to a 1000 years event at that time. Because of the protection of the structural defences that were building during late 1980s to early 1990s, less economic damage was caused and no loss of life was recorded.

However, it is expected that the frequency and intensity of flooding in Shanghai will increase in the future under the background of global climate change (Zepu Hu 2002). To cope with the increasing flood risks, Shanghai has been developing and upgrading its flood risk management approaches based on its structural defence system.

[6] Shanghai Bureau of Statistics, http://www.stats-sh.gov.cn/index.html
[7] "The Competitive Position of London as a Global Financial Center". http://www.zyen.com/PDF/LCGFC.pdf
[8] "Shanghai Overtakes S'pore as World's Busiest Port". *Straits Times*. 8 January 2011.

Figure 14. Location of the municipality of Shanghai[9]

3.3 Bangkok

Bangkok is the capital city of Thailand. With about12 million residences, it is the most densely populated city and also the commercial and financial center of Thailand.

Bangkok is located on the lower flat plain of the Chao Phraya River, extended to the Gulf of Thailand. Bangkok Metropolitan occupies an area of 1569 km^2 along the river banks, which forms the city's main geographical attraction and generates flood threats at the same time (BMA 2007).

The Chao Phraya River basin, the area surrounding Bangkok and the nearby provinces comprise a series of plains and river deltas that lead into the Bay of Bangkok about 30 km south of the city center (Wikipedia 2012c). Figure 15 provides a general idea of Bangkok's geographical location.

[9] Map available at: http://travel.shangdu.com/chinaditu/20110111-46626.shtml

Figure 15. Location of the municipality of Bangkok[10]

Since Bangkok lies about merely two meters above sea level, the city is prone to severe flooding, especially during the monsoon seasons. In 1942 a severe flood hit Bangkok with 1.5m water height and lasted for 2 months. In 1983 the city was flooded for 3-5 months due to the impact of several cyclones. In 2011 Bangkok was struck again by a severe flooding that spread through many provinces of Thailand along the Mekong and Chao Phraya river basins.

To strengthen its flood-coping ability, Bangkok has been developing a series of flood risk management measures and instruments in order to better protect the city from flooding.

[10] Map available at: http://www.mapsthailand.org/thailand-maps/bangkok-map.htm

Chapter 4 Materials and Methods

In this chapter, a survey in form of questionnaires to the FRM professionals and practitioners in the selected megacities is conducted to derive first-hand information about the FRM practices in these three megacities. The questionnaire is designed in accordance with the integrated FRM framework as well as the associated indicators and criteria proposed in Chapter 2.3. In addition, information from other sources, such as publications, authority websites or brochures, is also examined as a supplement to the survey.

4.1 Survey

The experiences and opinions of local FRM practitioners and professionals are of great value when it comes to the analysis of FRM practices. Therefore, a survey, in form of questionnaire, is designed to derive first-hand information from the practitioners and professionals in the selected megacities in order to help analyse the current FRM practices.

Questionnaire

The questionnaire is designed on the basis of Table 2 *Proposed indicators and criteria for the IFRM framework*. Aim of the questionnaire is to derive first-hand information from the FRM practitioners and professionals who have rich experiences on the FRM practices in their cities.

The questionnaire, with 32 questions in total, is divided into 4 sections. Section 1 focuses on the topic of flood risk analysis and the 2nd section covers the topic of risk evaluation, including the evaluation of risks and the evaluation of relevant risk reduction activities. Section 3 mainly deals with risk reduction activities, aiming to examine what measures and instruments are taken in the selected megacities and if there is a good combination of measures and instruments or a certain type of risk reduction activities dominates. With the first three sections focusing on the technologies that are implemented in practice, the 4th section covers the topic of flood risk management process with focus on legal and institutional arrangements as well as adaptive capabilities.

The questionnaire is designed in English and translated into Chinese for respondents in Shanghai. Exact questionnaire in these two languages are attached in Appendix.

Contacts and feedbacks

As the questionnaire is designed for the practitioners and professionals in the selected megacities, a first step is to investigate the managing structure of the FRM practices in London, Shanghai and Bangkok. Hereby, this study focuses primarily on the authority level that has a broader view of the FRM systems since their functions covers a range of activities from decision-making to policy setting, and to the execution of risk reduction activities. In addition to the authorities, other city-specific stakeholders such as scholars and insurance sectors are considered as well, depending on the city in question. The FRM managing structure in each megacity is introduced as follows along with the chosen respondents.

LONDON

London, among the three selected megacities, has the most complex managing structure in terms of flood risk management. The main FRM managing authorities in London are given in Table 3.

Table 3. FRM managing authorities in London*

FRM managing authorities	Organisation responsibility regarding FRM
The Department for Environment, Food and Rural Affairs (Defra)	Defra has overall policy responsibility for flood and coastal erosion risk management in England. Defra does not build or manage flood defences. Instead, it provides funding through grants to the Environment Agency and local authorities as well as the Internal Drainage Boards.[11] E.g. '*Appraisal of flood and coastal erosion risk management - A Defra policy statement'* (June 2009).
Communities and Local Government	Communities and Local Government is responsible for spatial planning policy and the operation of the planning system in England, which regulates development and the use of land in the public interest. It covers issues related principally to the location, layout and appearance of new development. Design and flood resilience issues not related to external appearance are matters for the Building Regulations also administered by Communities and Local Government. Flood risk and coastal planning is among its several responsibilities.[12]
Operating Authorities	
The Environment Agency	The Environment Agency is the principal flood defence operating authority in England. Under the Water Resources Act 1991, the Environment Agency has permissive powers for the management of flood risk arising from forecasting and flood warning dissemination, and for exercising a general supervision over matters relating to flood defence.[13]
Internal Drainage Boards	Internal Drainage Boards (IDBs) are independent bodies. Each Board operates within a defined area in which they have permissive powers under the Land Drainage Act 1991 to undertake flood denfence works, other than on watercourses that have been designated as 'Main'.[10]
London Local Authorities	Local authorities have certain permissive powers to undertake flood defence works under the Land Drainage Act 1991 on watercourses which have not been designated as Main Rivers and which are not within Internal Drainage Board areas.
E.g. London Assembly	A scrutinizing body elected by voters in London, at the same time as they vote for the Mayor of London. Its duties include investigating issues of London-wide significance and making proposals to appropriate stakeholders and to the Mayor.[14] E.g. '*London under threat? Flood risk in the Thames gateway'* by its Environment Committee (October 2005).

* Some FRM relevant authorities are not listed in this table because they have quite specific functions that cover only one small area of the FRM practice and therefore are not considered as candidates for questionnaire. These authorities are: *The Highways Authorities; Sewerage Undertakers; Reservior Undertakers* and *Emergency Services.*

[11] Source: PPS 25, http://www.defra.gov.uk/environment/flooding/
[12] Source: PPS 25
[13] Source: PPS 25, www.environment-agency.gov.uk/
[14] Source: http://www.london.gov.uk/who-runs-london/assembly

Besides the abovementioned managing authorities as in Table 3, several other stakeholders also participated in London's FRM practice, such as listed in Table 4.

Table 4. Other FRM practice stakeholders in London

Other FRM practice stakeholders	Outline organization aims and background
The Association of British Insurers (ABI)	The Association of British Insurers along with the Council of Mortgage Lenders will comment on individual proposals on which the Environment Agency object and where there appears to be a high risk. Those proposing development, especially speculative investment, are advised to consult ABI guidance at an early stage in order to understand the insurance industries concerns.
Thames Estuary Partnership	A charity that provides a neutral forum for local authorities, national agencies, industry, voluntary bodies, local communities and individuals to work together for the good of the Thames Estuary. It is a charity providing a framework for the management of the estuary.[15]
Thames Water	Thames Water as the Sewerage Undertaker in the City of London is responsible for surface and foul drainage discharge from developments, where disposal is to the adopted sewer network. Thames Water employs the City as its sewer management contractor with responsibility for the day to day maintenance of the network and looking after its interest in any associated planning issues.[16]

Based on the FRM managing structure, combined with the availability of a specific contact person, 9 questionnaires were sent out to the practitioners and professionals from the EA, London Assembly, Thames Estuary Partnership, ABI and private sector flood consultants.
Out of the 9 questionnaires, 3 feedbacks came back with detailed answers as shown in Table 5.

Table 5. London feedbacks

Organization	Contact person	Position held
The Environment Agency (EA)	Anthony Hammond	Regional Modeling & Hydrology, Technical Advisor
	Matt Akers	Flood Risk Mapping & Data Management Technical Specialist
	Ian Blackburn	Development Control Engineer

The feedback from Mr. Matt Akers is actually a group feedback. The questionnaire was further distributed by Mr. Akers to his colleagues for more well-rounded answers since it covers various topics of FRM and one individual may not be able to answer all questions with full clearance. Therefore, this feedback is regarded as the representation of a group of FRM professionals.

[15] Source: www.thamesweb.com
[16] Source: Strategic Flood Risk Assessment (for the City of London), by Mouchelparkman, 2007.

SHANGHAI

The FRM managing structure in Shanghai possesses a top-down nature. Unlike London, in Shanghai the FRM responsibility is an exclusively governmental issue. The main responsibility falls on the *Shanghai Flood Control Headquarter.* It is under the *State Flood Control and Drought Relief Headquarters* (national level) and in corporation with the *Yangtze River Water Conservancy Committee* and the *Taihu-Lake Administrative Bureau* which are the administration authorities of the two watersheds that Shanghai lies in. Under the *Shanghai Flood Control Headquarter* are flood control offices in each districts and flood control lead teams in relevant authorities.

In addition, the residence army and armed police in Shanghai are obliged to emergency rescue and evacuation. General structure of FRM in Shanghai is as Figure 16.

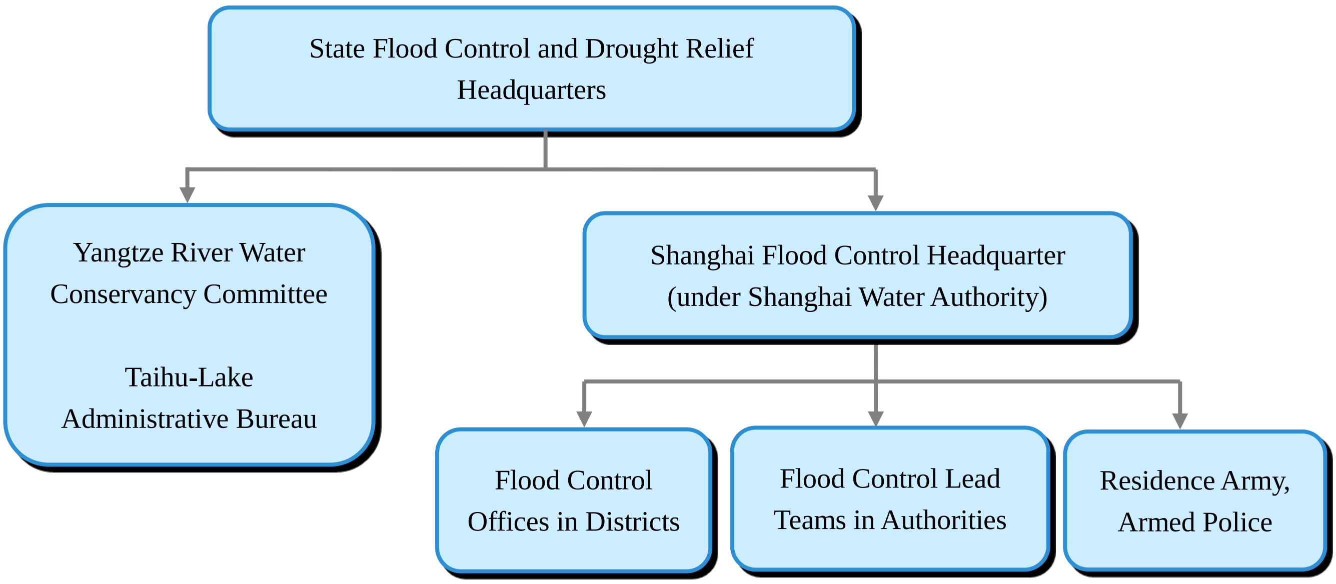

Figure 16. FRM managing structure in Shanghai

Based on the FRM managing structure in Shanghai combined with the availability of a specific contact person, 9 questionnaires were sent out to professionals from the State Flood Control and Draught Relief Headquarter, Shanghai Flood Control Headquarter and scholars/researchers in this field.

Out of 9 questionnaires, 7 came back as feedbacks as in Table 6.

