Project Synthesis Report

Building Urban Climate Resilience: The Economics of Alternative Development Pathways

Published by the Institute for Social and Environmental Transition-International
in partnership with the Institute for Social and Environmental Transition-Pakistan,
Gorakhpur Environmental Action Group, and Hue University

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List of Acronyms

ACCCRN	Asian Cities Climate Change Resilience Network
BAU	business as usual
BCR	benefit-cost ratio
CBA	cost-benefit analysis
CC	climate change
DEM	digital elevations map
EWS	early warning system
GDP	gross domestic product
GIS	geographical information system
IRR	internal rate of return
IT	information technology
NPV	net preset value
RCC	reinforced cement concrete
RP	resilient pathway
SLD	shared learning dialogue
O&M	operations and maintenance

Foreword

As global awareness concerning climate change increases there is, at an intuitive level, growing recognition that the development choices we make now are of fundamental importance to our ability to adapt and survive or thrive in the future. Such choices are perhaps nowhere of greater importance than in the burgeoning cities of Asia. Globally 50% of the world's population now resides in urban areas and this is projected to increase rapidly over coming decades. In Asia, urbanization is occurring at breakneck speed. Furthermore, much of this is occurring in coastal and river basin areas that already face severe risks from flooding, typhoons, heat waves, and other weather events of the type projected to increase in severity as climate changes. The risks associated with unregulated development in such areas are clear. The myriad of choices being made now to build coastal roads, develop ports, create residential areas in flood plains, and so establish development trajectories that will be all but impossible to change in the future. In many ways it is clear that such development pathways will determine future risks, opportunities and constraints. The economic implications are, however, far less clear.

Economic considerations are among the most important factors influencing investments by international organizations including global investment banks, governments, and the private sector in development activities. If the economic implications of different development pathways can be clearly documented, this could help shape the choices now being made.

This report represents an initial attempt to evaluate the economics of development choices in relation to risks from flood events under current conditions and those projected as a consequence of climate change. Rather than focusing on broad projections and scenarios, the report focuses on specific options in specific areas. Using cases from Gorakhpur in India and Da Nang in Vietnam, it evaluates the costs and benefits of measures to reduce flood impacts through improvements in open space, drainage, raising areas and building plinth heights above flood levels, and early warning system (EWS) implementation. These types of activities are important because they represent the very real types of measures cities and developers have in their power to undertake or influence. As a result, they illustrate in a very tangible manner the limitations and strengths of pure market forces in fueling urban growth that can influence real, day-to-day, development choices and the nearly irreversible pathways that result.

— Marcus Moench,
Founder of ISET-International

Photo by Gorakhpur Environmental Action Group, 2013

1 Introduction

Development pathways influence urban cities' greenhouse gas emission portfolios and global climate trends (Wilbanks et al., 2012). We define development pathways as alternative choices for developing the critical urban systems central to the operation, management, and existence of a city (transportation, energy, water, shelter, etc.). Together, these systems constitute an urban ecosystem. In addition to emission portfolios, it is this "choice" of where, how, and when these systems are developed/implemented—that is, the development pathway that is taken—that determines the vulnerability and exposure of these systems to climate-related events. Vulnerability and exposure of the urban ecosystem increase when local governments fail to take responsibility for expanding and upgrading infrastructure and services in ways that manage risk through building standards, appropriate land use management, and other measures (United Nations, 2011). Urban governments have explicit responsibilities for many assets (such as schools, hospitals, clinics, water supplies, sanitation, drainage, communication, roads, and bridges) that can be highly vulnerable to increased threats (International Federation of Red Cross and Red Crescent Societies, 2010). Yet capacity limitations, growing populations, insufficient tax bases with resulting budget shortages, and many more factors can influence how these systems are planned, designed, managed, and operated.

It is through this lens that we explore alternative development pathways in two medium-size urban cities in Asia. The goal is to use real examples that cities are considering or could consider to investigate alternatives to traditional development approaches. This research builds upon previous studies of building resilience in medium-size cities in South and Southeast Asia, where resilience strategies were developed and individual interventions to build resilience were identified through the Asian Cities Climate Change Resilience Network (ACCCRN[1]) (Tyler, S., & Moench, M., 2012). In the current study, we chose two of the ACCCRN cities and conducted a forward-looking climate-based economic analysis to explore the costs and benefits of specific choices currently being explored to build resilience. Focused mainly on the hazards of urban flooding, these cities illustrate what it will take to shift from a "business as usual" (BAU) approach to a more "resilient" strategy. The approach in this research was to study the contrasting returns from a base "development as usual" scenario and from scenarios that build resilience and reduce future exposure and losses (through strategic design changes in transportation, flood management, and shelter systems). These development scenarios/pathways have been evaluated over the medium term (from the present to the 2040s) in relation to downscaled precipitation projections from the most regionally appropriate general circulation models, as well as patterns of urban development projected over that period. This research will provide key insights into reducing vulnerabilities of what the cities are experiencing and suggest a suite of solutions that might alter the current hazards being faced within those cities.

This report is divided into six sections. Following this introductory section, Section 2 explores the growth of urban centers and their increasing exposure to hazards as climate changes. This section also talks about the importance of building resilience in medium-size cities and the current situation in the two case study cities—Gorakhpur, India, and Da Nang, Vietnam. Section 3 explains the approach and methodology used for this study by ISET-International and our in-country partners. The two development scenarios—business as usual and resilient—were developed in conjunction with each city's stakeholders through a series of visioning shared learning dialogues (SLDs) and are discussed in detail in Section 4. The cost-benefit analysis results from comparing alternative scenarios or development pathways are presented in Section 5. Conclusions from this research are discussed in Section 6.

1 ACCCRN (http://acccrn.net/) is a Rockefeller-supported program for building urban climate resilience.

Acknowledgments

This report is an outcome of dedicated teamwork across several countries. As in many other instances, Dr. Marcus Moench, (ISET-International) provided key intellectual inputs and overall support as advisor and guide to this study. Ms. Kathleen Hawley was an excellent and able project manager, and her support to the individual country teams was invaluable. Mr. Fawad Khan (ISET-Pakistan) was the overall lead and guide for the economic analysis while Dr. Phong Tran (ISET-International, Vietnam) and Dilip Singh (ISET-International, India) led the research activities in respective cities Da Nang and Gorakhpur, with support from the city partners Dr. Tuan Tran (Hue University) and Dr. Bijay Singh (Gorakhpur Environmental Action Group), respectively.

