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An Evaluation of Disaster Risk Reduction (DRR) Approaches for Coastal Delta Cities – A Comparative Analysis

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ABSTRACT

Deltas are the promising places with multifarious ecosystems and arable soils along with the ease of water transportation system; hence, a number of important cities are established in or near coastal delta regions. However, due to the geomorphic characteristics, those cities are extremely exposed to hydro-meteorological hazards, especially to riverine and coastal flood. Additionally, climate change, rapid urbanization and subsidence are exacerbating the existing situation and causing monumental loss. Researchers as well as various international organizations like United Nations Inter-Agency Secretariat of the International Strategy for Disaster Reduction have recognized the implications of formulating disaster risk reduction (DRR) plans for coastal delta cities. This demands for the excogitation of adaptation policies and measures in addition to the mitigation efforts to reduce flood risks. In this regard, to support the comprehensive concept development, this study elicits different components of flood risk reduction policies and measures, congenial for coastal delta cities in respect of physical and environmental perspectives. Eleven precedent (model) cities are selected to study their various initiatives for reducing coastal flood risks. Findings show that protecting cities from flooding and reducing exposure to floods are two different but interrelated approaches of DRR. Combinations of structural and non-structural measures are the prerequisites to achieve the goal of effective DRR.

Keywords: Coastal Delta Cities, Climate Change, Disaster Risk Reduction, Coastal Flooding.

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1. INTRODUCTION

Deltas are promising places with multifarious ecosystems and arable soils for agriculture and convenient transportation via river and coast facilitating active trading and supporting industrial production. These areas provide environmental prosperity to support biodiversity, human population centres and industrial and agricultural production (Krueger et al. 2012). Throughout the history, many important cities are established in coastal delta regions because of the ease of communication, transportation as well as for the opportunities that these regions can maintain. As of now, 13 out of the 20 largest cities in the world are located in the coastal regions, mainly in deltas. A number of research projects reveal that by the middle of this century, the majority of the world's population will inhabit around the cities in or near deltas, estuaries or coastal zones (Dircke et al. 2010; Hanson et al. 2011). However, these places are highly exposed to natural hazards, particularly of flooding. Flood exposure in those coastal regions has been augmenting, owing to the growing population associated with the expansion of built-up areas, climate change-induced downpour and land subsidence (Hallegatte et al. 2013). In addition, subsided elevation, sea level rise and recurrent storm surges are exacerbating flood impact in these regions (Nicholls et al. 2008; Syvitski 2008). In the recent past, the grimness of flood damage has superseded the all losses or casualties by other catastrophes that happened around the world (Hanson et al. 2011; Aerts et al. 2014; Prabhakar et al. 2009).

The Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report reveals that flood risks and other climate change impacts are inevitable and will continue to increase which asks for the excogitation of adaptation policies and measures in parallel to the mitigation efforts (Dircke et al. 2010). But, risk reduction in climatic hazards is a challenging task and convoluted in nature, since it is influenced by physical, socio-economic, environmental and political processes and their interactions. Kreibich et al. (2014) have proposed a novel framework for the integrated, continuous cost assessment in natural hazard risk management, which enables the early assessment of the efficiency of risk mitigation strategies. The aim to reduce risk of natural hazards is "to find a way to live with these phenomena, rather than die from them" (UNISDR 2004).

Cities pursue disparate approaches of disaster risk reduction (DRR) to increase the preparedness for the coastal flooding. Some approaches are more concentrated on the expensive structural defences like dikes or storm surge barriers, while others focus on the non-structural measures like the implementation of early warning systems (Kreibich et al. 2015; Hanson et al. 2011; Nicholls et al. 2008). Hanson et al. (2011) firmly claim that the choice of flood defence system may diverge from the immediate influence in the risk reduction to long-term options. Structural flood defences can reduce the contingency of flood occurrence but not the exposure, leaving high residual risk in case of overtopping or failure (Nicholls et al. 2008). In this circumstance, cities with limited resources are often struggle in developing an optimum adaptation and risk reduction strategy (Alerts et al. 2014). To esteem the development of adaptation strategies, this study elicits different components of flood risk reduction policies and measures congenial for coastal delta cities in regard to physical and environmental perspectives.

2. LITERATURE REVIEW

As flood risk is prevalent in the delta cities, this study is concentrating on flood risk reduction approaches in those areas. There are different sources of origin of flooding in the coastal delta cities, for example, pluvial, fluvial or tidal flooding (GLA 2012). Coastal flooding is mostly common in the coastal delta regions, which results from the extreme weather conditions like storm surge, cyclone, typhoon and hurricane. Moreover, the repeated occurrence of these hazards due to climate change is exasperating the situation (Klein et al. 2003; Prabhakar et al. 2009). High tides also inundate the low-lying coastal regions (NOAA 2013), which is aggravated by the sea level rise (Nicholls et al. 1999). Large number of people are exposed to coastal flooding (Hanson et al. 2011; Nicholls et al. 2008) and the productive nature of deltas is spurring further rapid urbanization that increases the number of population exposed to flood (Nicholls et al. 2008).

The conventional focus of disaster management was relying on the preparation and effective response during and after a particular hazardous event, respectively (UNISDR 2004). But the occurrence of disastrous natural hazards during the last few decades made it obvious that modern society cannot afford only to respond after losing lives and assets (UNISDR 2004; Wamsler 2004). Thus, a new, more efficient strategy is needed that significantly mitigates the impact of natural hazards. More holistic approaches which take into account the hazard, exposure and vulnerability to mitigate the natural hazard risk, seem more promising (Plate 2002; UNISDR 2004).

2.1 Paradigm shifts towards DRR

The increasing concern about the impact of climate change and associated risk has impelled the UN general assembly to declare 1990–1999 as the International Decade for Natural Disaster Reduction (IDNDR). During the early days, risk reduction was tendentious towards the scientific and technological solutions, but later on the necessity for a comprehensive risk reduction approach has been realized. As a successor of IDNDR, UN General Assembly founded International Strategy for Disaster Reduction (ISDR) in 2000. ISDR has accentuated on understanding, assessment and management of vulnerability rather than on the physical consequences of a particular hazard. However, towards promoting the DRR approaches, one of the two major milestones is 'The Yokohama Strategy and Plan of Action for a Safer World' that conceived at the 'World Conference on Natural Disaster Reduction' in Yokohama in 1994 (UNISDR 2004). Under this world conference, a number of principles, strategies and action plans complementary to DRR were adopted by expressing the deep concern about natural hazards. Later, in 2005 'Hyogo Framework for Action (HFA)' 2005–2015 was uncovered which has added some new ideas and filled some of the gaps that the Yokohama Strategy left (UNISDR 2005).