Table 6. Shanghai feedbacks

Organization	Contact person	Position held
Shanghai Flood Control Headquarter	Xiaoyang Zheng	Chief Engineer
East China University of Political Science and Law	Dr. Ruisong Quan	Lecture
East China Normal University	Prof. Dr. Kai Yang	Professor College of Resources and Environmental Sciences
East China Normal University	Prof. Dr. Min Liu	Professor Department of Geology
East China Normal University	Dr. Jun Liu	Associate Professor, Department of Geology
Shanghai Normal University	Prof. Dr. Jiahong Wen	Professor Department of Geology
Shanghai Normal University	Dr. Zhan'e Yin	Associate Professor Department of Geology

BANGKOK

The *Bangkok Metropolitan Administration* (BMA) is the leading authority regarding flood risk management in Bangkok. The *Department of Drainage and Sewerage* (DDS) under the BMA shoulders the responsibility for flood risk management, especially the infrastructural flood prevention and mitigation efforts in Bangkok. It coordinates with the national government, Royal Irrigation Department, and district governments, as well as other stakeholders in planning and implementing various flood management efforts throughout the city (Takemoto 2011). The DDS has 2 further units that directly involve in FRM activities – *The Flood Control Center* (FCC) and the *Flood Relief Operation Center.* The FCC is responsible for overall FRM activities and the *Flood Relief Operation Center* is in charge of relief activities during and after a flood event. It is usually closed to public in period of no flooding threats.

In addition, the *Fire and Rescue Department* (also under BMA) is responsible for rescuing and protecting the public from any hazards, thus disaster relief in Bangkok. The *Department of Environment* shoulders the main responsibility of climate change mitigation and plans. BMA is also subject to relevant national authorities, such as *Department of Water Resources* under the *Ministry of Natural Resources and Environment* and *Department of Disaster Prevention and Mitigation* under the *Ministry of Interior.*

Based on the FRM managing structure combined with the availability of specific contact persons, 8 questionnaires were sent out to the BMA, Department of Water Resources, Meteorological Department and Asia Disaster Preparedness Center (ADPC).

Of all the contacts, 2 feedbacks came back as in Table 7.

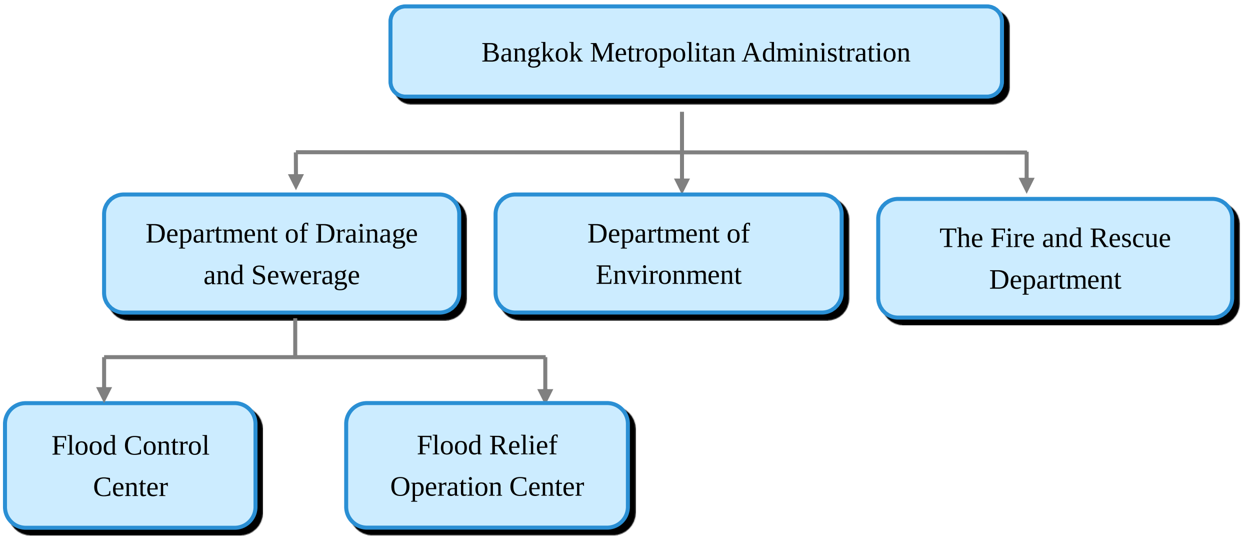

Figure 17. FRM managing structure in Bangkok

Table 7. Bangkok feedbacks

Organization	**Contact person**	**Position held**
Department of Water Resources (Ministry of Natural Resources and Environment)	Burachat Buasuwan	Senior Policy and Plan Analyst Specialist, National FMMP and M-IWRMP Coordination
Asian Disaster Preparedness Center (ADPC)	Chusit Apirumanekul	Project Manager, Resilient Cities and Urban Risk Management

4.2 Additional Information

In addition to the survey, FRM practice information from other public sources, such as websites and publications, are also researched as supplement so that a full picture of the current FRM practices in the three selected megacities could be captured.

LONDON

For the city of London, the following documents are closely examined according to the IFRM framework and the proposed indicators and criteria.

Flood and Water Management Act 2010

Appraisal of Flood and Coastal Erosion Risk Management – A Defra Policy Statement

Planning Policy Statement 25: Development and Flood Risk

TE 2100 Plan – Thames Estuary 2100, Managing Flood Risk through London and the Thames Estuary

Further information of these documents is listed in Table 8.

Table 8. Relevant documents regarding FRM in London

Document	Issued by	Outline of the document
Flood and Water Management Act 2010	National Law	The Flood and Water Management Act came into effect on 12th April 2010. The Act takes forward a number of recommendations from the Pitt Review[17] into the 2007 floods and places new responsibilities on the Environment Agency, local authorities and property developers (among others) to manage the risk of flooding.[18]
Appraisal of Flood and Coastal Erosion Risk Management – A Defra Policy Statement	Defra, 2009	The Appraisal sets out the principles that should guide decision making on the sustainable management of flood and coastal erosion risk in England. The operating authorities in England are required to follow these principles when developing a case for investing taxpayers' money in flood and erosion risk management projects. It also sets out the risk-based context within which appraisal should take place and the principles and policies that should guide the work.[19]
PPS 25	Communities and Local Government, 2010	Planning Policy Statements (PPS) set out the Government's national policies on different aspects of land use planning in England. This PPS 25 replaces Planning Policy Guidance Note 25: *Development and Flood Risk*, published in 2002, which is cancelled. The policies in this PPS 25 should be taken into account by regional planning bodies in the preparation of Regional Spatial Strategies; by the Mayor of Greater London in relation to the Spatial Development Strategy in London; and in general, by local planning authorities in the preparation of local development documents. They may also be material to decisions on individual planning applications.[20]
TE 2100	Environment Agency, 2009	The Thames Estuary 2100 project was established by the EA in 2002 with the aim of developing a strategic flood risk management plan for London and the Thames estuary through to the end of the century. The aim of TE 2100 is to develop a flood management plan for London and the Thames Estuary that is risk based, takes into account existing and future assets, is sustainable, includes the needs of stakeholders and addresses the issues in the context of a changing climate and varying socio-economic conditions that may develop over the next 100 years.[21]

The *Flood and Water Management Act 2010* and the *PPS 25* have given quite clear definition of roles and responsibilities regarding flood risk management authorities (p. 40, PPS 25). The *Flood and Water Management Act 2010* has placed new responsibilities placed on the Environment Agency (EA) for flood risk management and new responsibilities on local authorities for managing the risk of flooding. The *Act* also placed a duty on agencies involved in flood and coastal risk management to

[17] Pitt Review: on the 25 June 2008 Sir Michael Pitt published his final report into the summer 2007 flooding. The report examines both how to reduce the risk and impact of floods, and the emergency response to the floods in June and July 2007

[18] Source: Briefing on the Flood and Water Management Act 2010, by British Property Federation, 2010.

[19] Source: Appraisal of Flood and Coastal Erosion Risk Management – A Defra Policy Statement

[20] Source: PPS 25

[21] Source: TE 2100

cooperate. The *Act* additionally contains an amendment to be inserted into the *Building Act* to improve the flood resistance of existing buildings. It also requires the developer to construct sustainable drainage systems as part of the construction for any building or construction that results in a reduced ability of the land to drain rainwater (BPF 2010).

The *Appraisal of Flood and Coastal Erosion Risk Management – A Defra Policy Statement* clearly states that the impacts of climate change should be consistently taken into account, in accordance with the most up to date guidance. The appraisal should reflect options that are sufficiently flexible to allow for future adaptation and any future changes to current predictions on climate change impacts (pp. 28-29, Appraisal). According to the *Appraisal*, multicriteria techniques, such as weighing and scoring, should be used to aid the systematic comparison of options where all of the impacts have not been captured in monetary terms. It is not an alternative to cost benefit analysis but an extension of it, to ensure that non-monetised impacts are adequately considered in the appraisal processes (p.29, Appraisal). As for stakeholder participation, it regulates that operating authorities should ensure that arrangements are in place for effective public participation and consultation, and that procedures are adequate to demonstrate transparent decision making. Formal and informal consultation should be undertaken in the development of plans and projects, which should enable stakeholders affected to make a meaningful contribution to the appraisal processes. At a local level, information should be conveyed to stakeholders in a transparent way and the basis for flood and coastal erosion risk management decisions should be made available in the public realm, wherever possible (p.36, Appraisal). Operating authorities should have effective and independent arrangements to assure the quality of the appraisal, approval processes and governance of decision making through openness in communications, greater stakeholder participation and publication of information and decisions in the public domain (p.37, Appraisal).

The *PPS 25* states that the aims of planning policy on development and flood risk are to ensure that flood risk is taken into account at all stages in the planning process to avoid inappropriate development in areas at risk of flooding, and to direct development away from areas at highest risk (p. 2, PPS 25). *PPS 25* adopts a partnership approach aiming to work effectively with the Environment Agency, other operating authorities and other stakeholders to ensure the best use is made of their expertise and information. It ensures that spatial planning supports FRM policies and plans, River Basin Management Plans and emergency planning (p. 3, PPS 25). It clearly states that flood risk should be considered alongside other spatial planning issues such as transport, housing, economic growth, natural resources, regeneration, biodiversity, the historic environment and the management of other hazards (p. 7, PPS 25).

In addition, the Planning Policy 1 (PPS 1): *Delivering Sustainable Development* sets out how regional planning bodies and local planning authorities are expected to prepare development plan policies which avoid new development in areas at risk of flooding and sea level rise, and take climate change impacts into account in the location and design of the development (p. 13, PPS 25).

According to *TE 2100*, the review of the current flood risk management activities along the Thames Estuary is driven by certain future changes: climate change, ageing flood defences, the physical environment, the socio-economic change and public and institutional awareness of flood risk (p. 20, TE 2100). It is the first major flood risk management project in UK to have put climate change adaptation at its core (by scenario development) (p. 22, TE 2100). It has identified 3 time horizons, thus three themes for flood risk management: the first 25 years (2010-2034), the middle 35 years (2035 to 2069) and to the end of the century (from 2070 to 2100) (p. 34, TE 2100). This ensures the implementation of short-term activities as well as the adaptation to future changes. *TE 2100* recommends that flood risk is monitored and the *Plan* reviewed and updated at least every 10 years (p. 24, TE 2100). To help make decisions on which are the best flood risk management options and policies, *TE 2100* has assessed four impact categories – economic, environmental, social and technical risks (p. 38, TE 2100). The Economic Appraisal has adopted the cost-benefit analysis with multicriteria emerged in to the extent that wider environmental and social impacts are expressed in terms of money values (p. 38, TE 2100). In addition to the Economic Appraisal, Strategic Environmental Assessment and a Habitats Regulations Assessment are also conducted for the selection of the best FRM options (pp. 39 -40, TE 2100). *TE 2100* has a consultation period for landowners, the public, business and other interested groups, which ensures the participation of relevant stakeholders.

SHANGHAI

Unlike London, there is few comprehensive flood risk assessment report available for the city of Shanghai. Therefore the documents being examined for Shanghai are the regulations issued by the authorities. These documents are:

Flood Control Law of P.R.C.
Standard for Flood Control (of P.R.C)
Flood Control Regulation of Shanghai
Regulation on Management of River Courses (of P.R.C)
Overview of Shanghai Multi-hazard Early Warning System and the Role of Meteorological Services
Regulation on Urban Planning of Shanghai
General Planning on the Land Use of Shanghai
Controlled and Detailed Planning of Shanghai

Detailed information of these documents is in Table 9.

The *Flood Control Law of P.R.C.* regulates that every unit and individual has the responsibility to flood risk management. The important flood relief force is the P.R.C. Army and Armed Police. Flood risk management plans at city level shall be based on the comprehensive planning of the relevant watersheds and river courses. FRM funds come from budget allocation from financial department at the national and local level. There should be progressive implementation of flood insurance nationwide.