The authors wish to thank the Rockefeller Foundation for their funding support that made this research possible. We are thankful to Dr. Shiraz Wajih (Gorakhpur Environmental Action Group) and Nguyen Thanh Tung (Hue Planning Institute) for their encouragement and support for this study. We would like to acknowledge climate and hydrological modeling support provided by Dr. Sarah Opitz-Stapleton (Staplets Consulting LLC) and Mr. Anil Kumar (Arup International). The authors would also like to acknowledge the critical support and information provided by the officers from the city level departments and specific subject experts from the two cities (Gorakhpur, India and Da Nang, Vietnam), who participated in the Visioning Shared Learning Dialogues as well as other consultations. Finally we are grateful to the communities from the rural and urban areas of these two cities that participated in this research.

The project team would also like to acknowledge the Ms. Michelle F. Fox for art direction and communications support, Ms. Karen Foster and Ms. Kanmani Venkateswaran for editorial/literature review, and Ms. Linda Gorman for copyediting the report.

Photo by Gorakhpur Environmental Action Group, 2013

2 Urbanization, Flooding, and Climate Change: An Overview

Asia is urbanizing faster than any other region in the world and is projected to become 64% urban by 2050 (United Nations, 2014). Much of this urbanization is occurring in medium-size cities located in regions that are highly exposed to potential impacts from climate change. As a result, cities across East, Southeast, and South Asia are projected to experience major impacts from heat stress, extreme precipitation, and inland and coastal flooding, as well as drought and water scarcity (Land, 2014).

The Rise of Medium-Size Cities

The fastest growing urban settlements are not the megacities of more than 10 million people that are globally recognized, but rather medium-size cities, many of which have fewer than 1 million inhabitants (United Nations, 2014). The population in medium-size cities globally is expected to grow to 1.1 billion by 2030. This is followed closely by smaller cities of about 500,000 to 1 million inhabitants (United Nations, 2014). Most of the growth of medium-size and small cities will be located in low- and middle-income countries, where, in addition to climate, they often face a diverse set of challenges, including limited governmental and institutional capacity, lack of services and financial means to create and extend infrastructure systems, high rates of poverty, and rapid, uncontrolled growth.

With human influence on our climate system now *clearly established* and the urban areas in exposed locations across Asia growing rapidly, we face a new set of challenges to overcome in the next few decades. How we plan and implement development pathways in response to the likely increases in urban flooding and the projected influx of 1.1 billion people represents a major challenge. The development pathways these cities take now are key to shifting and transforming them in ways that ensure they are ready for the coming changes.

The Urban Flooding Phenomenon

Urban flooding is not a new phenomenon in cities. The alteration of natural landscapes and drainage basins due to forestry practices, agricultural uses, and urbanization is well known to create shifts in the movement and storage of water, resulting in flooding (Booth, 1991; Satterthwaite, 2011). Coupled with increases in projected heavy rainfall events, storm surges, sea level rise, and riverbank erosion, urban flooding is increasing (Lekuthai & Vongvisessomjai, 2001). Encroachment of floodplains, the presence of new structures, and improper regulatory environments (i.e., restricting settlements in the floodplain paths) are additional aggravators in the urban flooding regime (Suriya & Mudgal, 2012). A global review of the impacts associated with urban drainage and extreme rainfall found that significant problems resulted due to flooding of sewer mains and drainage canals, causing more frequent overflow and spills and resulting in increased flooding impacts (Willems et al., 2012).

Era of Resilience

In response to the challenges cited above, the concept of resilience has emerged as a major factor in climate and urban development debates. The emerging dialogue on resilience forces society as a whole to strive not for a stable, sustainable, balanced pattern of development but rather for ways to manage systems and approaches in an unbalanced world (Zolli & Healy, 2013). Resilience has emerged from an age of sustainability. While sustainability is still key in the path toward resilience, it is not a static goal. The concept of resilience requires altering some traditional planning and designing, engaging and advocating new paradigms, and understanding that society cannot realistically plan for all local and global disruptions (i.e., climate change, economic meltdowns, political strife), particularly when predicting such events involves high levels of uncertainty. Society, and particularly individuals involved in creating the urban futures that much of the population will reside in, needs to understand that change is imminent, that not all things can be predicted, and that systems will break, fail, rebuild, restructure, and reorganize before reemerging. So, how does a society plan a city with resilient systems that can thrive in the face of disruption?

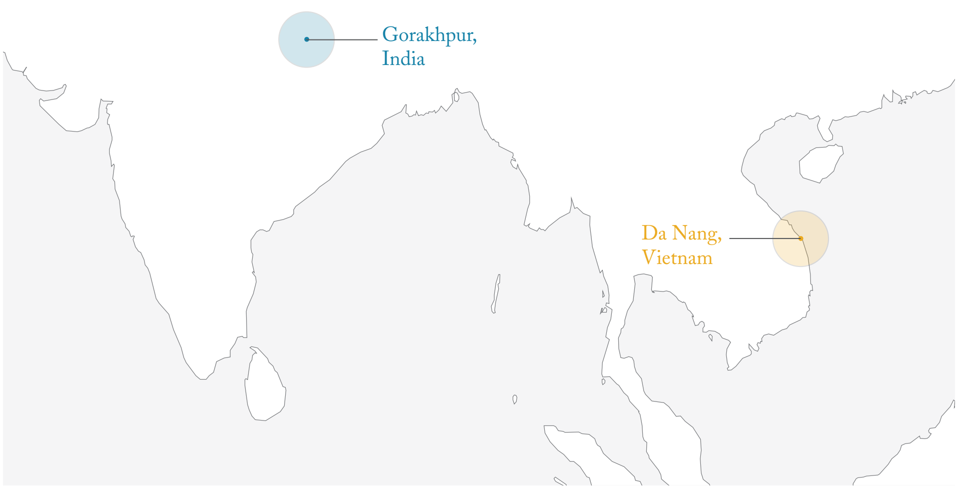
Current Urban States

Da Nang, Vietnam, and Gorakhpur, India, are the two cities we selected for our research on development pathways that could address the challenges we have outlined here. Both cities are experiencing rapid urbanization, expansion, and population growth; in fact, they are growing at about 3% annually, well above the 1.0% population growth rate that the rest of Asia is experiencing[1]. With about 1 million people, each city illustrates the realities of what a medium-size, growing city faces. Gorakhpur is the second-largest city in eastern Uttar Pradesh, one of the poorer sections of India, while Da Nang has led Vietnam with the highest gross domestic product (GDP) over recent years (at 11%). Geographically, the cities are quite different. Gorakhpur is a low-lying city on the Indo-Gangetic Plain, encircled by two major rivers, the Rapti and Rohini, and hills bordering the northeast side of the city. Da Nang is bordered