Although the paradigm has been shifted towards DRR, still a comprehensive approach for DRR is indispensible to facilitate coastal cities in risk reduction. UNISDR (2004) curtained that the epistemology of DRR is transforming the traditional approach of disaster management which comprises of response, recovery and rehabilitation. Klein et al. (2003) have explicated that a city can comply three generic approaches as a means of DRR. First, it can prefer to change the settlement locations and land uses by evading hazardous areas. Second, it can lessen the losses by precluding the effect of hazard and/or by modifying the effects. Third, it can maintain the impact of a particular hazard by sharing losses. The study further construed that cities are usually inclined towards the loss reduction. However, an optimal amalgam of these approaches is required. While underlining the prerequisites of different DRR approaches, Prabhakar et al. (2009) have figured out that some of the DRR policies and measures are formulated based on the contemporary risks and past experiences. But the dynamic nature of climate as well as the global bounce up of population and land use might lead to increase the threshold of risk to a hazard in a linear or exponential way. Hence, historical data might fail to reflect into the future vulnerabilities. To overcome this limitation, more recently some research works have attempted to envisage the future risks scenario. Hallegatte et al. (2013) and Nicholls et al. (2008) have simulated current and future flood losses in the major coastal cities. Outcome of those studies shows that at present, a number of cities are highly exposed to flood in terms of the number of population and value of asset. And there would be an enormous increase in exposed population and asset in the near future. Although they have admonished that those exposures should not be transformed into an impact, they have not proposed any particular approach to reduce the flood risk.

But Grossi and Muir-Wood (2006) have explicated different DRR approaches by riveting on coastal flooding in a more structured way. They have asserted that a city can develop its DRR plan either based on the flood experiences or future flood risks. In the former case, a city takes the experience of a particular hazard in account to demonstrate the future investment to renounce the potential threat for a recurrence of the similar types of hazard. For example, storm surge defences can be built or raised according to the height of the water that an area has experienced in order to prevent a repetition of the similar event. Since hazards are not a constant phenomenon (Prabhakar et al. 2009), therefore, this approach does not have the ability to address the future risk.

For this reason, during 1990 when the cities as well as the international stakeholders started cogitating about the climate change, researchers had turned their attention to search for the alternative approaches that incorporates the climate change in DRR. Consideration of future risk factor is one of those approaches through which a city can delineate different zones in accordance with the threshold of the risks and the future development can take place accordingly. This has the similar principle as what Klein et al. (2003) designated as ‘choose change’ that means changing the land use or choosing risk-free areas for development. The main strength of this approach is that it considers future risk which is determined either based on ‘risk threshold’ meaning the maximum level of flood risk that can take place in future or ‘target loss’ meaning the maximum expected loss due to flood in terms of population or asset (Grossi and Muir-Wood 2006).

Again, the need for climate change adaptation (CCA) has appeared in the international agenda when IPCC Third Assessment Report in 2001 revealed that the impact of climate change is inevitable (Birkmann and Teichman 2010; Mercer 2010). A number of international events such as the Global Platform for DRR in Geneva 2009 and the Conference of the Parties (COP) under the United Nations Framework Convention on Climate Change (UNFCCC) in Copenhagen in December 2009 have mentioned the urgencies for the incorporation of CCA in DRR plan (Birkmann and Teichman 2010). Both CCA and DRR approaches are aiming at risk management, but dissimilarities exist in the scale of implementation. While DRR policies and measures are associated with the local hazards, risks, vulnerabilities and capacities leading to planned interventions by the governments (Prabhakar et al. 2009), the CCA is more concerned with the global scale intervention (Mercer 2010; Thomalla et al. 2006). Again, CCA has referred for the scientific research background in formulating DRR plan. Otherwise, DRR was only focused on hazard events and exposure; solutions were predominantly based on technical means (Birkmann and Teichman 2010; Thomalla et al. 2006). Aerts et al. (2009) have explained that many cities especially from developed countries and also some cities from developing countries are now trying to adopt CCA approach along with the traditional approaches of DRR.

2.2 Policies and Measures Related to DRR

Approaches of DRR would not have any implication unless those are translated into some policies and measures. For that the prerequisite is to know the areas to be focused for formulating DRR policies and measures. At this point, the concept of disaster resilience can provide a significant aid for identifying the areas to address, because DRR can be one of the means for achieving resilience (Klein et al. 2003). In the field of disaster management, resilience implies the capacity of a system to withstand in a certain hazard and also the ability to bounce back after the crisis situation (Coles and Buckle 2004; Godschalk 2003; Gordon 1978; Klein et al. 2003; Twigg 2007; Zhou et al. 2010). In a broad sense, to ensure resilience, five broad aspects need to be taken into account e.g. environmental, physical, social, economic and institutional (Cutter et al. 2008; Shaw and IEDM Team 2009; Zhou et al. 2010). So, every DRR policie and measure should be scrutinized to know whether those have any significant positive impact to improve the resilience or not. UNISDR (2004) has proposed that along with the structural protection system, DRR plan should consider urban planning and environmental management policies.

2.2.1 Urban planning and DRR

Klein et al. (2003) have stated that the alteration of land use and location of development can help to avoid the impact of hazards, but the concern is on what basis these changes should be made. Answer exists in the 'Yokohama Strategy and Plan of Action for a Safer World' where it has been mentioned that risk assessment should be incorporated in formulating DRR policies and measures (UNISDR 2004). In the 'Hyogo Framework for Action', more emphasis is given on assessing risk and delineating risk-prone zones (UNISDR 2005). In this regard, urban planning and management especially land-use planning can play a significant role (Berke 1998; Burby et al. 1999; Hutter 2007; UNISDR 2004, 2005). Researchers have recommended that planning mechanism can play a pivotal role for long-term risk reduction (Hutter 2007) though planning regulations can only prevent or subside the losses rather than reacting to crisis situations instantly (Berke 1998). Planning practice encompasses the growth management either by circumscribing the density or the rate of development (Berke 1998; UNISDR 2004) with the use of the zoning regulations (Burby et al. 2000; Grossi and Muir-Wood 2006; UNISDR 2004). Planning mechanisms can also contribute to DRR by strengthening the existing development with the help of building code, special hazard resistance building standards or even by the retrofitting standards for existing building stocks (Berke 1998; Burby et al. 2000; UNISDR 2004). Klein et al. (2003) have already mentioned that by the improvement in the structural resilience can withstand the inauspicious impact of natural hazards.