The *Standard of Flood Control* (of P.R.C.) regulates that the return period for design level in large cities shall be at least 200 yrs. Whereas in Shanghai, the flood protection wall at the Huangpu River and at the sea shores have reached a return period of 1000 years.

Table 9. Relevant documents regarding FRM in Shanghai

Document	Issued by	Outline of the document
Flood Control Regulation of P.R.C.	State Council of P.R.C.	The Flood Control Regulation of P.R.C. came into force on 27th Jul., 2005. It defines the responsibilities regarding FRM activities, from the preparation to event management, to flood disaster relief. It also defines in general the financial source as well as the rewards and penalties regarding FRM.
Standard of Flood Control	Ministry of Housing and Urban-Rural Development of P.R.C.	The Standard of Flood Control came into force on 1st, Jan., 1995. It regulates the design level (return period) for cities and infrastructures.
Regulation on Management of River Courses	State Council of P.R.C	The Regulation on Management of River Courses defines the responsibility for river course management. It regulates the construction along and the protection of river courses. As far as FRM is considered, this document regulates mainly the structural measures against flood risk.
Flood Control Regulation of Shanghai	Municipality of Shanghai	The Flood Control Regulation of Shanghai came into force on 1st Sep., 2003. It defines the responsibilities regarding FRM activities in Shanghai, from the preparation to event management, to flood disaster relief. It also defines in general the financial source as well as the rewards and penalties regarding FRM.
Overview of Shanghai Multi-hazard Early Warning System and the Role of Meteorological Service	Shanghai Meteorological Bureau	A presentation at 'Training Workshop on Multi-Hazard Early Warning Systems (MHEWS) with focus on Institutional Partnerships and Cooperation' held on 22-25. Mar. 2010 in Costa Rica. It introduces Shanghai's multi-hazard early warning systems.
Regulation on Urban Planning of Shanghai	Municipality of Shanghai	The Regulation on Urban Planning of Shanghai came into force on 13th Nov. 2003. It defines responsibilities regarding urban planning and regulates the procedures for urban construction projects.
General Planning on the Land Use of Shanghai	Municipality of Shanghai	The General Planning on the Land Use of Shanghai states Shanghai's current land use management conditions and directs the strategy of future land uses.
Controlled and Detailed Planning of Shanghai	Municipality of Shanghai	The Controlled and Detailed Planning of Shanghai gives detailed planning for the city of Shanghai based on the Land Use Plans and other relevant documents. One section of this document is about flood control.

The *Flood Control Regulation of Shanghai* generally follows the content of the *Flood Control Law of P.R.C.* only downscales it to the municipality level. However, the *Flood Control Regulation of Shanghai* has an extra section regulating the structural defense measures.

The *Regulation on Urban Planning of Shanghai* states that the construction of structural flood defense facilities shall following relevant regulations and specification. This is the only line that is in relevance to flood risk management within the *Regulation*.

The *General Planning on the Land Use of Shanghai* and the *Controlled and Detailed Planning of Shanghai* give no specific attention to flood risk management.

The flood earning warning of Shanghai is embedded into the multi-hazard early warning system, where the Shanghai Meteorological Bureau is responsible for weather and climatic relevant warnings, which includes flood early warming. Shanghai has established an emergency plan especially for floods and typhoon - *Specific Emergency Plan of Flood and Typhoon.* In case of extended environmental pollution, the *Emergency Plan of Environmental Accidents* will automatically be executed.
The emergency excavation and rescue team, from the government side, consists of police department, drainage department, firefighting unit, power and meteorological department. In case of disastrous flooding, the armed police and army force can be dispatched upon order.
Early warning messages are distributed through traditional media like newspapers, TV and radios as well as social media like Weibo (Chinese 'twitter') and governmental webpages. In severe events, warning messages can also be sent as text messages through cellphones.
Monitored hydrological information can be derived at the website of Shanghai Water Authority, where a special page for flood prevention and control is established and published to the general public. The webpage is as follows:
http://www.shanghaiwater.gov.cn/web/homepage/new_index.jsp

BANGKOK
Because of the language barrier, the documents examined for Bangkok are published papers and presentations at international conferences that are written in English, as in Table 10. The only document issued by the authorities being examined is the *Summary of the Eleventh National Economic and Social Development Plan (2012-2016)*.
The examined documents are:
Summary of the Eleventh National Economic and Social Development Plan (2012-2016)
Historical Floods, Flood Management, Vulnerabilities, and Risk Assessment in Bangkok

Flood and Flood Management in Bangkok, Thailand
Thailand Country Report: Flood Forecasting and Warning Systems in Thailand

Table 10. Relevant documents regarding FRM in Bangkok

Document	Issued by	Outline of the document
Summary of the Eleventh National Economic and Social Development Plan	National plan	The 11th Plan sets out the vision, missions, objectives as well as targets of Thailand's national economic and social development for the period of 2012 – 2016.
Flood and Flood Management in Bangkok, Thailand	Kreeta Sroikeeree, Rattana Bannatham (BMA)	A report submitted to the Urban Training Programme held by UNU-EHS in Bonn, Germany, 2005. It introduces briefly the Flood situations as well as Flood Risk Management activities in Bangkok.
Thailand Country Report: Flood Forecasting and Warning Systems in Thailand	Dr. Janejira Tospornsampan, Thai National Mekong Committee	The report introduces the national flood forecasting and warning systems in Thailand, including the structure of the system, agencies involved and their respective functions.
Historical Floods, Flood Management, Vulnerabilities, and Risk Assessment in Bangkok	BMA	A presentation done by BMA that briefly introduces the flood situations as well as FRM activities in Bangkok. The report is published in the 4th Annual Mekong Flood Forum in Siem Reap, Cambodia, 2006.

The *Eleventh National Economic and Social Development Plan* points out that, as one of its development directions, Thailand's national preparedness is intended to cope with effects of climate change and natural disasters (p.viii, Summary of the 11th Plan). The corresponded strategy is to develop human resources aimed at increasing resilience for change, which includes learning to cope appropriately with climate change and disasters (p. xii, Summary of the 11th Plan).

According to the report *Flood and Flood Management in Bangkok, Thailand,* and the presentation *Disaster Management and Climate Change Adaptation,* Bangkok has implemented a series of flood risk reduction activities. However, it focuses greatly on structural, non-structural measures with few instruments. The measures taken are: main pump, polder embankments, dyke, canal improvement, scheme of drainage (inner pumps, sub canal and drain pipes), retention area, land use control, flood proofing, flood forecasting and warning and public information and education. During floods, the BMA coordinated with non-profit organizations and NGOs for food, clothes, temporary house supply.

Thailand Country Report: Flood Forecasting and Warning Systems in Thailand states that apart from the national forecasting and warning agencies (Thai Meteorological Department, Electricity Generating Authority of Thailand and the Royal Irrigation Department), the BMA is responsible for hydrological investigation in the lower Chao Phraya River nearby Bangkok and implement flood forecast in Bangkok. Normally the monitoring and forecasting products including warnings are published online.

As far as funding is concerned, most of the flood management projects in Bangkok are funded through the city's budget, while around 40% of infrastructure projects implemented in Bangkok are subsidised by the national government (Takemoto 2011).

4.3 Current FRM Practices in the Selected Megacities

In this section, the current FRM practices in London, Shanghai and Bangkok are analysed and outlined based on the result of the survey as well as the additional information examined. The FRM practices are outlined in accordance with the identified FRM framework so that a comparison of the practices and the framework can be drawn in the later chapter as a result.

Current FRM practice in London

Risk analysis

London models a series of return periods for fluvial flood hazard analysis, including 5 yrs, 20 yrs, 100 yrs, 200 yrs and 1000 yrs. 200 yrs and 1000 yrs return period are then evaluated in more detail. The hazard analysis also takes into account the impact of climate change by given an added 20% on peak flow. For the tidal river Thames, a number of return periods with risks of breach in the tidal defences are modeled.

1D, 2D and 1D/2D coupled hydraulic models are used to determine the critical parameters, such as water depth and flow velocity. DTM driven overland flow models are used for surface water simulation. Example: along the Thames River, statistical analysis of the tide gauge data is used to derive boundary conditions for the Tidal Thames ISIS 1D model, which then creates a range of in bank extreme water levels. Tuflow is then used with the hydrographs created from ISIS to simulate the 2D floodplain and create flood extents for various return periods and scenarios.

There is always uncertainty associated with flood risk analysis. For the fluvial flood risk modeling, it is dealt with through review of modeling outputs to ensure that they match known information about flood risk (e.g. historical flood outlines). Monte Carlo simulation is used within the extreme water level analysis. In addition, UK has a National Flood Risk Assessment (NaFRA)[22], where a probabilistic approach to flood risk modeling is used and many different scenarios are sampled to produce one overall result. It's also beginning to describe levels of confidence in results based on the input data and model performance.

The vulnerability analysis in London considers not just economic, but also social and environmental aspects.

Flood risk maps are available for return period 100 yrs and 1000 yrs. Vulnerability maps are limited, but the flood risk maps cover this element. In addition, flood maps with return period 200 yrs are also generated for flooding from the sea, though it is not specific for London. EA could also provide specific maps upon request. Within flood mapping, EA is able to produce various outputs including probability, depth,

[22] Available at: http://publications.environment-agency.gov.uk/PDF/GEH00306BKIX-E-E.pdf

velocity, height, hazard and extents and overlay this mapping onto given data such as vulnerable or socially deprived housing, schools, hospitals etc. An example is the project known as 'Drain London'[23] that has undertaken detailed surface water risk mapping for Boroughs in London.

Currently the flood risk models are run in real time for flood forecasting purposes using the latest rainfall/gauging station data plus rainfall forecasts to enable flood warnings. These models focus on flows and water levels at key locations rather than producing flood maps. Therefore there is no dynamic flood mapping at present, but the EA is working towards it.

The flood maps are available online for the public and are updated every three months with the most up to date data[24]. In addition, EA also has a data sharing portal for professional partners. Paper copies of maps are available on request. The public has in general easy access to these maps. Two feedbacks of the questionnaire holds the opinion that the public has very easy access to these flood maps, while the other thinks it is easy for the public to access to the maps instead of 'very easy'. The concern is that although the public can always ask for any mapping they desire or look on the EA website easily, it is whether or not they know about such maps or access processes that influences the access in many cases.

Risk evaluation

The tidal defences and the Thames Barrier protect London to a design standard of 1 in 1000 yrs event. Apart from the tidal defence, the development management process ensures that 200 yrs return period is considered when taking into account flood risk management.

London uses primarily cost-benefit analysis for the selection of optimal risk reduction options. Multicriteria evaluation (MCE) is relatively new in this regard and is limited to a specific level. Example: The TE 2100 project has adopted MCE to some extent by emerging it into the cost-benefit analysis and the result plans are already in place to drive London's flood risk management in the future. MCE is also recommended by Defra in its national policy *Appraisal of Flood and Coastal Erosion Risk Management*.

Risk reduction activities

London has a combination of structural and non-structural measures as well as instruments. However, all feedbacks agree that the structural measures dominate, in particular, the Thames tidal defence.

The pre-flood risk reduction activities include:

- Structural defences (e.g.Thames tidal defence walls);
- Promotion of flood resistant and resilience measures of buildings (e.g. some new buildings are built with ground floor being set aside for car parking);

[23] Information available at: http://www.london.gov.uk/drain-london
[24] Available at: http://maps.environment-agency.gov.uk/wiyby/wiybyController?x=531500.0&y=181500.0&topic=floodmap&ep=map&scale=3&location=London,%20City%20of%20London&lang=_e&layerGroups=default&textonly=off

- Land management techniques (e.g. water storage in parks/open spaces);
- Flood early warning system[25];
- Spatial planning taken into account flood risk reduction;
- Preparedness of local communities;
- Flood insurance.

The EA is very proactive at influencing the planning authorities to adopt policies that consider flood risk reduction measures in their spatial plans and prioritizing development in low risk areas. The EA and local authorities engage with the local communities to make them more aware of and better prepared for flood risks through various means, such as traditional media, social media, public events etc. Example: The EA conducts many public shows and advertise on local radios to highlight the risk of flooding to the public. Flood insurance in London is based on an individual basis with insurance companies, though the EA have a statement of principles with the ABI to ensure that everyone can receive affordable insurance against floods.

The flood event management activities include:

- Flood control measures (e.g. Thames Barrier and the associated gates, individual flood gates for riverside properties, automated river structure, pumps etc.);
- Real-time flood forecasting and warning;
- Emergency evacuation and rescue;
- Emergency management plans;

The evacuation and rescue are primarily governmental services. Third party (e.g. NGOs) aid would be possible upon request. Emergency management plans are created and led by the local authorities (each London Borough) in conjunction with the EA and the emergency services (e.g. Multi Agency Plan[26]).