1 http://www.unescap.org/stat/data/syb2011/I-People/Population.asp

MAP OF STUDY AREAS

Gorakhpur, India and Da Nang, Vietnam



by high mountains to the west and the ocean to the east and has a major river running through the southern part of the city.

Whereas Da Nang faces (and is already experiencing) numerous climate-related hazards such as landslides, typhoons, and sea level rise, Gorakhpur faces increased flooding, heat stress, and drought. Both cities currently face annual inland flooding events due to rising rivers and extreme rainfall periods. Waterlogging plagues Gorakhpur, affecting about 40% of the city, specifically the southern and western areas. By 2050, both cities are expected to experience an increase in extreme rainfall events (Opitz-Stapleton & Hawley, 2013a, 2013b).

FLOODING IN HOA VANG DISTRICT, DA NANG

Source: *Da Nang Newspaper, 2013*

FLOODING IN GORAKHPUR

Source: *Gorakhpur Environmental Action Group, 2014*

Development Pathways and Planning

Master Plans are currently under review and revision for both cities, opening an opportunity for feedback on and discussion of the results of the scenario analyses conducted under this project. The Master Plan process in each city investigates the current city systems, land use strategies, and trends to identify pathways for how to develop the city over the next 20 to 30 years. In order to contribute to this, we focused most of our analysis on avenues to build the resilience of specific city systems that could reduce future flood impacts.

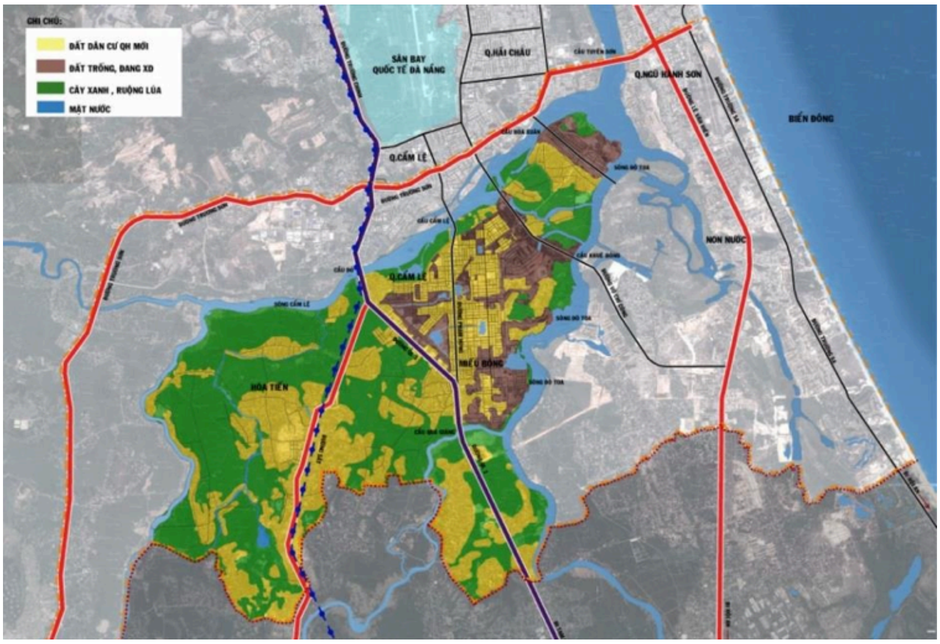
The Da Nang Story

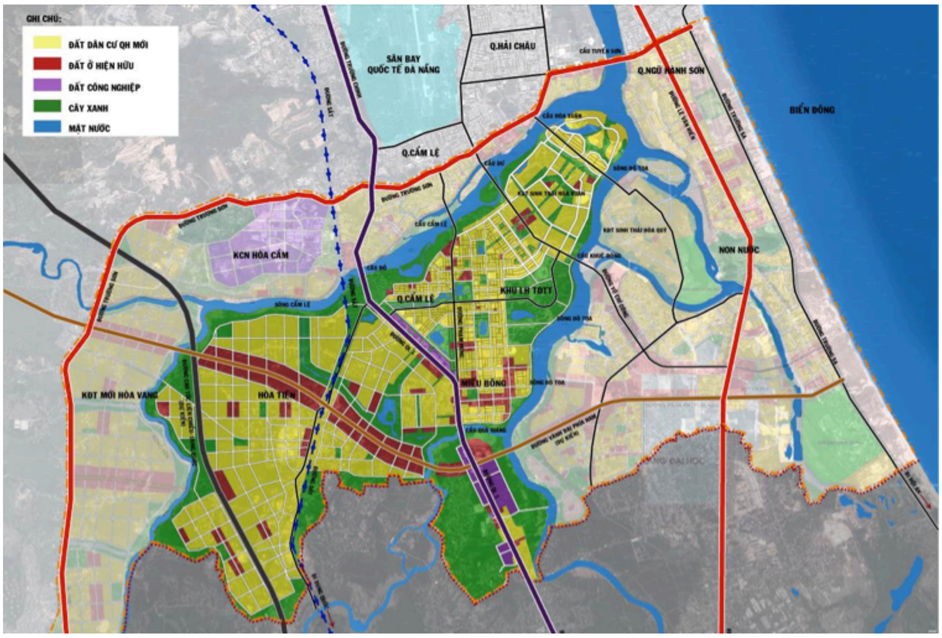
Da Nang is the most dynamically developed city in Central Vietnam, where both economic development and urbanization are occurring rapidly. The city's GDP is the highest in the country, at over 11% in recent years (Cu, 2008). The population of the city, including rural districts, is nearly 1 million, with an average density of 740 persons per km^2. However, in the central business district of the city (the Thanh Khe district), the population density surpasses 19,000 persons per km^2, more than 10 times the density of the peri-urban areas (Lien Chieu district; Da Nang UPI, 2012). The annual population growth rate in Da Nang is 3.48%, and the city is expected to reach 1.2 million in 2020 and 1.5 million in 2030, with most of the growth occurring in the urbanized districts of the city (Da Nang UPI, 2012). This uncontrolled boom and high population growth rate are among the challenges Da Nang faces and contribute to an increase of risks and vulnerabilities (Da Nang UPI, 2012).