2.2.2 Policies and measures related structural protection

Although planning regulations have the ability to reduce the exposure to hazards, at the same time, it does not have the scope to react immediately during emergency situation. In that case, structural protection measures need to be integrated with the overall DRR plan (Alerts et al. 2014). Structural measures have received some of the criticisms that cities in affluent countries are more capable to undertake the structural protection systems (Alerts et al. 2014; Hanson et al. 2011; Klein et al. 2003; Nicholls et al. 2008). Besides, without having the policy to reduce the exposure by means of urban planning and management, failure in the structural protection system can have a significant repercussion to human lives and properties (Nicholls et al. 2008). Moreover, structural protection measure may have baneful impact on the environment especially on the ecosystem (Aerts et al. 2014). In general, it takes long period of time to construct structural protection systems (Hanson et al. 2011). Furthermore, Hanson et al. (2011) have stated that the willingness to adopt structural measures does not solely dependent on the wealth; a number of non-financial factors can influence the decision such as possibilities of collective actions, quality of public policies, roles of state or the redistribution of significant resources from other priorities. But the advantages that these sorts of measures provide cannot be abnegated. In evaluating coastal flood resilience strategies, Aerts et al. (2014) have explained that structural flood barriers can prevent the coastal flooding, but the prerequisite is that it has to be integrated with the planning mechanism. But Hanson et al. (2011) argue that structural measures are more efficacious against impacts during the most frequent, but less intense events.

2.2.3 Environmental management and DRR

Another dimension that should be given much precedency is the environmental factors, because environmental degradation causes climate change which exacerbates the hazard situations (UNISDR 2004). So, environmental management can reduce the impact of hazards and can make cities more adaptive. A number of international organizations have acknowledged this fact; for example, the International Union for Conservation of Nature (IUCN) and the International Institute for Sustainable Development (IISD) with the support of the Stockholm Environment Institute (SEI) have launched an initiative to promote the use of environmental management tools to reduce the vulnerability of communities from the growing threat of climate change and climate-related disasters. Hyogo Framework for Action (HFA) has also recommended for undertaking the environmental and natural resource management initiatives of DRR (UNISDR 2004, 2005). This approach is considered as one of the cost-effective means of DRR, (UNISDR 2004) although uncertainty exists on whether this measure is feasible for different contexts or not. Nicholls et al. (2008) and Hanson et al. (2011) have stated that environmental measure is more important and feasible in developed region where the rate of urbanization is relatively low. But considering the consequences of climate change, at present, cities from developed as well as developing countries are trying to adopt environmental management policies to enhance the adaptability in emergency situation (Dircke et al. 2010). So the above discussion shows that DRR is a complex process, and numerous attributes are pertained to this concept.

3. METHODOLOGY

A number of precedent (model) cities have been selected based on several criteria including their DRR initiatives with the focus on flood hazard. The DRR initiatives of those precedent cities were analysed to identify the components of DRR plans.

3.1 Selection of Precedent Cities

The delta city network (Aerts et al. 2009) is being used as the cornerstone to select the precedent cities. The fundamental objective of the delta city network is 'to establish a network of delta cities that are active in the field of climate change-related spatial development, water management, and adaptation, in order to exchange knowledge on climate adaptation and share best practices to support cities in developing their own adaptation strategies' (Alerts et al. 2009). Within this network, there are a total of forty member cities and nineteen affiliated cities, and among them, 11 cities were selected for this study.

Table 1 shows the chosen precedent cities together with the selection criteria. Within the delta city network, only eleven cities have inaugurated climate adaptation plans which are fully functioning. These cities have been spearheading in adaptation planning that are transferable to other delta cities within the 'Delta City Network'. Thus, DRR policies and measures of these cities have been used as the touchstone within the scope of this study. Table 1 is further showing the flood protection standards of those selected cities. Except Jakarta and Ho Chi Minh City, most of these cities are following high flood protection standards which resolve that along with flood adaption plans, they are concerned about the structural flood defence system.

Table 1. Cities position on the basis of risk reduction initiatives

Cities	**Climate adaptation strategy**	**Under active Delta network**	**Transferable DRR policies**	**Flood protection standard** (return period in years)
New York	√	√	√	100
New Orleans	√	√	√	100
Rotterdam	√	√	√	10000
London	√	√	√	1000

Cities	**Climate adaptation strategy**	**Under active Delta network**	**Transferable DRR policies**	**Flood protection standard** (return period in years)
Copenhagen	√	√	√	200
Melbourne	√	√	√	100
Ho Chi Minh City	√	√	√	50
Jakarta	√	√	√	10
Tokyo	√	√	√	1000
Hong Kong	√	√	√	900
Shanghai	√	√	√	1000

(Data source: Aerts et al. 2009; McGranahan et al. 2007)

3.2 Identifying the components of flood risk reduction

A generic analysis framework has been developed for the identification of DRR components. To develop this analysis structure, Hyogo Framework for Action (HFA), documents from the United Nations Inter-Agency Secretariat of the International Strategy for Disaster Reduction (UNISDR 2004) and two research works done by Burby et al. (2000) and Hanson et al. (2011) have been used as key references. HFA is one of the latest documents that provide DRR policies. However, HFA has only provided DRR policies from three perspectives (Table 2) and that is why three other documents have been used to broaden the range of policies in the analysis framework. Table 2 summarizes the DRR policies and measures that have been found in those four documents and furthermore, highlights the selected policies for the formulation of the analysis framework.