The post-flood recovery and reconstruction activities include:

- Reconstruction and resilience measures;
- Recovery and resilience plans

The recovery and resilience plan is the responsibility of and led by local authorities. It is generally part of the local authority Multi Agency Flood Plans[27].

Flood risk management process

Of the 3 feedbacks, 2 answered the questions of this section. This is because the other feedback is a technical expert and not involved in management process.

Both feedbacks agree that London has clear legal definition of roles and responsibilities regarding FRM stakeholders and has an appropriate legislative framework supporting the FRM practices. As for the legal support of FRM practice, both feedbacks consider that there is strong legal support for the management of flood

[25] Available at: http://www.environment-agency.gov.uk/homeandleisure/floods/default.aspx

[26] Information available at: http://www.environment-agency.gov.uk/research/planning/124685.aspx

[27] An example of London Borough of Richmond can be found at: http://www.richmond.gov.uk/lbrut_flood_plan.pdf

risk in London, especially for structural and non-structural measures. However, 'there has been a trend to move away somewhat from structural measures more so to non-structural and human reliant solutions', according to one feedback. The public and local community involvement in London is regarded as effective. The public are involved in FRM practice through brochures, media, public events, consultations etc. There is also a formal collaboration platform for relevant FRM stakeholders to work together. This formal collaboration is carried out through partnership funding approach and meetings are usually held quarterly. Examples are the 'Drain London Forum[28]' set up by the Greater London Authority for partnership working across London and the 'Local Resilience Forum' that consists of emergency services, local authorities, the National Health Service, the EA and other partners. Generally there is a wide participation of relevant stakeholders into the FRM practice in London, though it may deviate from borough to borough. The members include but not limited to the Defra, EA, local government/authorities, flood and/or emergency forums, community action groups, flood risk consultancies, ABI etc. Both feedbacks agree that all relevant stakeholders are included in the FRM process. The stakeholders' capacity building is incorporated into the FRM practice by education and trainings. Both feedbacks regard the FRM considerations as very well integrated into development and strategy plans, such as the catchment management plans, asset management plans, surface water drainage system plans, TE 2100 plan and other local development frameworks. The FRM plans and strategies are monitored, periodically evaluated and updated wherever in need. These plans and strategies also take into account the climate change considerations by a 20% - 30% increase in flows based on the latest UKCIP research results. As adaptation, climate change scenarios are taken into account when design schemes or policy influencing, such as recommendations of building design as well as asset and how they're likely to perform in the future. Generally speaking, there is enough staff working on flood risk management. However, it is also a matter of funding. If there is more funding, more staff could be employed and more work could be achieved. As one feedback says, EA is doing the best they can within the current funding and staff and a lot has been achieved.

In general, London has a quite well functioning FRM system. However, the standard of flood defence is very high (1: 1000). This means it's only the performance of the defence of flooding that people sees rather than the management system itself, according to one feedback. Therefore, EA holds flood exercises to assess how they would perform in a real event. As one feedback points out, despite some bureaucratic inefficiencies the task of managing flood risk and planning for the future of flood risk management in London is being achieved to a high standard.

[28] http://www.london.gov.uk/drain-london

Current FRM practice in Shanghai

Risk analysis

Shanghai models a series return period for hazard analysis, include 10 yrs, 20 yrs, 50 yrs, 100 yrs, 200 yrs and 1000 yrs. 1D and 2D hydraulic models are used to determine the critical parameters (depth and velocity) of a flood event. Uncertainty analysis is included when analyse flood risks through Monte Carlo simulation as well as scenario calculations. Shanghai uses multicriteria for vulnerability analysis that cover economic, social and environmental/ecological dimensions. Vulnerability and hazard maps are not specifically produced, but these two elements are covered by/within the risk maps. Dynamic flood mapping are used in Shanghai for the purpose of real-time flood forecasting and warning. The produced maps are displayed at the governmental websites and paper copies are in place at the authority. However, it is generally difficult for the public to reach these maps. Of the 7 feedbacks, 5 agree that it is difficult for the public to access to the flood maps, while the rest 2 feedbacks regard it as 'not easy, but some access possible'.

Risk evaluation

The flood defence walls along the Huangpu River protect Shanghai to a standard of 1 in 1000 yrs event. The generally design level for risk reduction activities is of 200 yrs return period. Cost-benefit analysis is primarily used to select the optimal risk reduction options.

Risk reduction activities

Shanghai has a series of risk reduction activities that involves structural and non-structural measures as well as instruments. However, structural measures dominate strongly.

The pre-flood risk reduction activities include:

- Structural defences (e.g. tidal and fluvial flood defence walls);
- Land management techniques (e.g. water storage in green areas, retention by water bodies, increased pervious areas);
- Spatial planning takes into account FRM (e.g. transport planning);
- Flood early warning – through traditional media (TV, radio, newspapers), social media (weibo[29], websites) as well as text messages;
- Preparedness of local community – through workshops and trainings, brochure, TV and websites;
- Flood insurance.

Though Shanghai has begun to take FRM into account in spatial planning, it is still at an early stage. Of the 7 feedbacks, only 3 agree that spatial planning has been used as pre-flood risk reduction measures in Shanghai.

[29] A Chinese social websites, similar to 'twitter'.

The flood event management activities include:

- Flood control measures (e.g. urban pumping, water/flood gates control)
- Dynamic flood risk mapping and real-time food warning
- Emergency evacuation and rescue – primarily governmental services, combined with community self-aid, third party (e.g. NGOs) aid on request
- Emergency management plan - both at municipal and district level, each relevant agency also has its specific emergency plans (e.g. emergency plan of urban sewer department).

The post-flood risk reduction activities include:

- Reconstruction and resilience measures – primarily reconstruction of damaged buildings and infrastructures;
- Financial subsidy for relief and recovery;
- Recovery and resilience plans.

The funding for flood disaster relief activities is from national and local financial budget, flood insurance (based on individual contract) as well as public donations in terms of severe flooding.

Flood risk management process

The legal definition of roles and responsibilities regarding FRM stakeholders in Shanghai is not satisfactory. Of the 6 feedbacks that answered this question, 3 hold the opinion that the legal definition is not clear, and the other 3 regard it as somewhat clear. None has approved it as clear. The majorities of the feedbacks (4/6) agree that there is a legislative framework supporting FRM practice in Shanghai, but not so well formed and improvement needed. The legal support for FRM practice in Shanghai is regarded as weak. There is a form of public/local participation regarding FRM practice, but the effect is less satisfactory. 4 out 7 feedbacks hold the opinion that there is no effective public/local community participation in Shanghai. 4 out of 7 feedbacks agree that there is no platform or coordination mechanism for stakeholder collaboration, while the other 3 hold the opinion there is a platform/coordination mechanism, but depends on informal personal networks. Most of the relevant sectors and stakeholders are already involved in the FRM practice. The remaining sectors that are not yet in the scheme are the development and planning authorities, especially the local development and planning departments as well as the supervision departments whose responsibilities shall be to supervise the procedures and qualities of the various FRM activities. The stakeholder’s capacity building is incorporated into the FRM system through education and trainings as well as consideration of experts’ advice. 5 out of 7 feedbacks hold the opinion that the FRM considerations are partially integrated into development plans and strategies, while the other 2 regard it as poorly integrated. Therefore, the integration of FRM considerations into development plans and strategies is considered as less satisfactory. There is monitoring and periodical evaluation of the current FRM plans by the FRM authorities and update is made wherever in need. Shanghai’s FRM plans have taken into account the impact of climate change through scenarios calculation and analysis, and adaptation measures are taken through structural measures, such as the current on-going feasibility study of building up water gates at the mouth of Haungpu River. There is currently around 10 staff working on managing flood risks in Shanghai at the municipal level. This number is considered as not enough. As for the general performance of the FRM practice in Shanghai, 5 out of 7 feedbacks regard it as 'functioning, but needs improvement' and 1 thinks it as 'functioning well' and the other 'poor performance'.

Generally speaking the FRM system in Shanghai is functioning, but largely due to the high standard of protection of the structure defensive facilities (1:1000). In terms of the managing system itself especially from the process perspective, much improvement is still to be done.

Current FRM practice in Bangkok

Risk analysis

Bangkok uses 50 yrs return period for its flood hazard analysis. 1D/2D coupled hydraulic modeling are used to determine the critical parameters of floods. Uncertainty analysis is also included within the process through scenario calculations. The vulnerability analysis takes only economic considerations into account, without covering social and environmental/ecological dimensions. There are vulnerability maps, hazard maps and risk maps in place, primarily in form of paper copies or digital maps at the authority. The public has no easy access to these maps.

Risk evaluation

The return period for design level of risk reduction activities is 50 yrs. Cost-benefit analysis is used for the selection of optimal risk reduction options. Multicriteria is not in use.

Risk reduction activities

Bangkok has a combination of structural and non-structural measures as well as instruments, but structural measures dominate.

The pre-flood activities include:

- Structural defence (e.g. polder embankment, dykes);
- Flood proof buildings;
- Spatial planning takes into account FRM;
- Flood early warning system;
- Preparedness of local community – through trainings.

The flood event management activities include:

- Flood control measures (e.g. urban pumping, water/flood gate control, temporary flood barrier - sand bags);
- Emergency evacuation and rescue – primarily governmental services, also community self-aid and third party aid (e.g. NGOs);

- Setting up of evacuation camps – but with little experience on evacuation camp management;
- Emergency management plans (e.g. evacuation plan).

The post-flood activities include:

- Reconstruction measures – primarily reconstruction of damaged buildings and infrastructures;
- Flood subsidy.

Work on flood early warning system and preparedness of public/local communities, especially school children need to be further improved, according to the 2 feedbacks.

The funding of the flood disaster relief activities comes from governmental budget, at both the national and city level.

Flood risk management process

The 2 feedbacks from Bangkok, one from the government (Department of Water Resources) and the other from the practice side (ADPC), holds quite different views concerning the legal aspects of the FRM process in Bangkok.

The government feedback considers Bangkok as having somewhat clear legal definition of roles and responsibilities regarding the FRM stakeholders, while the practice feedback regards it as no such definition at all. The government feedback holds the opinion that there is an appropriate legislative framework supporting the FRM practice in Bangkok, while the practice feedback indicates that there is no appropriate legislative framework at all. As for the legal support, the government feedback suggests that there is some legal support in place while the practice feedback's answer is no legal support at all. It is worth noticing that the evaluation from the government feedback is generally more positive than that from the practice feedback. This may suggest that the policy or legislation is already in place, but the translation into practice is missing. Implication of this difference is further discussed in Chapter 6.

The public/local community involvement into the FRM practice is managed through workshops and trainings, but the effect is less satisfactory. There is some form of stakeholder collaboration in both formal and informal channels. Formal collaboration is achieved through meetings. However, there is no regular meeting in place, but held upon needs when the situation calls for and there is usually no follow-up afterwards. Therefore the formal collaboration channel is not effective. The informal channel of stakeholder collaboration is through personal networks. It is regarded as effective but less practical according the feedback from the practice side, since many actions need to be decided by decision makers which require formal procedures. As far as the stakeholder participation is concerned, the feedbacks hold different opinions. The government feedback states that all related sectors and stakeholders are included while the practice feedback indicates that some sectors/stakeholders have been left out, especially the local communities and planning departments. In addition, the concerned stakeholders are still lacking of collaboration. According to the different opinions from the 2 feedbacks, it could be concluded that the stakeholder participation in Bangkok already covers a variety of sectors, but how wide and how deep are they involved remains questionable. Stakeholder's capacity building is achieved through education and training, but not on a regular base. The integration of FRM considerations into development plans and strategies is regarded as poor by the government feedback and the practice feedback states that the development plans and strategies do not consider FRM at all. Both feedbacks agree that there is no monitoring or periodical evaluation of the current FRM plans and strategies, neither the update of them. It is also indicated by both feedbacks that the current FRM plans do not have climate change considerations incorporated. Both feedbacks indicate that there is enough staff and experts working on the FRM but bringing them together and asking the politicians to take experts' ideas is a challenge

Generally speaking, the performance of FRM practice in Bangkok is not satisfactory and much improvement is needed.

Chapter 5 Results

5.1 Comparison of the FRM Practices and IFRM Framework

As results, the FRM practices in the three selected megacities are firstly integrated into the FRM framework separately (Table 11, Table 12 and Table 13), so that detailed information can be merged in and a close examination of the practice in each megacity can be made.

Then the practices in the three megacities are put together at a broader scale as to compare with the FRM framework and the associated indicators and criteria (Table 14). Here, the marks '+', '+/-' and '-' are used for evaluation of the practices. '+' means that the corresponding criterion is fulfilled, while '+/-' indicates that the criterion is partially fulfilled but further improvement is needed and '-' means criteria not fulfilled. By this comparison at a broader scale, an impression of the general performance of the FRM practices can be achieved and the strengths and weaknesses of the three megacities can be captured.