A new residential development in southern Da Nang has focused rapid urbanization in that area. This new development resides on both sides of two rivers, the Quá Giáng and Cẩm Lệ, and is situated in an area that used to be a floodplain zone for river overflow (see Figure 1). To develop this region, soil and matter from the mountains surrounding Da Nang have been brought in to fill the floodplain. Naturally, as part of the floodplain, the area experiences large inflows of water from upstream areas, resulting in recurrent flooding. The construction of ring roads to service the city has added to existing hazards by obstructing the water's natural pathways and directing it to the new residential area and beyond, causing harsher flooding in neighboring wards. This is very likely to lead to critical urban problems, such as failed infrastructure and services, and environmental urban degradation. Housing, road planning, and EWS are key areas where climate risk can be reduced and vulnerability to disasters diminished.

Figure 1: DA NANG STUDY AREA

Top: Land use map in 2013
Bottom: Master plan for 2050





With regard to buildings, townhouses are quite common in urban areas. These are reinforced concrete structures, two to three stories high, with heterogeneous architectural styles. This type of housing works well in response to floods due to the reinforced concrete structure and usual multi-story height. However, the high density of these townhouses significantly reduces the spaces where water can flow and drainage can occur. Road construction further exacerbates flooding. By building the ring roads across the flood paths, drainage is constrained throughout the area. Flood levels are estimated to be higher in the future, and this is likely to result in the total closure of the ring roads when such flooding occurs. Current methods used to warn and address the Cẩ m L̉ community during flooding events are limited. The communication hardware systems are out of date and not functioning properly, public loudspeakers do not reach everyone within the area, and layers of bureaucracy lead to warning delays.

The Gorakhpur Tale

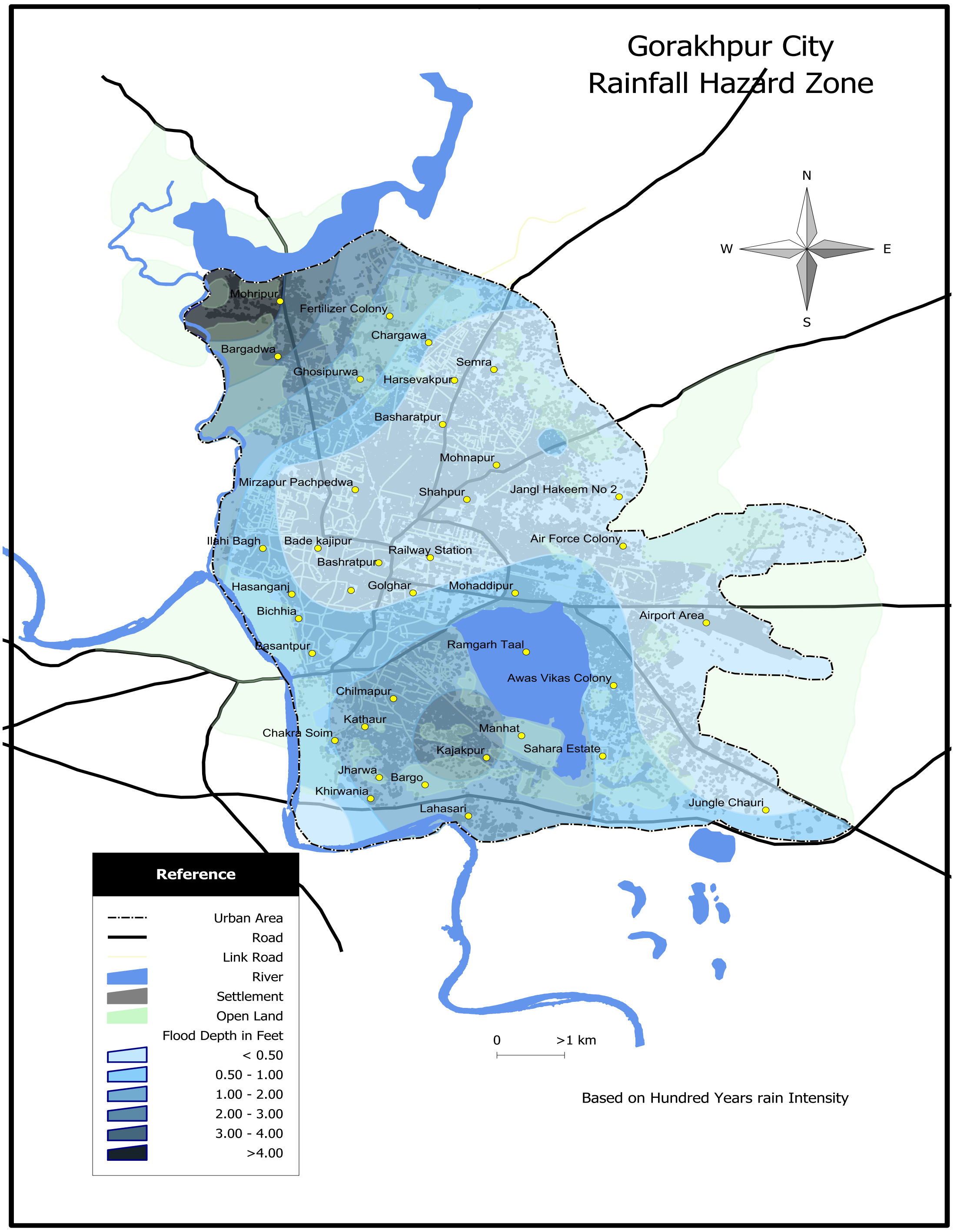
Gorakhpur is the second-largest urban center in eastern Uttar Pradesh, India, located in the mid-Gangetic Plain between the Rapti and Rohini river basins, and is a major socioeconomic, commercial, and cultural activity center. The current population of Gorakhpur is estimated to be 1,136,353 (CIDC & GMC, 2014) (subject to verification), although the Census of India (GoI, 2011) estimates it at 673,446. The population is growing at 3.40% per year, rapidly creating an urban hub of activity for migrant workers around eastern Uttar Pradesh, Bihar, and Nepal. Ironically, one of the most fertile areas in the country is also one where poverty is very high.