Table 2. DRR policies and measures that incorporated in four key documents

Document	**Policies and Measures**
Hyogo Framework for Action (HFA)	***a) Environmental and natural resource management*** • Sustainable management and preserving ecosystem. • Natural resource management and encourage nonstructural measure of DRR. • Consideration of climate change in DRR strategy **b) Social and economic development practices** • Promote food security

	• *Protecting critical facility like health facility, infrastructure* • Enhance social safety net mechanism and post-disaster recovery scheme. • Incorporation of DRR into post-disaster recovery and rehabilitation processes • *Provide financial security or disaster insurance* • Development Public private partnership for DRR ***c) Land-use planning and other technical measures*** • Incorporating urban planning and management in DRR • Consideration of DRR into planning procedure for major infrastructural project • Proper implementation of planning guideline and monitoring • Development based on risk assessment • Update building codes, planning standard considering risk factor
United Nations Inter-Agency Secretariat of the International Strategy for Disaster Reduction (UNISDR, 2004)	• *Environmental management* • *Land-use planning* • *Safe building construction and protection of critical facilities* • Financial and economic tools • Early warning systems
Burby et al., 2000	• *Risk mapping* • *Building standards* • *Development regulations* • *Critical and public facilities policies* • *Land and property acquisition* • Taxation and fiscal policies • Information dissemination
Hanson, et al. (2011)	• *Upgraded protection* • *Managing subsidence* • *Building regulations* • *Land-use planning to reduce exposure, including focusing new development away from the floodplain, and preserving space for future infrastructure development* • *Selective relocation away from existing city areas to reduce exposure more rapidly than is possible by only focussing on new development* • *Risk sharing through insurance and reinsurance*

* Italicised policies are selected for the analysis framework

Selected DRR policies are categorized under three broad approaches and about ten policies and measures have been listed (Fig. 1).

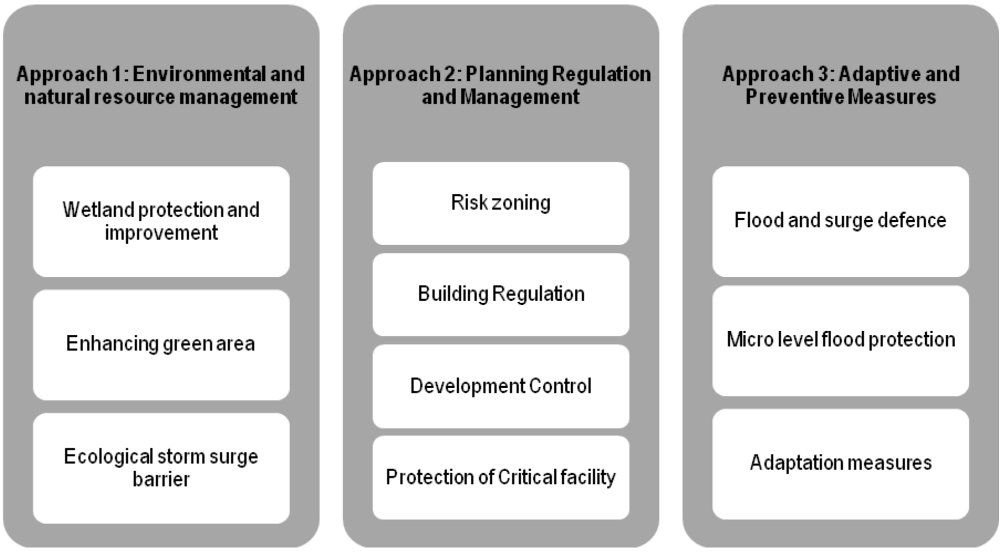

Figure 1. Analysis structure to identify DRR policies

Based on these policies and measures, the DRR initiatives by 11 precedent cities have been characterized and comparatively analysed.

4. ANALYSIS

Table 3 is summarizing the various policies which have been adopted by precedent cities.

Table 3. DRR policies adopted by eleven precedent cities

DRR Policies	**City**										
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**	**(11)**
Wetland Protection and improvement	√	√	√	x	√	x	√	√	√	x	√
Enhancing Green area	x	√	√	√	√	x	√	√	x	√	√
Ecological storm surge barrier	√	√	x	x	x	x	x	x	x	x	√
Risk zoning	√	√	x	√	√	x	√	√	x	√	x
Building Regulation	√	√	x	x	x	√	√	x	x	√	x
Development control	√	√	x	x	x	x	√	x	x	x	x
Protection of critical facility	x	√	√	x	√	x	√	x	x	x	x
Flood and surge defence	√	√	√	√	√	x	√	√	√	x	√
Micro level flood protection	√	√	√	√	√	x	√	x	√	√	√
Adaptation measures	√	√	√	√	x	√	√	√	√	√	x

(1) = New York; (2) = New Orleans; (3) = Rotterdam; (4) = London; (5) = Copenhagen; (6) = Melbourne; (7) = Ho Chi Minh City; (8) = Jakarta; (9) = Tokyo; (10) = Hong Kong; (11) = Shanghai

Data source: (ADB 2010; BNPB 2012; City-of-Copenhagen 2011; City-of-New-York 2007; Dircke et al. 2010; DOCC 2009; EPD 2010; GLA 2012; Grossi & Muir-Wood 2006; Yongjin 2010)

4.1 Approach 1: Environmental and natural resource management

4.1.1 Wetland protection and improvement

Policies to protect and improve the wetlands can play a significant role in flood risk reduction by accumulating excessive surface run-off that might be caused by heavy downpour, tidal flow or storm surge (UNISDR 2004). It is evident that eight out of eleven cities have taken measures to protect and improve the wetlands (Table 4). However, it is also observed that the implementation of this measure varies from city to city.

Table 4. **Adoption of wetland improvement measure by different cities**

Cities	Aim	Type of policy and measure	Area of implementation
New York	Improve surge water storage capacity	Construction and rehabilitation of wetlands	Waterfront
New Orleans	improve water storage capacity	Restoration of existing wetland	Whole city
Rotterdam	Improve rainwater storage capacity	Construction of new water detention area, restoration of existing wetland	Whole city
London	x	x	x
Copenhagen	Improve water capacity	Identification of new wetlands and preservation of existing one	Whole city
Melbourne	x	x	x
Ho Chi Minh City	Improve river navigability and water detention area	Restoration of existing wetland	River and other water bodies
Jakarta	Improve river navigability and water detention area	Restoration of existing wetland	River and other water bodies
Tokyo	Store over flooded river water	Construction of multipurpose water storage basin	Riverbank
Hong Kong	x	x	x
Shanghai	Limit the reduction of water surface	Development restriction in wetlands	River and lakes

Data source: (ADB 2010; BNPB 2012; City-of-Copenhagen 2011; City-of-New-York 2007; Dircke et al. 2010; DOCC 2009; EPD 2010; GLA 2012; Grossi & Muir-Wood 2006; Yongjin 2010)

Cities that have undertaken this measure is mostly for the improvement of the water storage system that makes those cities more adaptive to flood. Upholding existing wetlands and if possible, construction of new would be an efficient way to hold excessive flood water. In the New York City, the coastal areas are the most endangered part as those areas incur the utmost impact of hurricanes. New York City has taken initiatives on a macro scale through the coordination between Federal and State coastal zone protection in Local Waterfront Revitalization Program (LWRP). The policy includes the construction and rehabilitation of wetlands within the coastal settlements (Dircke et al. 2010). New Orleans has almost similar policy, but it is applicable for the entire city as more than 50 % of city population lives on the low lands (Hallegatte et al. 2013). However, the city also has special care for the coastal regions, and it reflects in the New Orleans Hazard Mitigation Plan 2010 where there is a policy for the restoration of coastal wetlands (Dircke et al. 2010; NOHSEP 2011). Rotterdam and Copenhagen have also been underscoring on policies regarding wetlands restoration for the whole city. Though Rotterdam has one of best flood defence systems, the city is concerned about the rain water storage system. Consequently, various initiatives are introduced, such as retrofitting of ponds in the city parks or adjusting the canals to store excessive water so as to avoid the inundation of surrounding areas during the heavy precipitation. Besides, water plazas have been proposed so that those can act simultaneously as detention ponds during the peak rainfall and can be used as a playground in the dry seasons (Dircke et al. 2010).