LONDON

In general, London has a quite strong FRM system that is functioning well. The overall performance of its FRM practice is quite satisfactory.

Two deviations from the FRM framework are found, which suggests the corresponding criteria are partially fulfilled and further improvement is needed. They're the issues of:

- dynamic flood mapping , and
- combination of measures and instruments for risk reduction activities.

'Dynamic flood mapping' is recommended by the framework for real-time flood forecasting and warning purposes. Though no dynamic flood mapping at present, London does has a real-time flood forecasting and warning system currently by using and issuing Heavy Rainfall Warnings. The real-time flood modeling uses the latest rainfall or gauging station data plus rainfall forecasts to enable flood warning. However, the models focuse on flows and water levels at key locations rather than producing flood maps. The use of dynamic flood mapping will further enhance the real-time flood forecasting and warning system by at least a wider geographic coverage. As the professionals from the EA stated, EA is working towards dynamic flood mapping.

'Combination of measures and instruments' is the criterion for risk reduction activities in the IFRM framework. Along with the shift from structural defence measures to integrated flood risk management, it is widely accepted that non-structural measures and instruments are an indispensable part of the risk reduction activities. London currently has a series of risk reduction activities including both measures (structural and non-structural) and instruments. However, the structural measures dominate. It is not to say that there are certain non-structural measures or instruments that are lacking within the risk reduction system. The question lies on how deep and how wide the non-structural measures and risk reduction instruments are implemented or integrated.

SHANGHAI

Generally speaking, Shanghai has a comprehensive FRM system, which is currently functioning. Though, the overall performance of its FRM practice is less satisfactory. There are several deviations from the framework being found, where some of the criteria are partially fulfilled and need further improvements while the others not fulfilled at all.

Deviations where indicators and/or criteria are partially fulfilled and further improvements are needed:

- combination of measures and instruments for risk reduction activities,
- spatial planning that takes into FRM considerations,
- preparedness of local community,
- legal support,
- stakeholder participation,
- effective public and local community involvement, and
- integration of FRM into development plans and strategies.

Deviations where indicators and/or criteria are not fulfilled:

- easy access of flood maps for the public,
- multicriteria for risk evaluation,
- flood proof buildings,
- platform for effective stakeholders collaboration, and
- long-term FRM plans and strategies that take into account climate change and societal changes.

Flood risk maps are produced for different return periods in Shanghai, such as 200 and 1000 yrs, which are the design level for FRM activities and structural defence facilities respectively. These risk maps are in place in form of paper copies at the authority as well as on government websites. However, they’re not open to the public and usually only available for FRM practitioners within the governmental units. The public could have access to these maps on request, but not easy.

Shanghai currently uses cost-benefit analysis for risk evaluation and selection of optimal risk reduction options. The cost-benefit analysis is based primarily on economic considerations. Multicriteria are not adopted at all. That is to say, no social and environmental/ecological considerations are taken into account.

The same as London, Shanghai already owns a series of risk reduction activities that consist of both measures (structural and non-structural) and instruments. However, structural measures still dominate. There are certain measures and instruments needs to be either added into the risk reduction systems or further enhanced. Flood proof buildings is currently not widely used or promoted in Shanghai and there is no regulations require so. Spatial planning and preparedness of local community are currently in practice, but the degree of implementation and the effectiveness remains questionable. Shanghai also lacks a platform for effective stakeholder collaboration

Compare with the technical aspect, Shanghai's main weakness lies on its flood risk management process. The legal support of FRM practice in Shanghai is weak. There is a legislative framework supporting FRM activities and some definition of roles and responsibilities regarding FRM stakeholder, but the degree of such support is not sufficient and the execution of relevant laws and regulations is sometimes lacking. There is a relatively wide participation of different sectors/stakeholders in the FRM practice in Shanghai, but not all sectors are involved. Local planning departments and supervision department are missing and the involvement of public and local communities are not wide or effective enough. There is no effective platform for stakeholder collaboration in place. Stakeholder collaboration is done through informal channels of personal networks. Such channel doesn't provide regular communications and stakeholders involved depend highly on individual cases. Informal collaboration has its advantages of being more flexible, fast and is usually not bureaucratic. It is an important supplement to formal collaborations. However, it cannot supersede formal collaborations. Especially that many actions need to be decided by decision makers, where formal procedures are required. Therefore, Shanghai needs to establish a formal channel for effective stakeholder collaboration. The integration of FRM considerations into development plans and strategies is also where efforts need to be put in for improvement. Currently, only transport planning and river bank planning has taken FRM consideration into account, since they're closely linked to flooding issues. Other development plans and strategies seldom consider FRM. Another aspect that Shanghai lacks is the long-term FRM plans and strategies that consider climate change and societal changes. Shanghai has implemented certain climate change adaptations by reinforcing its structural defence. However, there is no long-term plan or strategy in place that provides generally guidance on how to cope with future changes, especially climate change and societal development.

BANGKOK

Bangkok has already set up a FRM system consists of a variety of activities. However, the system is still in development, therefore it is relatively weak and the performance is not satisfactory yet. There are certain deviations from the framework being found, where some of the criteria are partially fulfilled and need further improvements while the others not fulfilled at all.

Deviations where indicators and/or criteria are partially fulfilled and further improvements are needed:

- combination of measures and instruments for risk reduction activities,
- spatial planning that takes into FRM considerations,
- preparedness of local community,
- emergency evacuation,
- legal support,
- stakeholder participation,
- capacity building,
- integration of FRM into development plans and strategies.

Deviations where indicator and/or criteria are not fulfilled:

- A series of return periods for hazard analysis,
- Vulnerability analysis that covers economic, social and environmental/ecological dimensions,
- easy access of flood maps for the public,
- return period for design level
- multicriteria for risk evaluation,
- land management techniques,
- platform for effective stakeholders collaboration,
- effective public and community involvement,
- climate change and societal considerations,
- Integration of FRM into development plans and strategies,
- Adaptive management.

The return period for flood hazard analysis in Bangkok is 50 yrs. There is not a series of return periods being used for hazard analysis. For vulnerability analysis, Bangkok considers only the economic dimensions, without social and environmental/ecological considerations. Flood maps are in place but not easy for the public to access. The return period for design level is 50 yrs in Bangkok, which is quite low for a megacity. For risk evaluation and selection of optimal risk reduction options, Bangkok uses cost-benefit analysis that focuses only on economic benefits and losses without taking into account social and environmental/ecological aspects.

Bangkok has a series risk reduction activities that combines both measures and instruments. However, as the other 2 cities, structural measures dominate. Bangkok could add in land management techniques into its risk reduction activities and have the effect of spatial planning, preparedness of local community and emergency evacuation deepened to enhance its risk reduction performance.

Compare with the technical aspect, greater weakness of Bangkok’s FRM practice lies on its management process. Through there is definition of roles and responsibilities and a legislative framework supporting FRM activities, the overall legal support is weak. Not all sectors/stakeholders are involved in the FRM practices. The public and local communities are in many cases left out. There is no platform in place for effective stakeholder collaboration. Although there is a formal channel for the stakeholders to sit together and discuss about the flooding issues, no regular meeting is held. The meetings are held only when the situation calls for and there is usually no follow-up action afterwards, which results in ineffectiveness. Informal channel for collaboration, primarily through personal networks, is in place. Such collaboration is usually effective for emergency cases, but not practical as in general. The reason is that many actions require the approval of decision makers, which can only be achieved through formal procedures. As for climate change and societal changes, Bangkok has neither specific adaptation measures nor long-term plans or strategies that take climate change and societal development into consideration. The integration of FRM into development plans and strategies is quite poor and there is basically no adaptive management, meaning no monitoring, evaluation or update of its FRM plans.

Table 11. FRM practice within the framework– London

FRM tasks	Indicators	Practice
Risk Analysis	Return period for simulation/calculation	Fluvial: 5, 20, 100, 200, 1000 yrs and 100 yrs for climate change (currently an added 20% on peak flow); Tidal: a number of return periods including the risk of breach in the tidal defences. 200 yrs and 1000 yrs are modeled in more detail.
	Hydraulic modeling	1D, 2D and 1D/2D coupled for fluvial and tidal flood flows (e.g. ISIS 1D, Tuflow 2D) DTM (digital terrain model) driven overland flow models of Surface Water.
	Uncertainty analysis	Review of modeling outputs to ensure that they match known information (e.g. historical flood outlines); Monte Carlo analysis is used within the extreme water level work.
	Vulnerability analysis	Multicriteria covers economic, social and environmental/ecological dimensions
	Vulnerability, hazard and risk mapping	Hazard maps and risk maps are available; Vulnerability mapping is limited, but risk maps cover this element; Risk maps are available to review the flood risk for return period of 100 and 1000 yrs; No dynamic flood mapping at the moment, but working towards it.
	Availability of the maps	Maps online and updated every three months with the most up to date data for public; Data sharing portal for professional partners; Paper maps available on request.
Risk Evaluation	Return period for design level	100 yrs for non -tidal flood risk management; 1000 yrs for tidal flood (e.g. Thames Barrier)
	Risk evaluation (also consideration of the efficiency of risk reduction activities)	Cost-benefit analysis (following the 'Multi Coloured Manual'); Multicriteria analysis is quite new and is only adopted to a specific level; The newly issued TE 2100 has used MCA and the plans are in place for FRM in the future.
Risk Reduction	Risk reduction activities	Combination of structural and non-structural measures as well as instruments, but structural measures currently dominate - particularly the Thames tidal defence.

	Pre-flood risk reduction activities	*Measures*	*Instruments*
		Structural defence - flood defence walls, secondary defences, automated structures that help to manage flows in rivers, etc.	Spatial planning – considering flood risk reduction measures in spatial plans and prioritising development in low risk areas.
		Promotion of flood resistance and resilience measures of buildings (e.g. ground floor being aside for car parking).	Flood early warning system. Flood insurance – based on individual.
		Land management techniques – flood storage in parks/open spaces.	Preparedness of local community – through media, social media and meetings (e.g. public shows and advertise on local radios).
	Flood event management	*Measures*	*Instruments*
		Flood control measures – Thames barrier and associated gates, individual flood gates for riverside properties, pumps etc.	Real-time flood modeling focuses on flows and water levels for flood warnings.
		Emergency evacuation – primarily governmental services, though third party would come up on request	Real-time flood forecasting by using and issuing Heavy Rainfall Warnings. Evacuation and emergency plans, safe evacuation routes
	Post-flood reduction activities	*Measures*	*Instruments*
		Reconstruction – recovery measures for buildings to reduce property damage.	Recovery and resilience plan
	Relief funding	Bellwin Fund (government funding)	
Flood risk management process	Legal support	Clear legal definition of roles and responsibilities regarding FRM stakeholders Appropriate legislative framework supporting FRM Strong legal support for FRM practices (e.g. Flood and Water Management Act provides a strong legislative base for FRM).	