Gorakhpur is bowl shaped, with a low-to-flat gradient and high groundwater tables. Historically, there were 103 bodies of water that served as natural drainage within the city. With urbanization, fewer than a third of these bodies remain. During the monsoon, a large part of the city's elevation becomes lower than the Rapti river's water level leading to periodic waterlogging of lands and flooding. The bulk of the waterlogging problem affects about 40% of the city, particularly in the southern and western areas. However, the drainage system for the entire city is constrained and the impacts of waterlogging are likely to increase. Waterlogging has been getting worse in recent years due to changes in rainfall, the degradation of water bodies, and unplanned development (land encroachment). Unmanaged solid waste disposal is another urban risk that the city is facing. With no incinerator or water treatment plant, the problem has become acute. Prolonged waterlogging, together with poor waste management, has caused an increase in the incidence of vector-borne diseases and related health problems, as well as contamination of groundwater. Malaria and dysentery have historically been a problem, and recent years have seen increases in diarrheal diseases and vector-borne diseases such as Japanese encephalitis. Waterlogging and flooding also lead to disruptions in transport systems and damage to roads and property, thus affecting livelihoods and increasing the vulnerability of the poor.

Climate change brings a new dimension to the problem, as more intense and untimely rainfall may occur. In recent years, floods that occurred earlier in the season than usual, historically, caught the population off guard and caused more damage than normal. Climate change is likely to increase the intensity of rain events throughout Gorakhpur over the next 50 years. It is projected that by 2050, small duration rain events might increase in intensity by 10%–20%, while more severe events may increase in intensity by 2%–25%. Overall, climate change will affect rainfall amounts, resulting in continued and potentially worse flooding scenarios (Opitz–Stapleton & Hawley, 2013b).

Instead of focusing on a specific area within the city, this study investigates the development pathways for the entire city and the impacts expected with rapid urbanization. Housing practices in Gorakhpur have changed a lot in the past decade. Where historically many buildings used mud-brick construction, most new construction uses reinforced concrete and includes pillars and columns for reinforcement. In many areas where waterlogging occurs and water remains for 2–3 hours or more after every rainfall, the houses have raised plinths. In many cases, this involves raising the lowest plinth as much as 2 meters from the ground. This is expensive, however, and such locations are populated by high- and middle-income households. In contrast, areas that are chronically waterlogged (where water stays for 3 continuous days or more) are generally inhabited by low-income households. While these households often attempt to raise plinth levels as well, this tactic is often unaffordable. As a result, only the roads are available as open spaces for water to flow. In many new areas where expansion is taking place and sometimes even within the city, encroachments into public land or open spaces are also restricting pathways for the free flow of water. (See Figure 2)

Figure 2: GORAKHPUR CITY RAINFALL HAZARD MAP



***Source:** Gorakhpur Environmental Action Group, 2014*

In addition to housing development within the city, the rapid expansion of the city is prompting the construction of major roads to connect outlying areas. Many of these roads are already built and are catalyzing new settlement areas. One of the major roads, the Medical College road going toward the northeast, is attracting a large growth in urban development. Residential areas have already expanded along the major roads, and several private developers have announced residential projects in these areas, just outside the municipal boundary. Traffic congestion is already a major issue, and the expansion plans, urban population growth, and new road systems—mainly for motorized transport—will only exacerbate the problem.

Flooding and waterlogging are constant phenomena in Gorakhpur. To pump out the rainwater from waterlogged areas, nine pumping stations have been established in the city (GDMA, 2013). The embankments also need regular maintenance, but since the Irrigation Department (responsible for maintenance of embankments) does not get any special budget provision for this, the maintenance of embankments is carried out only in the form of repairs. Coupled with inadequate coverage of the storm water drainage system, Gorakhpur cannot seem to manage the annual flooding and waterlogging issues. Most new areas are developed in an unplanned manner and are not connected to the city's current drainage system, only adding to the urban flooding issues faced by residents.

Photo by Michelle Fox, ISET-International 2014

3 Approach & Methodology

The research focused on estimating the benefits of investing in urban development that has elements of resilience built in, as opposed to the current (largely unplanned or planned but unenforced) development of cities. The hypothesis is that additional investments in a resilient development pathway would result in savings in terms of avoided loss and damage to systems, people, and their livelihoods in the face of climate change–induced disasters such as flooding or waterlogging. To conduct the analysis, ISET-International joined hands with Gorakhpur Environmental Action Group (India) and Hue University (Vietnam) for research on Gorakhpur and Da Nang, both mid-size cities. As established in earlier sections, both cities suffer from flooding and waterlogging.

Cost-benefit analysis (CBA) allows comparison of the *benefits* of doing a project, implementing policies, or delivering a program with the costs of doing such things. CBA attempts to take into consideration all social well-being that accrues with implementing one, a few, or many interventions, but often this is a challenge and limitations exist within any study's time frame. For this project, the research team utilized a slightly different approach from most conventional CBAs by engaging in a probabilistic climate-based CBA. Using historical information from past flood events and their associated losses (Mechler R, et.al, 2008), we investigated what the losses might be in the future as climate changes. Then we investigated the costs of resilient interventions to reduce the losses that might occur now and into the future. This strategy is explored through the use of scenario planning. Once losses are determined, they are compared to the costs of interventions. In this case, we compare the BAU scenario to the resilient pathway scenario. By comparing scenarios, we are able to determine the overall net benefit of doing things differently to prevent future flooding and waterlogging.

The focus of the project has been on systems most affected by climate change (transport, flood management, and shelter systems), along with their implications for land use and settlement patterns.