Nevertheless, cities from Asia are more focused on river and lake than any other countries, because of the presence of crisscrossed rivers in those cities. Improvement in the river navigability and natural drainage systems can reduce the surface run-off significantly. However, Jakarta and Ho Chi Minh City (HCMC) have a huge problem of river navigability. In Jakarta, inept waste disposal system is one of the main causes of filling up the rivers and lakes, whereas in the HCMC, siltation is worth to mention (ADB 2010; Aerts et al. 2009; Dircke et al. 2010). Both of these cities have initiated dredging programme to ameliorate the water carrying capacity for reducing the risk of overflowing the rivers and lakes. City like Tokyo is vulnerable to flood due to the spill over from the river, and for this reason, its climate adaptation plan incorporates the construction of multipurpose water storage basin along the river bank (Dircke et al. 2010). Shanghai has slightly different problem where the new development is encroaching the wetlands. Due to the reduction of wetlands in the recent past, Shanghai introduces the development control policy that rigorously limits the development initiatives by filling up wetlands (Yongjin 2010).

4.1.2 Enhancing green area

By following a simple principle, i.e. the reduction of the surface run-off, a city can reduce the probability of flood occurrence. Various cities have taken measures of different forms (Table 5) for enhancing the green areas to attain this objective.

Table 5. **Enhancing green area to reduce the risk of natural hazard in precedent cities**

Cities	Aim	Type of measure	Area of implementation
New York	x	x	x
New Orleans	Increase area of soft surface and ground water recharge	Re greening	Whole city
Rotterdam	Reduce surface runoff	Green roof	Individual property
London	Improve ground water recharge, reduce surface runoff	Tree cover Green roof	Central city; individual property
Copenhagen	Improve water holding capacity	Park, green sports field, individual garden etc	Whole city; individual property
Melbourne	x	x	x
Ho Chi Minh City	Reduce pressure on storm sewerage	Capturing rainwater	Individual property
Jakarta	Improve ground water recharge	Re greening	Floodplain
Tokyo	x	x	x
Hong Kong	Improve water holding capacity	Conservation of green area; green roof	Whole city Individual property
Shanghai	Reduce surface runoff	Green roof; Street and lowland vegetation	

Data source: (ADB 2010; BNPB 2012; City-of-Copenhagen 2011; City-of-New-York 2007; Dircke et al. 2010; DOCC 2009; EPD 2010; GLA 2012; Grossi & Muir-Wood 2006; Yongjin 2010)

Green areas create soft surfaces that allow rainwater to percolate through. At the same time, measure like green roofs subsides the flow of surface run-off, as those areas impede rainwater while reaching the ground. Simultaneously, this will abate the surface run-off and expedite the ground water recharging. New Orleans, Copenhagen and Jakarta are following the former path where their policies are aiming at expanding the green areas. This will reduce the water velocity during the heavy downpour or even during the storm surges, and also the water will get the opportunity to infiltrate through the soil. On the other hand, Rotterdam has taken the policy to enhance green roof on an individual property level. Study shows that green roofs slow down the rate of run-off and can retain 10–20 mm of rain water, which equals an average of 100–200 m3 of water per roof in the Rotterdam (Dircke et al. 2010). However, to reduce the run-off Ho Chi Minh City has promoted measures of capturing rainwater that simultaneously allow them to deploy the accumulated water for domestic purposes (Lempert et al. 2013). Other cities like London, Hong Kong and Shanghai are following both of these strategies that mentioned above. Furthermore, Shanghai has the goal of enhancing the green covers in the low lands to designate those areas as the leisure centres and to hold water during the flood as well (Yongjin 2010).

4.1.3 Ecological Storm surge barrier

Since, some of the precedent cities are susceptible to suffer from storm surge, typhoon or hurricane, so appropriate measures can abate the intensity of these extreme events. Ecological storm surge barrier is one of those measures, however, it is not that popular, as only three precedent cities have tried to introduce it (Table 6).

Table 6. **Adoption of ecological storm surge barrier by some precedent cities**

Cities	Aim	Type of measure	Area of implementation
New York	Restrict surge water to enter into the city	Water belt Beach nourishment	Coastline
New Orleans	Reduce the wind impact and barrier to surge	Coastal forest	Coastline
Rotterdam	x	x	x
London	x	x	x
Copenhagen	x	x	x
Melbourne	x	x	x
Ho Chi Minh City	x	x	x
Jakarta	x	x	x
Tokyo	x	x	x
Hong Kong	x	x	x
Shanghai	Restrict surge water to enter into the city	Beach nourishment	Coastline

Data source: (ADB 2010; BNPB 2012; City-of-Copenhagen 2011; City-of-New-York 2007; Dircke et al. 2010; DOCC 2009; EPD 2010; GLA 2012; Grossi & Muir-Wood 2006; Yongjin 2010)

One of the major initiatives for DRR in the New York is the ‘Staten Island Blue-belt Program’ which is an ecologically sound and cost-effective storm water management system. The program includes the preservation of natural drainage corridors which is called Blue-belts that incorporates streams, ponds and other wetland areas. Preservation of this network of wetlands allows the city to perform the functions of conveying, storing and filtering storm water (Aerts et al. 2009). Moreover, the measure to nourish the beach is adding extra stability to the coastline (City of New York 2007). Though, it is an expensive measure that might be difficult to implement for many low-income countries. New Orleans has more long-term vision of creating coastal forest as an ecological storm surge barrier (NOHSEP 2011). But Shanghai has accepted more expensive measure of beach nourishment like the New York City with the intention to play an important role for protecting the city from heavy wave during the storm surge (Yongjin 2010).