Stakeholder participation	All relevant sectors are involved Wide participation of different actors - Defra, EA, Local Government/authorities, Flood and/or emergency forums, Community action groups, Flood risk consultancies, ABI etc.
Stakeholder collaboration	Formal collaboration - partnership funding approach (e.g. Drain London Forum, Local resilience forums) Meetings usually held quarterly.
Capacity building	Trainings and education of stakeholders, consideration of expert advice.
Public and local community involvement	Effective, through brochures, media (e.g. public events), meetings (e.g. consultations) etc.
Climate change and societal changes	Climate change impact is added to the input hydrology - 20% -30% increase in flows based on the latest UKCIP science (scenario analysis), Design of schemes or policy influencing takes climate change scenarios into account – e.g. recommendations of building design as well as assets and how they're likely to perform in the future.
Integration of FRM into development plans	Well integrated – FRM considerations are integrated into the local development frameworks as well as more site specific development plans and policies
Adaptive management	Monitor and periodical evaluation of FRM plans and strategies Review and update of FRM plans and strategies (e.g. TE 2100)

Table 12. FRM practice within the framework– Shanghai

FRM tasks	**Indicators**	**Practice**	
Risk Analysis	Return period for simulation/calculation	5, 20, 100, 200, 1000 yrs.	
	Hydraulic modeling	1D, 2D.	
	Uncertainty analysis	Monte Carlo analysis and scenario calculation.	
	Vulnerability analysis	Multicriteria cover economic, social and environmental/ecological dimensions.	
	Vulnerability, hazard and risk mapping	Risk maps are available for different return periods (e.g. 200 yrs and 1000 yrs); Vulnerability and hazard mapping are limited, but covered by risk maps; Dynamic flood mapping in place for real-time flood forecasting.	
	Availability of the maps	Paper copies at the authority and on governmental websites; Not easy for the public to access these maps.	
Risk Evaluation	Return period for design level	200 yrs for general flood risk management; 1000 yrs flood defence walls.	
	Risk evaluation (also consideration of the efficiency of risk reduction activities)	Cost-benefit analysis.	
Risk Reduction	Risk reduction activities	Combination of structural and non-structural measures as well as instruments, but structural measures currently dominate.	
	Pre-flood risk reduction activities	*Measures*	*Instruments*
		Structural defence – tidal defence walls, flood protection walls along Huangpu river	Spatial planning Flood insurance – based on individual choice
		Land management techniques – flood storage in parks and green areas, retention by water body, increased pervious area	Flood early warning system – through TV, radio, websites, weibo, text messages. Preparedness of local community – through workshops, brochures, training, social media (e.g. websites) and traditional median (e.g.TV)

	Flood event management	*Measures*	*Instruments*
		Flood control measures – urban pumps, dam/flood gates control.	Real-time flood forecasting and warning
		Dynamic flood risk mapping Emergency evacuation – primarily governmental services, also community self-aid and third party up on request	A series of emergency plans - both at municipal and district level, each relevant agency also has its specific emergency plan (e.g. emergency plan of urban sewer department). Evacuation plans, safe evacuation routes
	Post-flood reduction activities	*Measures*	*Instruments*
		Reconstruction – reconstruction of damaged buildings and infrastructures.	Recovery and resilience plan Financial subsidy for relief and recovery
	Relief funding	Insurance, central and municipal financial budget, public donations	
Flood risk management process	Legal support	The legal definition of roles of responsibilities regarding FRM stakeholders is NOT clear	
		There is a legislative framework supporting the FRM practices, but NOT so well.	
		Weak legal support for FRM practices.	
	Stakeholder participation	Participation of different actors, including governments, NGOs, local communities and private sectors. Most stakeholders are involved.	
	Stakeholder collaboration	Informal collaboration – personal networks.	
	Capacity building	Trainings and education of stakeholders, consideration of expert advice.	
	Public and local community involvement	Less effective, through brochures, media (e.g. public events), workshops, meetings.	
	Climate change and societal changes	Through scenarios analysis; Adaptation through reinforcement of structural measures (e.g. feasibility study of flood gates at the Huangpu river mouth).	
	Integration of FRM into development plans	Partially integrated – transport planning, river bank planning	
	Adaptive management	Monitor and periodical evaluation of FRM plans and strategies.	
		Review and update of FRM plans and strategies.	

Table 13. FRM practice within the framework– Bangkok

FRM tasks	Indicators	Practice	
Risk Analysis	Return period for simulation/calculation	50 yrs.	
	Hydraulic modeling	1D/2D coupled.	
	Uncertainty analysis	Through scenario calculations.	
	Vulnerability analysis	Economic considerations.	
	Vulnerability, hazard and risk mapping	Vulnerability maps, hazard maps and risk maps are available;	
	Availability of the maps	Paper copies or digital maps at the authority; Not easy for the pubic to reach the maps, but some access possible.	
Risk Evaluation	Return period for design level	50 yrs.	
	Risk evaluation (also consideration of the efficiency of risk reduction activities)	Cost-benefit analysis.	
Risk Reduction	Risk reduction activities	Combination of structural and non-structural measures as well as instruments, but structural measures currently dominate.	
	Pre-flood risk reduction activities	*Measures*	*Instruments*
		Structural defence – polder embankment, dykes, etc.	Spatial planning with consideration of flood risk reduction.
		Flood proof buildings	Flood early warning system.
			Flood insurance – based on individual.
			Preparedness of local community – through trainings.
	Flood event management	*Measures*	*Instruments*
		Flood control measures – urban pumping, water/flood gate control, drainage tunnel, temporary flood barrier (sandbags).	Real-time flood forecasting and warning,

		Emergency evacuation – primarily governmental services, also community self-aid and third party aid; set-up of evacuation camp, but with little experience on evacuation camp management	Evacuation and emergency plans.
	Post-flood reduction activities	*Measures*	*Instruments*
		Reconstruction – reconstruction of damaged buildings and infrastructures	Recovery and resilience plan
	Relief funding	Government budget	Financial subsidy for relief and recovery
Flood risk management process	Legal support	Somewhat clear legal definition of roles and responsibilities regarding FRM stakeholders, Less appropriate legislative framework supporting FRM. Weak legal support for FRM practices.	
	Stakeholder participation	Most sectors are involved, but lack of collaboration.	
	Stakeholder collaboration	Formal collaboration – no regular meetings, meeting upon needs. Not effective since there is usually no follow up after the meeting. Informal collaboration – through personal networks. Effective, but not practical, since many actions need to be decided by decision maker which requires formal channel.	
	Capacity building	Through education and trainings, but not regular.	
	Public and local community involvement	Public/local communities are through trainings and workshops as well as regular meetings, Not effective	
	Climate change and societal changes	No consideration of climate change or future changes of society	
	Integration of FRM into development plans	Poorly integrated.	
	Adaptive management	No regular monitoring or evaluation of FRM plans and strategies	

Table 14. Comparison of FRM practices and IFRM framework

	FRM Framework		*FRM practices in the selected megacities*		
FRM tasks	**Indicators**	**Criteria**	**London**	**Shanghai**	**Bangkok**
Risk Analysis	Return period for hazard analysis	A series of return periods.	+	+	-
	Hydraulic modeling	1D, 2D, 1D/2D.	+	+	+
	Uncertainty analysis	Shall be included.	+	+	+
	Vulnerability analysis	Covers social, economic and environmental/ecological dimensions, instead of 'only economic consideration'.	+	+	-
	Vulnerability, hazard and risk mapping	Vulnerability maps, hazard maps, risk maps in place;	+	+	+
		Possibly also dynamic flood mapping for real-time flood forecasting and warning.	+/-	+	?[30]
	Availability of the maps	Paper copies at authorities, brochures, websites, etc. ;	+	+	+
		Easy access for the public.	+	-	-
Risk Evaluation	Return period for design level	100 yrs, 200 yrs, or higher；	+ (100 and 1000 yrs)	+ (200 and 1000 yrs)	- (50 yrs)
	Risk evaluation	At least cost-benefit analysis and/or cost-efficiency analysis;	+	+	+
		Better multicriteria evaluation (MCE).	+	-	-
Risk Reduction	Risk reduction activities	Combination of measures and instruments.	+/- (structural measures dominates)	+/- (structural measures dominates)	+/- (structural measures dominates)
	Pre-flood risk reduction activities	*Measures*			
		Structural defence (e.g. dikes and walls);	+	+	+
		Flood proof buildings;	+	-	+

[30] Evaluation cannot be made since the feedbacks hold completely different opinions.

		Land management techniques	+	+	-
		Instruments			
		Spatial planning;	+	+/-	+/-
		Flood early warning;	+	+	+
		Preparedness of local community;	+	+/-	+/-
		Flood insurance.	+	+	+
	Flood event management	*Measures*			
		Flood control measures (e.g. urban pumping);	+	+	+
		Emergency evacuation.	+	+	+/-
		Instruments			
		Emergency plan/ evacuation plan;	+	+	+
		Real-time flood forecasting and warning.	+	+	+
	Post-flood reduction activities	*Measures*			
		Reconstruction and resilience measures;	+	+	+
		Emergency evacuation.	+	+	+
		Instruments			
		Subsidy and flood insurance;	+	+	+
		Recovery and resilience plan;	+	+	+
	Relief funding	Governmental budget, insurance, etc..	+	+	+
Flood Risk Management Process	Legal support	Clear definition of roles and responsibilities.	+	+/-	+/-
		Appropriate legislative framework supporting FRM.	+	+/-	+/-
		Strong legal support.	+	-	-

Stakeholder participation	Relevant sectors involved.	+	+/-	+/-
Stakeholder collaboration	Platform for effective collaboration in place.	+	-	-
Capacity building	Trainings and education of stakeholders.	+	+	+/-
Public and local community involvement	Effective involvement.	+	+/-	-
Climate change and societal changes	Climate change adaptation;	+	+	-
	Long-term plans and strategies.	+	-	-
Integration of FRM into development plans and strategies	Consideration of flood risk into spatial planning, urban planning as well as development strategies.	+	+/-	-
Adaptive management	Monitor and periodical evaluation of FRM plans and strategies;	+	+	-
	Update of FRM plans and strategies.	+	+	-

'+' – Criteria fulfilled, positive; '+/-' – Criteria partially fulfilled, needs further improvement; '-' – Criteria not fulfilled, negative.

5.2 Recommendations

London, Shanghai and Bangkok are quite different cities in terms of political structure, economic development as well as social custom and cultures. Whether a specific FRM activity/action can be successfully implemented in a given country/city is in close link with the local political, economic as well as social environment. How to implement or adapt a specific FRM action in a certain city is already a broad topic itself and needs investigation of the political, social and economic environment of the city. Therefore the recommendations given here are not detailed into specific actions, but rather on a general level as suggestions or directions for further improvement.

London
London, among the three selected megacities, has the most comprehensive and well-functioning FRM system. There is no significant weakness with regard to its FRM system. The only recommendation for London is that it should keep and widen the implementation of non-structural measures and risk reduction instruments.

Shanghai
Shanghai's main weakness lies on its flood risk management process. Therefore, it is highly recommended that Shanghai puts more effort on the improvement of its FRM process.

The legal support of FRM practice should be strengthened, not just through a clearer definition of roles and responsibility and an appropriate legislative framework but more importantly through strong execution of relevant laws and regulations. Shanghai should also establish a formal stakeholder collaboration platform, within which regular meetings are held and important issues are discovered and discussed. Along with the establishment and running of this platform is the involvement of all relevant stakeholders. Currently FRM is still more a governmental issue that only authorities actively participate in. It is important to also effectively involve the private sectors as well as the public. Regarding stakeholder participation, London's partnership funding approach is working well. Though this may not be practical for Shanghai concerning the different political and social structures of the two cities, the variety of sectors involved and the coordination among these sectors in London is still worth for reference. Another issue that Shanghai should work on is the awareness and preparedness of local communities. Currently, the local communities are not so aware of the flood risks they're facing and are quite passive in acquiring flood risk information. It is also the government's responsibility to raise the awareness of the local communities and inform them with what channels they can access the flood risk information. At the moment Shanghai has yet no long-term FRM plans or strategies for coping with future changes, especially climate change. As a coastal city with low elevation, it is important that such long-term plans or strategies are in place to react to the future changes with a full range of actions instead of just reinforcing the structural defence measures.

As for the technical aspect, it is important that Shanghai takes multicriteria for its risk evaluation and selection of optimal risk reduction activities. If a full multicriteria evaluation is not yet practical at present, at least the social and environmental/ecological losses and benefits should be monetised wherever possible and merged into the cost-benefit analysis. Besides, Shanghai should also strengthen the implementation of non-structural risk reduction measures as well risk reduction instruments, such as to increase the water retention areas by green areas and parks.

Bangkok

Of the 3 selected megacities, Bangkok has the weakest FRM system. It has significant weakness on both technical aspect and flood risk management process.

Bangkok should include a series of return periods for flood hazard analysis, instead of only 1 return period (50 yrs). The design level (currently 50 yrs return period) is also low. It is recommended that at least 200 yrs return period is used for design of risk reduction activities. Currently, no matter for the vulnerability analysis or the risk evaluation, Bangkok only considers economic aspects. Recommendation is that social and environmental/ecological aspects should also be taken into consideration. If multicriteria is not applicable yet for risk evaluation, at least the social, environmental/ecological loss and benefit should be monetised and merged into cost-benefit analysis. As for risk reduction activities, Bangkok currently relies greatly on structural defence measures. In the future, it should strengthen the implementation of its non-structural measures as well as risk reduction instruments.

From the process perspective, Bangkok's main efforts should be put on five aspects. First, enhance the legal support for FRM practice. The feedbacks from Bangkok for questions about legal support are quite interesting. The government feedback states that there is some legal support for FRM practice with an appropriate legislative framework, while the practitioner feedback indicates that there is no legal support at all, neither a legislative framework. This suggests that there is a gap between the legislation set-up and the execution/implementation into practice. How to transfer the laws and regulations into practice, which is a broad topic itself, is a task that Bangkok needs to work on. Despite the broad topic, the recommendation given here is to enhance the execution of relevant FRM laws and regulations.

Second, establish an effective stakeholder collaboration platform that gathers all relevant sectors/stakeholders to sit together regularly and discuss about FRM issues. Within this platform, a follow-up mechanism should be set up to ensure the execution of actions decided.

Third, enhance the public/local community involvement, especially focus on the preparedness of local communities.

Fourth, set up long-term plans and strategies that take future changes, especially climate change into consideration. These plans and strategies should be able to provide guidance on how to cope with the future changes on an overall level.