Research Methods Used

Key elements of the research methods used in this study common to both cities are discussed in the following sections.

Shared Learning Dialogues (SLDs)

To improve our understanding of the growth patterns of cities and the drivers that affect this growth, various SLDs were conducted with different stakeholders in both cities to develop broad scenarios of different development pathways and glean specific information related to current development activities. These SLDs were instrumental in supplementing information on historical flood damage from primary surveys, and more importantly, were valuable in developing the future visions for each city and identifying the drivers of change.

Semistructured Key Informant Interviews

In addition to the wide-based SLDs, semistructured interviews were conducted in each city with specific departments and persons to gain better insights on issues related to their sectors. For example, in Gorakhpur, interviews with the former chief engineer of the drainage department of Gorakhpur Municipal Corporation provided the team with information about the whole planning process and the issues related to implementing the current Drainage Master Plan. This information was corroborated through interviews with the current engineer of the drainage department. Similarly, interviews and discussions with builders and architects revealed the trends of the types of houses being built and the areas where maximum growth is occurring. This information was used by the urban planner developing the 2041 development scenario plan for

Gorakhpur that served as a basis for analysis. A similar approach was used in Da Nang.

Hazard Assessment

Climate analysis for the project was focused on precipitation only. A historical daily rainfall data set for the two cities had to be compiled and interpolated from a number of data sources due to the inconsistencies of available records. Additional historical data was accessed to validate and supplement gaps in the sparse station records. This information was than coupled with a range of global circulation models and regional circulation models (Stapleton & Hawley, 2013a and Stapleton & Hawley, 2013b) to ensure accuracy. The climate information was accessed through daily precipitation data (simulated historical and projected future) from the CMIP5 Multi-Model Ensemble Database.[1, 2]

Exposure and Fragility Assessment

Gorakhpur. Exposure and fragility of different sectors such as households and business/commerce in the city was estimated using GIS mapping (elevation levels throughout the city) and inundation depths provided by a hydrological modeling exercise. InfoWorks Integrated Catchment Modeling software was used for hydrological flood modeling to estimate the inundation depths at specific points in the city for various rainfall return periods based on both historical and projected rainfall and physical development. Based on these points of inundation, contours were drawn for Gorakhpur on a GIS platform. From an SLD exercise, areas on the map were marked according to different categories of households—low, middle, and high income. By overlaying these two sets of information (inundation contours and household areas), the area under each category of household was calculated for various inundation depth bands.

Da Nang. Exposure and fragility of the city was estimated based on results of hydrology and an urban development simulation model project (Da Nang's DoC, 2013). Specifically, past, present, and future digital elevation maps (DEMs) of Da Nang were simulated based on current maps. These were then overlaid with elevation plans and drainage maps (from June 2011) and draft

1 For further information, see *Gorakhpur: Extreme Rainfall, Climate Change, and Flooding* (Opitz-Stapleton & Hawley, 2013b).

2 For further information concerning the climate downscaling used, see *Da Nang: Extreme Rainfall and Climate Change by the 2020s and 2050s* (Opitz-Stapleton & Hawley, 2013a).

modifications of the development plan. To develop the flood maps for Da Nang, hydrologic-hydraulic modeling was conducted. The project used the city's historical flood data (from 2007, 2009, and 2010) and historical DEMs and combined them with MIKE NAM and MIKE FLOOD models results to develop a set of hydrologic-hydraulic parameters and produce probabalistic flood projections.

Impact and Damage Assessment

Impact and damage assessment for various sectors (such as households and the commercial sector in Gorakhpur) was estimated through primary surveys and available secondary information (for Da Nang) for past damages due to specific incidents.

Risk Mitigation Options

As discussed earlier, the main hazards to these cities are flooding and waterlogging. During visioning SLDs and discussions with communities and experts in each city, many resilient pathways for future development of Gorakhpur and Da Nang were envisioned. For Gorakhpur, the year 2041 was selected as the target year for which the costs and benefits would be assessed; for Da Nang, 2030 and 2050 were selected. The resilience-building pathways that have been investigated and suggested in this study include interventions in the drainage, housing, and transport sectors, as well as options such as open spaces for better flow of water and EWS.

Investigation of Benefits and Costs

Benefits. The benefits accrued in these scenarios are reflected by the avoided damages that households, businesses, and governments can achieve through planning for disaster risk reduction. To estimate this, historical damages to households, businesses, and the public infrastructure have been collected for different inundation levels. These damages are mostly quantitative, but some qualitative values were discussed and shared during the SLDs. Costs were gathered from key informant sources and reflect only the quantitative costs associated with different resilience measures.

This dataset was used to create the depth-damage curve (and trend line). Using the trend-line equation, damages were calculated for the inundation levels given by the hydrological model for future rainfall return periods. The area under the curve—drawn with these damages and inverse of return periods (exceedence probability)—is the total estimated loss/damages incurred in any given year for all future probable rainfall return periods.

Costs. The costs considered here are the incremental or additional costs for implementing the resilience measures along with any recurrent costs that could be identified. For example, since the drainage plan has not been implemented in Gorakhpur, the incremental cost for this measure is the total implementation cost of the Drainage Master Plan as well as its annual operation and maintenance costs. However, to construct buildings on reinforced cement concrete (RCC) stilts instead of block plinths (a brick wall enclosure filled with mud and sand), the additional or incremental cost of constructing the RCC stilts versus the block plinths is considered as a one-time cost for this measure with no recurrent costs. In Da Nang, such costs included raising the road and leaving culverts to reduce flooding impact.

Benefit-cost ratio. Once we determined the benefits and costs of the resilience measures, the net discounted costs and benefits were calculated for the lifetime of the measures, using a suitable discount rate. The ratio of net discounted benefits to net discounted costs is the benefit-cost ratio (BCR). Additionally, the net preset value (NPV) and internal rate of return (IRR) have been calculated for better comparison and understanding of the costs and returns involved for each set of resilience measures.

Photo by Michelle Fox, ISET-International 2014

4 Scenarios

The research developed contrasting "business as usual" (BAU) and "resilient pathway" (RP) scenarios.