4.2 Approach 2: Planning and management

Urban planning offers several tools that can be used as the means to DRR. It has been mentioned that four measures are identified within planning and management practice (Fig. 1) that should be incorporated in the DRR plan. Table 3 has shown the distribution of various precedent cities in respect of different planning measures that those cities have undertaken.

4.2.1 Risk Zoning

Probably, the most efficient way to avoid catastrophic impact of a particular flood is by the restriction of development in the more flood prone zones. This can be done by using land-use regulations with the demarcation of risk zones. From Table 7, it is clear that most of the precedent cities have adopted the risk zoning policy. But the regulations of managing risk zones vary from city to city. As for example, New York, New Orleans and Hong Kong are predominantly concerned with reducing exposure of the population and asset (City of New York 2007; NOHSEP 2011). So, the target for those cities is to manoeuvre the future development to reduce the flood exposure, whereas London and Jakarta are intending to relocate people from hazard prone areas (BAPPENAS 2010; GLA 2012). Ho Chi Minh City has slightly different vision that emphasizes low-income settlements and industrial zones. Usually, low-income settlements are the most vulnerable to flood, and industrial zones are the most economically productive areas. So, according to their regulations, these two types of land uses have to be located outside the flood prone zones (ADB 2010). However, Copenhagen delineates flood risk zones in order to guide flood water towards those areas, and development in those areas is usually prohibited (City of Copenhagen 2011).

Table 7. **Precedent cities with risk zoning policy of DRR**

Cities	Aim	Type of measure	Area of implementation
New York	Reduce exposed area	Vulnerability mapping	Coastal area
New Orleans	Development control in vulnerable zone	Delineating flood prone zone	Whole city
Rotterdam	x	x	x
London	Relocation settlement from vulnerable area	Locating flood vulnerable land	Whole city
Copenhagen	Guide flood water to an area with least damage cost	Delineating areas with least damage cost	Whole city
Melbourne	x	x	x
Ho Chi Minh City	Low income housing and Industrial development outside of risk zone	Delineating flood prone zone	Whole city
Jakarta	Reduce risk to the settlement in risk	Locating settlement that are in risk	Whole city
Tokyo	x	x	x
Hong Kong	Protect built environment and infrastructure	Flood risk map	Whole city
Shanghai	x	x	x

Data source: (ADB 2010; BNPB 2012; City-of-Copenhagen 2011; City-of-New-York 2007; Dircke et al. 2010; DOCC 2009; EPD 2010; GLA 2012; Grossi & Muir-Wood 2006; Yongjin 2010)

4.2.2 Building regulation

In a flood prone area, structures should be built in a safest possible means to make those structures more resilient (UNISDR 2004). Among the 11 precedent cities, five have building regulations, purporting at flood risk reduction (Table 8). New York and New Orleans have the experience of worst type of hurricane, and still these cities are susceptible to face those extreme natural events. For these cities, ensuring structural resilience is a must (City of New York 2007; NOHSEP 2011). However, in New York, the coastal areas possess more risks; thus, this measure is particularly applicable for those regions. In Ho Chi Minh City, again low-income areas get the top priority, and the city has adopted this measure so that those settlements can combat against flood (ADB 2010). Melbourne and Hong Kong are not as vulnerable as other cities; still they have taken climate change scenario earnestly and undertaken this measure to ascertain the maximum safety (DOCC 2009; EPD 2010).

Table 8. **Precedent cities with building regulation for risk reduction**

Cities	Aim	Type of measure	Area of implementation
New York	Ensure structural resilience	Building code	Waterfront areas
New Orleans	Flood resistance structures	Building code	Whole city
Rotterdam	x	x	x
London	x	x	x
Copenhagen	x	x	x
Melbourne	Make structures adaptive to climate	Building code	Whole city
Ho Chi Minh City	Reduce structural vulnerability	Fixation of minimum standard	Low income settlement
Jakarta	x	x	x
Tokyo	x	x	x
Hong Kong	Make structures adaptive to cyclone	Building code	Whole city
Shanghai	x	x	x

Data source: (ADB 2010; BNPB 2012; City-of-Copenhagen 2011; City-of-New-York 2007; Dircke et al. 2010; DOCC 2009; EPD 2010; GLA 2012; Grossi & Muir-Wood 2006; Yongjin 2010)

4.2.3 Development Control

Since the most ascendant cities are located in the coastal delta regions, enforcing restriction on development is quite difficult to execute, and therefore, development control measure is not much in use to most of the precedent cities. Only three out of 11 cities have attempted to introduce this measure (Table 9). New York City has the policy to reduce density near the water front because those areas receive the highest impact during hurricanes (Dircke et al. 2010). New Orleans has initiated an innovative approach where the property owners could choose to move out of a high-risk area to a lower risk area (NOHSEP 2011). Ho Chi Minh City prefers to relocate people from areas which suffer from higher level of inundation (Lempert et al. 2013).

Table 9. **Development control as a means of DRR in precedent cities**

Cities	Aim	Type of measure	Area of implementation
New York	Reduce density in vulnerable area	Restriction on new development	Waterfront area
New Orleans	Reduce density in vulnerable area	Relocation, compensation	Flood risk area

Cities	Aim	Type of measure	Area of implementation
Rotterdam	x	x	x
London	x	x	x
Copenhagen	x	x	x
Melbourne	x	x	x
Ho Chi Minh City	Reduce exposure	Relocation	Flood risk area
Jakarta	x	x	x
Tokyo	x	x	x
Hong Kong	x	x	x
Shanghai	x	x	x

Data source: (ADB 2010; BNPB 2012; City-of-Copenhagen 2011; City-of-New-York 2007; Dircke et al. 2010; DOCC 2009; EPD 2010; GLA 2012; Grossi & Muir-Wood 2006; Yongjin 2010)

4.2.4 Protection of Critical facility

Most of the seaports are located in the coastal delta cities, and those port areas are vital for national as well as global economy (Nicholls et al. 2008). So, undertaking of substantial initiatives to reduce the flood exposure of the pivotal asset like ports should be of the utmost priority. Rotterdam has special measure for the port area, because it is the commercial hub of the Europe. Historically, this port has been established on a land with relatively high altitude, although the city has a very low average elevation from the sea level (Dircke et al. 2010). Also, the New Orleans has the same strategy as Rotterdam. Other cities like Ho Chi Minh City (HCMC) and Copenhagen have the inclination towards the transportation route, as these cities denote transport routes as the critical facility. These cities are endeavouring to protect the roads during flood. In this regard, Copenhagen has the provision of channelizing flood water from the main roads. HCMC has the aim to develop alternative transport roads (Table 10), so that people can have more options in case of the inundation of one road and it is reflected in their national transport plan (ADB 2010; City of Copenhagen 2011).