Fifth, monitor and evaluate of the current FRM plans on a regular basis and update when needed. The performance of the FRM practice needs to be monitored and evaluated regularly to ensure that the FRM practice is always effective and efficient.

Chapter 6 Discussion

Shift from defensive approach to IFRM

Currently, the three selected megacities all possess a series of risk reduction activities consisting of both measures and instruments. However, they all still have structural measures dominate. The extent and depth of the implementation of non-structural measures as well as instruments are to be further strengthened. This may suggest that the shift from defensive approach to IFRM is still on-going, just as stated in Chapter 2.1.2 'though the IFRM concept has been widely acknowledged and some attempts of integrated approaches have been taken, traditional defensive measures still dominate in flood protection practices'. As indispensable as the structural measures, full protection is neither achievable nor affordable. The three megacities have all agreed on the effectiveness and efficiency of IFRM and are working towards a full range of implementation. As one feedback from London addressed, 'there has been a trend to move away somewhat from structural measures more so to non-structural and human reliant solutions'. Therefore, though the shift from defensive approach to IFRM is still on-going, the trend has already been set.

From scientific research to practice

According to this study, the conversion of scientific research results into FRM practice is quite positive. Many of the advanced research results have already been used or at least partially implemented in the practice activities. London, as an example, almost fulfills all the IFRM framework indicators and criteria, many of which are identified from recent scientific literatures. This is even clearer in terms of the technical aspect. For example, all three megacities have implemented 1D/2D coupled or 2D hydraulic models for their flood modeling and produced risk maps. The advanced multicriteria evaluation (MCE) is partially used in London through mergence into cost-benefit analysis.

Flood risk perception and communication in different social and cultural context

It is noticed during the survey that the perception of flood risk as well as the ways of communication are a bit different in these three megacities. In Shanghai, the flood risk is not a common concern for the public. It is generally regarded as a topic for the government and authorities. The communication between the authorities and the public follows a one-way pattern – from the authorities to the public. The public, especially as an individual, only receives information from the authorities whenever an event is approaching. This may help explain why the public involvement in Shanghai is less effective. On one hand, the authorities consider FRM as their own responsibility and therefore do not disclose information actively to the public. On the other hand, the public also holds the idea that FRM is the job of the authorities so that there is no active information acquirement. As an opposite case, FRM is considered in London as a topic the entire society should take part in. In terms of public involvement, there is a mutual communication in place between the authorities and the public/individuals.

Weak management process in developing countries/cities (Shanghai and Bangkok)

As the international organisations pointed out, developing countries usually have greater weakness in their flood risk management process. Compare with London, Shanghai and Bangkok's flood risk management process are much less satisfactory.

Issues range from weak legal support to ineffective stakeholder participation and collaboration, to lack of long-term strategies and adaptive management. The weakness in management process is not a genuine issue that only exists in the field of FRM. It is a problem in all issues relate to public administration. A healthy management process is in close link to the political and social structures as well as the economic and development status of a society. Therefore, it is somehow reasonable that Shanghai and Bangkok present greater weakness in their flood risk management processes and to improve and strengthen the process efforts on all aspects of the society are needed, rather than focusing solely on FRM.

Limitations

The survey of this study is done through questionnaires. Advantage of questionnaires is that the respondents are more flexible in terms of time and location. They can finish the questionnaires piece by piece and are not restricted to physical whereabouts. It fits especially to this study since the respondents are from three different countries across the ocean and many of them are quite busy most of the time. Therefore, the survey of this study requires certain flexibility in time and location. However, the shortcoming of questionnaires is also obvious. The information acquired is limited. With a questionnaire, the amount of acquired information depends highly on how deep the respondents reply the questions. Within this study, 2 respondents from London have given quite detailed answers with a few references while the answers from Shanghai and Bangkok are much less in detail. Therefore, more information about London is derived through survey than Shanghai and Bangkok. Another shortcoming of questionnaires lies on the lack of communication between the investigator and the respondents. With telephone or face-to-face interviews, the interviewer (investigator) can always ask further questions to derive clearer or more specific information. With questionnaires this kind of communication is not possible. Emails could be written for clearance or further discussion, but this depends again on the time and availability of the respondents. Though less information about Shanghai's FRM is acquired through the survey, other information channels such as publications and website research are used as strong supplement. Therefore, the information for Shanghai is considered as sufficient. Bangkok is, however, another case. Because of the language barrier, not much information is read or analysed since they're mostly in Thai. Therefore, the information about Bangkok's FRM might not be fully sufficient and this may affect the result.

The feedback of questionnaires for London and Bangkok is limited. There are 3 feedbacks from London and 2 from Bangkok. Since the information provided by the feedbacks from London is quite in detail, together with the documents being examined, there is in general sufficient information about London's FRM. However, the lack of enough feedbacks from Bangkok does result in limitation for the study. If more feedbacks are received, the result for Bangkok could have been improved.

London, as a megacity with a strong FRM system, has many practical examples that can serve as references for Shanghai and Bangkok. These examples can help the other megacities get an in-depth understanding of the indicators and criteria as well as better facilitate their FRM practices. However, with the time scale of this study, it is not possible to extend these examples within this thesis.

This study has tried its best to focus on the local level when analyse the FRM practices. However, FRM practices are closely connected to the national policies and regulations as well as the execution of relevant legislations. For the case of London, many activities are under direct lead of the EA at the national level. This connection between the national and local level exist in all three selected megacities. This may result in a less clear elaboration sometimes.

Chapter 7 Conclusion

Megacities, with its distinguished characteristics of high population density, large sealed surface, high land use values and assets and its complex social-economical systems, are usually prone to natural disasters, including floods. This becomes even more critical within the changing climate. The damage a destructive flood event could cause to a megacity is far more severe than that of other areas and it is both time and economically consuming for a megacity to recovery after a flood disaster due to its complexity. Within this aspect, a sound and efficient flood risk management system is of vital importance for megacities. To give a deep investigation on this topic, three megacities – London, Shanghai and Bangkok, are selected as case study cities, the FRM practices of which are analysed and evaluated based on the IFRM framework identified from literatures and international guidelines to examine the strengths and weaknesses of the current FRM practices in megacities.

London, among the three selected megacities, has the strongest and most well-running FRM system. Its FRM practice fits well to the IFRM framework and the associated indicators and criteria. London has been keeping up with the advanced scientific research from the technical aspect, such as the use of 1D/2D coupled hydraulic models and the implementation of multicriteria evaluation (MCE) for risk evaluation. From the process perspective, London is also doing well through strong legal support, effective stakeholder participation and public involvement as well as the consideration of future changes. The only weakness that London faces is that structural defense measures still dominate its risk reduction activities. The depth and coverage of non-structural measures as well risk reduction instruments are to be further strengthened. However, the trend for more non-structural measures and human reliant solutions is already set.

Shanghai's FRM system is currently functioning effectively due to its high standard of protection through structural measures as well as its strength in the technical aspect, such as hydraulic modeling, risk maps, flood early warning, real-time forecasting and warning, etc. Shanghai is basically able to follow the advanced scientific research and have the results implemented in practice. Shanghai's main weakness lies on its flood risk management process. Its legal support, stakeholder collaboration, public involvement as well as long-term plans and strategies are the aspects where more efforts are needed.

Bangkok has the weakest FRM system among the three selected megacities. Its weakness lies on both the technical aspect and flood risk management process. Bangkok is not yet fully able to keep up with the advanced scientific research. In terms of flood risk management process, Bangkok also has a lot to improve. The legal support for FRM practice as well as the execution of relevant legislation is a great challenge. Stakeholder collaboration, among others, is another urgent issue that needs improvement.

Generally speaking, London's FRM system is well formed and the practice has gained good performance. Some of its actions and approaches can be used by the other megacities as reference to improve their own FRM practices, especially in terms of flood risk management process.

The result that the three selected megacities, despite their different economic, social and cultural backgrounds, all possess a combination of measures and instruments as their risk reduction activities with dominance of structural measures indicates that the shift from defensive approach to integrated flood risk management is still on-going. But the trend of such a shift is already set and widely accepted. Shanghai and Bangkok's weakness in FRM process suggests that developing countries often have greater weakness in management processes, which is a common issue in areas related to public administration, since it depends on greatly on the political and social structure as well as economic status of a country. Therefore, to improve their FRM processes efforts from all aspects of the society are required.

Future work of this study can be done from three aspects.
London has some actions and approaches that can be used as good examples to help the FRM practitioners in other megacities have better understanding of the IFRM framework and the associated indicators and criteria. It could also help the other megacities better facilitate their FRM practices to match the IFRM framework. Further work could be done in this aspect as to collect examples from London as 'best practice'.

Whether a certain action or approach can be successfully implemented in one region depends on a range of factors, such as the political structural, social and cultural context as well as economic development status. How to transfer relevant FRM ideas or approaches into different megacities under specific societal context is where future work is required.

Risk financing is a topic that recently has been intensively discussed by the international community of FRM practice. The traditional relief funding sources, such as government budget, tax increase, international aid etc. sometimes cannot provide sufficient funds in severe events, especially for the less-developed countries. There has been discussion of a multi-facet risk financing mechanism that involves new financial risk transfer solutions such as sovereign insurance. This aspect of risk financing is not included in the study and future work can be put in this direction to complete the structure of FRM practice.

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Appendix

Appendix A. Questionnaire about the Flood Risk Management (FRM) practices in selected Mega-cities (English)

Questionnaire about the Flood Risk Management (FRM) practices in selected Mega-cities

Mega-cities, with its distinguished characteristics of very high population density, large sealed surface, high land use values and assets and its very complex social-economical systems, are usually prone to natural disasters. This becomes even more critical within the changing climate. It is with such a background that we designed the study of *Analysis and Evaluation of Flood Risk Management Practices in Selected Mega-cities*, hoping to examine the strengths and gaps that the current FRM practices may have.

To achieve the desired objective, your expert experience and opinions are of great value as well as help to us. Therefore, it would be greatly appreciated if we could hear your experience and opinions by filling out this questionnaire.

Thank you for taking the time to answer this questionnaire. A variety of questions about the flood risk management activities are designed to help us understand more about the flood risk management practices in London. You do not have to answer all the questions if some are not applicable or not in your line of responsibilities. However, the more information we could collect, the better understanding we would have on this important issue.

Name___________________ Department/Unit____________________ Position held____________________

Section 1. Risk analysis and mapping

1 What is the return period of floods for hazard analysis (e.g. 100 years) in London in general?
Please specify_________

2 Is hydraulic modelling used to determine critical parameters (e.g. water depth, flow velocity)?
Yes □ No □

What kinds of models are used? Please specify_________

3 Is uncertainty analysis included when analysing the flood risk? And how (e.g. Monte Carlo simulation)?

please specify_______

4 Which dimensions (economic, social, environmental/ecological) are taken into consideration for vulnerability analysis and how? (e.g. multicriteria analysis that do not just consider economic but also social and environmental dimensions).

please specify_______

5 Are there maps available and what kind?

Vulnerability maps □ Hazard maps □ Risk maps □ Others □, please specify___________

6 Is there dynamic flood risk mapping and if so, what is it used for? (e.g. for real-time flood warning)
please specify_______

7 In what way are the maps available for the stakeholders and public? (e.g. Paper copies at the authority, brochures, websites etc.)

please specify_______

8 Do you think the public have easy access to these maps?
Very easy □ Easy □ Not easy, but some access possible □ Difficult □

Section 2. Risk evaluation

9 What is the return period for the design level of risk reduction activities?
Please specify_______

10 Which methods are used to evaluate the flood risk (considering the efficiency of different risk reduction activities for the selection of optimal risk reduction options)?

Cost-benefit or cost-effectiveness analysis □ Multicriteria analysis (MCA) (e.g. AHP) □ Others □, please specify___________

Please add any additional comments you have on the topics covered by these two sections (section 1 and 2).

Section 3. Risk reduction activities

11 Do you know the overall expenditure in flood risk reduction activities in London for the last 10 years?
If possible, please specify_________

12 What would you say about the risk reduction activities in London?

Structural measures dominate □ A combination of structural and non-structural measures as well instruments □

13 What risk reduction measures and instruments are taken concerning pre-flood activities?
Structural defence (e.g. mobile walls) □, please specify_________
flood proof buildings □
Land management techniques (e.g. transformation of forest) □, please specify_________
Spatial planning with focus on flood risk reduction □
Preparedness of local community (e.g. workshops, brochure, training) □, please specify_________
Financial penalties □

Others □, please specify_________

14 What measures and instruments are taken regarding flood event management?
Flood early warning system □
Flood control measures (e.g. urban pumping, dam control) □, please specify_________
Dynamic flood risk mapping for real-time flood forecast □
Emergency evacuation and rescue: governmental services □, community self-aid □, third party aid (e.g. NGO, international organizations) □
Emergency management plans (e.g. evacuation plan) □, please specify_________

Others □, please specify_________

15 What measures and instruments are taken regarding post flood recovery and reconstructions?
Reconstruction measures (e.g. reconstruction of damaged buildings and infrastructures) □, please specify_________
Flood subsidies □
Flood disaster insurance: life insurance □, property insurance □, insurance for public infrastructure □, others □, please specify_________
Recovery and resilience plans □, please specify_________
Others □, please specify_________

16 What other risk reduction activities do you think shall be included in the future? Please specify_________

17 What are the relief fund sources in London (e.g. insurance, tax increase, relocating from other budget items, accessing domestic and international credit, etc.)? Please specify_________

Please add any additional comments you have on the topics covered by this section.