Business as usual scenario. The BAU scenario takes into consideration the current trends of development within the city. It investigates areas that are currently proposed for residential development and road networks that are planned to connect the city, as well as open space that potentially will be filled in with formal and informal settlements, thus hindering the flow of floodwater through the city.

Resilient pathway scenario. The RP scenario alters existing pathways and shifts the focus to flood reduction and waterlogging prevention. By utilizing a few key strategies—such as house construction techniques that do not impede water flow, implementation of a drainage system, EWS, roads with culverts, and the creation of more open spaces—the research will investigate how these measures can reduce the losses incurred in various sectors.

Scenario development was also key to identifying and developing alternative future visions for the development of a city. As shared earlier, both of the case study cities are on a rapid urbanizing path that will alter the vulnerability of key systems within and around those cities with the increased threat of climate change. The scenario approach helps in understanding what might happen if BAU development and growth continue to occur or if a path shift can take place, resulting in a resilient development. Scenarios were developed through key consultations with stakeholders and expertise shared by urban planners, city engineers, and developers through the SLDs. The drivers for change in these urban centers, as identified during various consultations, and the key aspects of the different scenarios are outlined in Table 1.

Business as Usual Scenario

It is the year 2020. Rapid urbanization, growth, and expansion have continued to stretch the limits of both Da Nang and Gorakhpur. Da Nang is being driven by image and innovation. Gorakhpur has become the largest business center for the hinterland and a major medical and educational hub. The boundaries of both cities have been reached, swallowing up the peri-urban areas.

Economic revenue is the key driver of the land transformation in both cities. To ensure high profits, sale of the land by the government is occurring at a rapid rate. All aspects of the city are focused on the short-term objective of quick land sales to real estate developers to gain fast returns. The private sector continues to influence many of the technical departments within the city by influencing development plans and aligning agendas. Centralized planning is plaguing Da Nang's development and is still siloed within departments; limited coordination between offices is leading to further issues with land use planning, and the associated vulnerabilities are becoming more apparent. Gorakhpur is facing similar planning constraints. New residential areas on the outskirts of the city along major roads (already built or planned) have been developed. These new areas are being planned and developed independently, with no coordination between the departments and actors. In Da Nang, land values have fallen or remained stagnant since the 2011 recession. Since a majority of the city's budget is based on land resale, a budget crisis is occurring and there is a need to find a mechanism to make up the deficit caused by reduced land values. Public participation in the planning process is virtually nonexistent, and active civil voices are not heard by the government of either city.

In Gorakhpur, employment is mostly in the service sector, with the education and medical sectors being the largest employers. Other economic activities such as commerce and business continue to be important sectors, as they cater to a large population. Large-scale industries are not part of the planning regime, nor are they major employers. In Da Nang, tourism development has become

Table 1: OVERVIEW OF BUSINESS AS USUAL AND RESILIENT PATHWAY SCENARIOS

	Drivers	**Business as usual scenario**	**Resilient pathway scenario**
Leadership	Image Governance behavior Land use	Siloed government departments Lack of community participation Lack of transparency; corruption at all levels Revenue streams not recovered from citizens Master Plans not followed	Transparent, collaborative government Participative planning at ward and community level Diversified revenue streams from tax base Master Plans flexible and resilient
Demand	Tourism Service research Private sector Population growth	No clear vision of which economies will drive the city Education and medical hubs established Continued urban/rural migration Increased alignment of private sector with government	Education, medical, and tourism services have become the driving forces of the city Urban growth continues rapidly Drainage plan implemented and maintained for the whole city
Technology	Innovation mobility Infrastructure Information technology (IT)	Lack of innovative construction Mobility of public only by car and bus; no consideration for large transportation scheme Still dependent on hard infrastructure solutions Adoption of IT solutions limited	Green construction techniques adopted Critical IT solutions adopted for both EWS and planning purposes Hard and soft infrastructure (open space) used effectively throughout the city
Environment	Hazard Climate change Disaster risk reduction	Development in floodplain area Follow the traditional ways, raise foundations, raise lands Early warning systems not functional Increased intensity and frequency of rainfall events	Floodplain kept as open space and no infilling practices occurring EWS functional to 100% of the population Increased intensity and frequency of rainfall events

the next key focus area for city revenue, with domestic and foreign investors promoting Da Nang as a tourist destination. There is also a continued push from leaders to make Da Nang a high tech capital, but due to a lack of traction, incentives, and focus, they have failed to push this agenda forward.

Development Pathways Outlook

BAU continues to permeate key urban systems throughout both cities. Open space has been overtaken by shelter development and road networks that disrupt natural drainage systems. In Da Nang, the development and construction of roads, transportation networks, and ports have been based on old plans that did not consider the future impacts of sea level rise, increased rainfall, and typhoons. This key development path has also not considered the socioeconomic impacts that occur with road development and the reality that Da Nang residents follow the road for business opportunities, residing and relocating along the roadside. Shelter designs have stayed traditional—one-row and two-row homes—with little focus on building resilience to future extreme events. Residential areas continue to expand in the floodplain areas, mostly spearheaded by real estate developers. Infilling is still the most common practice for flood mitigation, and the impacts are being severely felt in the upstream communities in the neighboring province. Areas that have been identified as green space are not sufficient to reduce the impacts of predicted climate change (See Figure 3).

In Gorakhpur, most open space areas have been encroached by illegal development, as affordability and accessibility to low-income housing are still out of the reach of the most vulnerable. There is an increase in slum clusters throughout the city, mostly in the low-lying areas. Because these settlements were unplanned, they have not been connected to the city's service system, thus limiting the inhabitants' access to drinking water, storm water, and sewage facilities. This haphazard development has led to an increase in vector-borne diseases, sanitation issues, and pollution throughout the city. The storm water Drainage Master Plan (built to withstand a 1-in-2-years rainfall event) has been partially implemented but not maintained properly, causing pollution and continued clogging of open-drain systems. Traffic congestion is common, construction of road projects is ongoing, and minimal attention has been paid to streamline and create more efficient multi-use transportation systems.