Table 10. **Protection of critical facility to reduce risk in precedent cities**

Cities	Aim	Type of measure	Area of implementation
New York	x	x	x
New Orleans	Uninterrupted trading	Increase land elevation	Port area
Rotterdam	Uninterrupted trading	High land elevation	Port area
London	x	x	x

Cities	Aim	Type of measure	Area of implementation
Copenhagen	Ease of accessibility	Channelling rainwater to wetland	Transport route
Melbourne	x	x	x
Ho Chi Minh City	Ease of accessibility	Alternative road	Flood prone area
Jakarta	x	x	x
Tokyo	x	x	x
Hong Kong	x	x	x
Shanghai	x	x	x

Data source: (ADB 2010; BNPB 2012; City-of-Copenhagen 2011; City-of-New-York 2007; Dircke et al. 2010; DOCC 2009; EPD 2010; GLA 2012; Grossi & Muir-Wood 2006; Yongjin 2010)

4.3 Approach 3: Adaptive and Preventive Measures

This approach predominantly deals with the structural measures of flood protection. But some non-structural measures are also been considered here. This approach is proved to be very far reaching, as nine out of eleven precedent cities have exercised all of the three measures under this approach (Table 3).

4.3.1 Flood and surge defence

Construction of flood and surge defence systems is one of the most popular and widely accepted means of coastal flood protection. Nine precedent cities have undertaken this measure (Table 11). Rotterdam is well known for using this measure. Historically, in Rotterdam as well as in the whole Netherlands, a significant portion of land has been reclaimed by constructing ring dikes along the river and coastline and thus creates the polder areas. In addition, there is a surge barrier to protect the port area (Dircke et al. 2010). New York and New Orleans have also undertaken a number of structural measures to protect the city from coastal flooding. It includes surge barrier, dikes, multipurpose levee and so on (City of New York 2007; NOHSEP 2011). The expansion of the New Orleans city has taken place in the low-lying marsh land in between the Lake Pontchartrain and Mississippi river, therefore, maximum protection for that area is being ensured (Rogers 2008). However, measures like flood and surge defence have the ability to withstand during flooding, but do not necessarily reduce the exposure of population and assets. London has river wall for Thames to shield the city from the tidal flood. However, considering the climate change and sea level rise, currently the city is considering of constructing a second Thames barrier (GLA

2011). Jakarta and Ho Chi Minh City (HCMC) have also introduced these types of structural flood protection systems in their respective adaptation plans. HCMC has adopted an immense project of constructing 200 km of dikes which includes hundreds of tidal gates (Dircke et al. 2010). Shanghai has the aim to implement surge defence system to prevent the overtopping of water during typhoon (Yongjin 2010). For similar type of reason, Copenhagen has adopted this measure.

Table 11. **Precedent cities with flood and surge defence**

Cities	Aim	Type of measure	Area of implementation
New York	Reduce vulnerability to coastal settlement	Surge barrier; multipurpose levee	Coastline
New Orleans	Reduce vulnerability	Surge barrier; dikes; levee system	Coastline, lake and riverbank
Rotterdam	Reduce vulnerability and ensuring uninterrupted trading	Dikes; surge barrier	Port, coastline and riverbank
London	Protect the city from tidal flooding	River wall	Riverbank
Copenhagen	Protect the city from flood	Dike	Coastline
Melbourne	x	x	x
Ho Chi Minh City	Protect the city from flood	Dike	Coastline and riverbank
Jakarta	Protect the city from flood	Dike	Coastline and riverbank
Tokyo	Protect city from flood	Super levee	Along river
Hong Kong	x	x	x
Shanghai	Protect city from flood and typhoon	Sea dike; surge barrier	Estuary, coastline

Data source: (ADB 2010; BNPB 2012; City-of-Copenhagen 2011; City-of-New-York 2007; Dircke et al. 2010; DOCC 2009; EPD 2010; GLA 2012; Grossi & Muir-Wood 2006; Yongjin 2010)

4.3.2 Micro level flood protection

Another way of reducing flood risk is to pacify the impact of flood hazard in a relatively smaller scale. This can be done either though protecting individual property or by avoiding the impact of flood in some specific areas such as roads and storm sewerage lines. However, both adaptive and preventive measures can be applied to achieve this goal. From Table 12, it is apparent that most of the cities are more willing to increase elevation in certain areas for reducing the impact of flood. New York and Hong Kong are concerned about the coastline, so these cities have initiatives for increasing land elevation in the coastline in order to protect settlements from flood. New York also tried to stabilize coastal edge by using bulkheads, revetments, groins, etc. (City of New York 2007). In the coastal areas of Hong Kong, the entrances of individual buildings have been made elevated to deny flood water to enter into the house (EPD 2010). London and Copenhagen are more concerned about the protection their infrastructures related to flood management; for example, initiatives are taken to avoid storm sewerage line from being inundated. These two cities have either increased the elevation or improved the capacity of storm sewerage drainage (City of Copenhagen 2011; GLA 2012). In the New Orleans, there is the levee system which actually an obstacle to the natural drainage system. From the past, the city is relying on technical solution to pump out the rainwater. Besides, the city has adopted the measure of increasing elevation of individual property (Dircke et al. 2010; NOHSEP 2011). Rotterdam has one of best flood protection systems in the world, and the city is protected by a number of ring levee systems. Still, to ensure accessibility during emergency situation, they have raised the elevation of roads (Dircke et al. 2010). Ho Chi Minh City has recently undertaken the policy to elevate homes, and this policy is preponderantly applicable to all single story buildings. However, buildings which are more than one story are beyond the scope of this policy as it is too difficult to elevate relatively higher buildings (Lempert et al. 2013).