Section 4. Flood risk management process

18 Do you think there is clear legal definition of roles and responsibilities regarding flood risk management stakeholders?

Clear □ Somewhat clear □ Not clear □ No such definition at all □

19 Do you think there is an appropriate legislative framework supporting the FRM practices (e.g. Integrated Water Resource Management, Nature Conservation Law that takes into account the reduction of flood risks)?

Yes □ Not so well □ Not at all □

20 How would you evaluate the legal support for flood risk management practices in London? (e.g. strong legal support for structural measures, weak support for non-structural measures such as land management techniques).

Please specify__________

21 Do you think there is effective public/local community involvement?

Yes □ No □

In what form is the public involved?

Brochures □ Media □ Training and workshops □ Regular meetings □ Others □, please specify___________

22 Is there a platform/coordination mechanism for stakeholder collaborations?

Yes □ No □

If yes, in what kind?

Formal collaboration (e.g. official meetings) □ Informal networks (e.g. personal networks to retrieve information) □

Others □, please specify____________

If formal collaboration, how often are the meetings held?

Regular meetings □, please specify frequency___________ No regular meeting, meeting upon needs □

Others □, please specify___________

23 Is there a wide participation of governmental, non-governmental, community and private sector actors in the platform/coordination mechanism?

Please list the members_________

24 Do you think all related sectors/stakeholders are included in the FRM processes? (e.g. water authorities, insurance sectors, local community)

Yes □ Most of them □ No □

Which stakeholder(s) is/are not included, but shall be?

Please specify_________

25 Is stakeholders' capacity building part of the FRM practice?

Yes □ No □

If yes, in what form is it realized?

Education and trainings □ Consideration and intake of expert advice □ Others □, please specify__________

26 How well do you think the FRM considerations are integrated into development/strategy plans? (e.g. spatial or urban planning with focus on flood risk reduction, sustainable development plans)

Well integrated □ Partially integrated □ Poorly integrated □ No consideration of FRM at all □

In which development/ strategy plans are they integrated?

Please list the documents _________

27 Is there monitoring and periodical evaluation of the current FRM plans and strategies?

Yes □ No □

28 Is there periodical update of the current FRM plans and strategies?

Yes □ No □

29 Do the FRM strategies and plans take into account climate change considerations?

Yes □ No □

If yes, a) how is the impact of climate change assessed?

please specify_________

b) what climate change adaptation activities are taken (or to be taken)?

please specify_________

30 Do you think there is enough staff working on FRM regarding your line of responsibility? (e.g. am working on early warning systems, there is not enough staff; or am working on structural defence measures, we are seriously short-handed)

Please answer_________

31 What is your general impression of the FRM practice performance in London?
Please answer__________

32 What improvements would you suggest?
Please specify__________

Please add any additional comments you have on the topics covered by this section or any comments you have in general about the FRM practice in London!

Thank you very much for taking the time to tell us your expert opinions and experience. Please return completed questionnaires by 3. August 2012 (Friday) via email to:
li.meiling82@gmail.com ,

Meiling Li Shanghai, July 27, 2012

Appendix B. Questionnaire about the Flood Risk Management (FRM) practices in selected Mega-cities (Chinese)

关于超大城市洪水风险管理实践的调查问卷

超大城市的显著特征之一即其具有超高的人口密度，大量的封闭地表，高土地利用价值和资产以及复杂的社会-经济系统。这些特征决定了超大城市极易受到自然灾害的影响。这一点在全球气候变化的大环境下显得更为严峻。基于此，我们设计了"超大城市的洪水风险管理实践的分析与评价"该研究，以上海、伦敦和曼谷为例，希望能够探讨目前超大城市在洪水风险管理方面的优势和差距，以进一步增强超大城市应对洪水灾害的能力。

为达到预期的目标，您的专家意见和经验对我们有重要的价值及帮助。因此，如果您能通过填写这份问卷将您的经验和意见传达给我们，我们将不胜感激。

非常感谢您抽出宝贵时间回答这份问卷。问卷涵盖了洪水风险管理领域的各有关问题，旨在帮助我们更多地了解您所在城市的洪水风险管理方面的实践。您不需要回答所有问题，若有些问题不适用或不在您的职责范围内。但是，收集的信息越多，我们对超大城市洪水风险管理这一重要问题的了解就越深入，我们的研究结果也就越有实践意义。

姓名____________________ 工作单位____________________ 职务____________________

第一部分. 风险分析与风险制图

1 用作危害分析(hazard analysis)的洪水重现期（如，100 年） 是_________?

2 是否运用水利学模型对模拟洪水事件的重要参数进行计算 （如，水深、流速）？

是 □ 否 □

如果是，运用了哪类模型？

一维模型（1D）□ 二维模型（2D）□ 一二维耦合模型（1D/2D）□ 三维模型（3D）□

3 在分析洪水风险时是否纳入了不确定性分析？

是 □ 否 □

如果是，运用了何种方法进行不确定性分析？

蒙特-卡罗模拟（Monte Carlo simulation）□ 情景分析（Scenarios calculation）□ 其他 □, 请注明____________

4 在进行脆弱性分析时考虑了哪些层面的因素（经济、社会、环境 / 生态）？

只考虑经济层面 □ 多准则（涵盖经济、社会、环境 / 生态三个层面）□ 无脆弱性分析环节 □

其他 □，请注明______________

5 生成了何种灾害地图?

脆弱性地图（vulnerability maps）□ 危害图（hazard maps）□ 风险图（Risk maps）□ 其他 □, 请注明_____________

6 是否生成动态洪水风险图

是, 用于实时预警（real-time flood warning） □ 其他用途 □，请注明__________ 无动态洪水风险图 □

7 上述洪水地图以何种形式公布给利益相关方和公众?

纸质本，存放于权力部门（Paper copies at the authority）□ 小册子/宣传册（Brochures）□ 网站/网络 □

其他 □，请注明________________

8 在您看来公众是否能够容易的获取这些洪水地图?

很容易 □ 容易 □ 不容易，但有可能 □ 困难 □

第二部分. 风险评估

9 上海用于设计制定防汛减灾措施的洪水重现期是（即防洪标准，如 500 年一遇的洪水）？请注明_________

10 运用何种方法评估上海的洪水风险（同时考虑各防汛减灾措施的成本及效率以选择最佳防汛减灾措施组合）?

成本收益或成本效率分析 □ 多准则分析 （Multicriteria Analysis, 如，层次分析法-AHP） □

其他 □，请注明_______________

如您对上述两部分所涉及的内容有任何其他意见或评论，欢迎您在此注明。

第三部分. 防汛减灾措施

11 您是否知晓过去十年上海市用于防汛减灾的整体开支是多少？ 若知晓，请注明______________

12 您将如何概括上海的防汛减灾措施？

工程措施占主导 □ 工程与非工程措施及各类防汛减灾工具（如，政策工具，金融保险工具）相结合 □

13 上海采用了哪些**汛前**防汛减灾措施？
工程措施（如，可活动防护墙）□，请注明______________
具有一定抗洪能力的建筑 □
土地管理技术（如，林业改造）□，请注明______________
考虑到防汛减灾的空间规划(Spatial planning with focus on flood risk reduction) □
防洪预警 □
社区备灾（如，研讨会、宣传册、培训）□，请注明____________
经济处罚（如，在防洪保护区违规建筑处以罚款）□

其他 □，请注明___________

14 上海制定了哪些**汛中**管理措施以做到防汛减灾？
洪水控制措施（如，城市泵站排水、水坝调控) □，请注明__________
动态洪水风险图与实时预警 □
紧急疏散和救援：政府行为 □，社区自救 □，第三方救援（如，非政府组织、国际组织）□
应急管理预案（如，紧急疏散预案）□，请注明_________

其他 □，请注明_________

15 上海制定了哪些**汛后**措施以做到防汛减灾？
重建措施（如，受损房屋和基础设施的重建）□，请注明____________
经济补贴 □
洪水灾害保险：人身保险 □， 财产险□， 公共基础设施保险 □，其他 □，请注明____________
灾后恢复重建方案 □，请注明____________

其他 □。请注明_________

16 您认为还有哪些防汛减灾措施需要被纳入到目前的减灾措施体系当中？请注明_________

17 上海赈灾资金的来源有哪些（如，灾害保险、适度增税、从其他项目预算迁款、国内与国际信贷、向多边机构借款，中央或地方财政拨款，等）？请注明_________

如您对上部分所涉及的内容有任何其他意见或评论，欢迎您请在此注明。

第四部分 洪水风险管理过程

18 您认为目前对于洪水风险管理利益相关者的角色和职责是否有明确的法律定义？

明确的法律定义 □ 比较明确□ 不明确 □ 无相关法律定义 □

19 您认为目前是否存在一个适当的法律法规框架支持洪水风险管理实践？

是 □ 存在一个法律法规框架，但仍需改进 □ 否，无此类法律法规框架作支持 □

20 您如何评价上海洪水风险管理实践所得到的法律法规支持？

强有力的法律法规支持 □ 一定程度的法律法规支持 □ 较弱的法律法规支持 □ 无法律法规支持 □

21 您认为是否存在有效的公众及社区参与？

是 □ 否 □

何种公众参与形式？

宣传册 □ 媒体宣传 □ 培训和研讨会 □ 定期会议 □ 其他 □，请注明_________

22 是否存在一个利益相关者合作的平台或协调机制？

是 □ 否 □

如果是，该合作平台或协调机制的形式为？

正式合作（如，正式会议）□ 非正式关系网络（informal networks，如，通过个人关系网获得信息）□ 其他 □，请注明___________

如果是正式合作形式，会议举行的频率为？

定期会议 □ 请注明频率__________ 无定期会议，根据需要随时举行 □ 其他□，请注明__________

23 上述的合作平台/协调机制是否有政府部门、非政府组织、社区和私营部门的广泛参与？
请注明参与方__________

24 您认为所有的相关部门/利益相关方都参与到上海的洪水风险管理中了么？（如，水务部门、保险行业、本地社区）
是 □ 大部分 □ 否 □

您认为还有哪些利益相关方需要被纳入到上海的洪水风险管理中来？ 请注明____________

25 利益相关方的能力建设是否为上海洪水风险管理实践的一部分？
是 □ 否 □

如果是，该能力建设是以何种方式实现的？

教育和培训□ 考虑和纳入专家意见 □ 其他 □，请注明__________

26 您认为关于洪水风险管理方面的考虑是否在城市发展/战略规划中得到良好体现（如，空间规划、城市规划、可持续发展规划）？

良好体现 □ 有所体现，但不完全 □ 有所体现，但很少 □ 完全没有关于洪水风险管理方面的考虑 □

具体在哪些发展/战略规划中所有体现？请注明这些文件___________

27 对于当前执行的洪水风险管理计划及管理策略是否定期进行监测和评估？
是 □ 否 □

28 对于当前执行的洪水风险管理计划及管理策略是否定期更新？
是 □ 否 □

29 上海的洪水风险管理策略及管理计划是否考虑了全球气候变化这一影响因素？
是 □ 否 □

如果是，a) 以何种方式评估全球气候变化带来的影响？
通过气候变化情景分析（如，IPCC 气候变化情景）□ 通过其他方式 □，请注明_________
b) 采取了（或即将采取）哪些应对措施以适应全球气候变化带来的影响？请注明__________

30 您认为目前从事洪水风险管理工作的人员数量是否足够？
足够 □ 目前还可以，但最好能添加人员 □ 人员不够 □ 人员严重短缺 □
31 您对上海洪水风险管理实践的整体印象是？
运作良好 □ 正常运作，但需要改进 □ 运作效果不佳，需要很大改进 □
32 您会建议何种改进措施？请注明____________

如您对上部分所涉及的内容或对于上海的洪水风险管理时间有任何其他意见及评论，欢迎您在此注明。

非常感谢您抽出宝贵时间告知我们您的专家意见和经验！
烦请您将填妥的问卷于8月10日（周五）前通过如下电子邮件反馈于我们:
li.meiling82@gmail.com ,

李梅玲/Meiling Li 上海， 7月27日, 2012