Table 12. **Micro level flood protection system in precedent cities**

Cities	Aim	Type of measure	Area of implementation
New York	Protection from sea level rise impact	Increase land elevation	Coastline
New Orleans	Protect individual property from flood	Increase land elevation	Individual property
Rotterdam	Maintain accessibility	Increase elevation	Road, port
London	Improve rainwater discharge	Increase elevation	Storm sewerage
Copenhagen	Improve rainwater discharge	Increase pipeline dimension; install pumping station	Storm sewerage
Melbourne	x	x	x
Ho Chi Minh City	Protect individual property	Increase elevation	1 story building
Jakarta	x	x	x
Tokyo	Maintain accessibility	Increase elevation	Road along water basin
Hong Kong	To make coastal settlement safe	Increase elevation	Coastal area
	Denying flood water	Increase entrance	Individual

	from entering	elevation	property
Shanghai	Reduce surface runoff	Impervious road surface	Road

Data source: (ADB 2010; BNPB 2012; City-of-Copenhagen 2011; City-of-New-York 2007; Dircke et al. 2010; DOCC 2009; EPD 2010; GLA 2012; Grossi & Muir-Wood 2006; Yongjin 2010)

4.3.3 Adaptation measures

Even high level of flood protection system might fail to protect the city from being inundated considering the mercurial nature of the climate. So, these extremely susceptible coastal delta cities must be ready to conform to the flood and to recover as quickly as possible after a particular flood. Table 13 has cumulated the policies that various cities have undertaken to cope with the flood. New York, Rotterdam, London, Melbourne and Hong Kong have the provision of flood insurance. This is the non-structural means of flood risk reduction and the insurance covers for building as well as contents, in London as for example (GLA 2011). Other cities or even some of the aforementioned cities are depending on the structural combined with mechanical means of flood adaptation. For example, New Orleans has the initiative to make structures as permeable as possible, so that using the topography flood water can go following the direction to a specific point; thus water can be pumped out of the levee system (NOHSEP 2011). Similarly, Tokyo is also following the same principle that the roads or other built-up areas should be made of porous material so that flood water can percolate to the ground water. Jakarta has the problem of improper solid waste disposal which usually causes clogging up the drainage, lakes or even rivers. So their way of adaptation is to dredge out the wastes from these drains and water bodies so as to increase the holding capacity of water (Dircke et al. 2010). Similar to Jakarta, Ho Chi Minh City has adopted the measure of dredging the river to improve navigability (ADB 2010). Hong Kong has taken initiative to separate storm sewerage lines from general drainage system, and at the same time in some points, there will be pumping station to get rid of the flood water (Dircke et al. 2010).

Table 13. Precedent cities with adaptation measures of risk reduction

Cities	**Targeting**	**Type of measure**	**Area of implementation**
New York	Quick recovery	Insurance	Household level
New Orleans	Channelize flood water	Permeable structure	Individual property
Rotterdam	Quick recovery	Insurance	Household level

London	Quick recovery from loss	Insurance	Household level
Copenhagen	x	x	x
Melbourne	Improve water discharge efficiency	Improve capacity for storm sewerage	Storm sewerage line
	Quick recovery	Insurance	Household level
	Reduce runoff	Increase porous surface	Whole city
Ho Chi Minh City	Improve navigability	Dredging	River
Jakarta	Improve navigability	Dredging; proper waste disposal	River; whole city
Tokyo	Reduce runoff	Increase porous surface	Whole city
Hong Kong	Quick recovery from loss	Insurance	Household level
	Improve water discharge	Separate storm sewerage from	Sewerage line
	Improve water discharge	Pumping station	Specific points
Shanghai	x	x	x

Data source: (ADB 2010; BNPB 2012; City-of-Copenhagen 2011; City-of-New-York 2007; Dircke et al., 2010; DOCC 2009; EPD 2010; GLA 2012; Grossi & Muir-Wood 2006; Yongjin 2010)

5. DISCUSSION AND CONCLUSION

To identify the components of DRR plan from the physical and environmental perspective is the main objective of this study. Most of the research works related to DRR have focused on a particular component of DRR plans. But to reduce the risk for a particular city, single solution is not enough. Besides, policies and measures can vary depending upon the different contexts. This study has shown all possible solutions that a delta city can adopt to reduce the risk from coastal flooding.

In this regard, a city can follow three different approaches of DRR such as environmental and natural resource management; planning and management; adaptation and prevention. Firstly, incorporation of environmental attribute in the DRR is relatively a new approach. Policies and measures within this approach are mostly non-structural and management oriented. Environmental policies and measures are applicable for every segments of a particular city. To store excessive rain water, which usually causes flood, precedent cities have taken initiatives to undertake this approach. Besides, ecological storm surge barrier can reduce the concentration and intensity of wind during cyclone. Moreover, enhancing green areas can stabilize climatic situations.

Secondly, to reduce flood exposure, cities have to adopt various urban planning tools. This holistic approach is to ensure guided city development, with the consideration of risk of flood hazard. For the comprehensiveness of this approach, risk zoning policy is more popular in various precedent cities. Cities are more concerned about the redistribution of population density rather than reducing it. On the other hand, restriction of development might have been applied in some high risk-prone zones, but very few cities are motivated to reduce the gross development density. Besides, in order to reduce assets exposure, cities have resolved to take special care for some critical facilities and infrastructures, which in turn will help to ensure flood adaptation.

Thirdly, it is manifested from the comparative analysis that structural preventive measures are the most ostentatious means of DRR. Planning approach can reduce the exposure to flood but cannot protect the city during a catastrophic situation. On the other hand, some of the policies under the environmental approach have the ability to protect cities, but a city cannot rely entirely on that. So, along with other two approaches cities need to build structural flood protection system. Again, a city can also reduce flood risk by implementing structural measures on a micro-scale. However, now-a-days cities from developed countries are adopting flood insurance policy. It is a very efficient way of securing human life and property. But this policy is very difficult to execute in developing countries, still it can be conceived within the long-term vision of those countries.

Finally, it can be said that in accordance with the rate of climate change, the recurrent occurrence of natural hazards and its intensity is following the augmented trend pattern. So, the effectiveness and appropriateness of DRR plan depends on the risk assessments, vision or projections. Cities always face a dilemma when they come to the point of implementing appropriate policies and measures especially in developing countries. By thinking superficially, public bodies sometimes perceive that structural protection measures are the best means of reducing risk. It is true that only through the planning and management policy, it is not quite possible to prevent the occurrence of natural hazard like flood (Burby and French 1981), but it has certain advantages that should not be unmarked (Nicholls et al. 2008). So, by practicing environmental and planning management in addition to the structural protection system will assist cities significantly to achieve the goal of risk reduction. This example is a small part of the bigger picture, because there are numerous measures which have the ability to reduce the risk from natural hazards. All we need to understand these measures in respect of the context of usage, benefits, jurisdiction and so forth. This research is a mere attempt to explore those policies and measures.

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