Climate Realities

Both the intensity and frequency of rainfall events and prolonged flooding and waterlogging have increased in Gorakhpur and Da Nang. Climate impacts have continued to rise in both cities, and in addition to the increased intensity and frequency of rainfall, typhoons regularly batter Da Nang. The city of Da Nang remains focused on traditional, hard infrastructure flood management strategies that do not consider the associated environmental and societal costs. The EWS is still only partially operational in certain areas of the city. In Gorakhpur, climate impacts occur as predicted, with increased frequency and intensity of rainfall events rendering the partially implemented drainage system ineffective. The pumping stations along the river operate at full capacity during monsoon months at a huge cost to the government. However, this still does not prevent waterlogging from occurring throughout the city and disrupting daily life. (See Figure 4.)

Figure 3: IMPACT OF BUSINESS AS USUAL DEVELOPMENT IN DA NANG

Annual damages in 2013, 2030 & 2050 with business as usual development

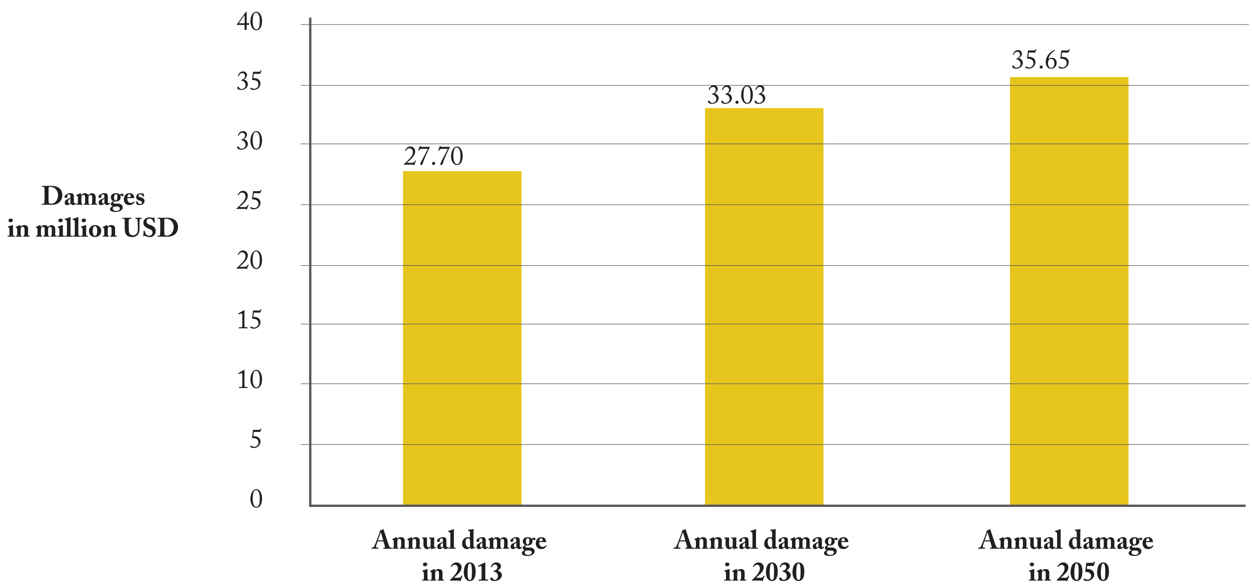
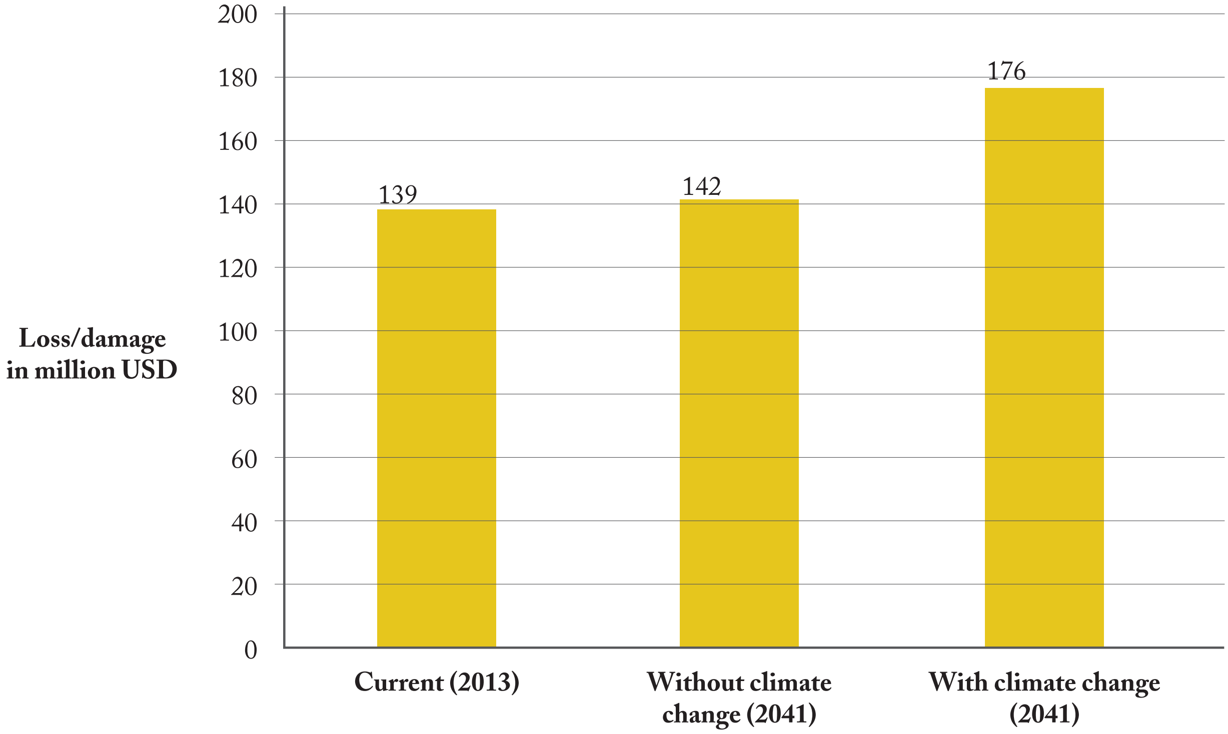


Figure 4: IMPACT OF BUSINESS AS USUAL DEVELOPMENT IN GORAKHPUR

Aggregate annual loss/damage with business as usual development



Resilient Pathway Scenario

A transformation has occurred. In Gorakhpur, the city leadership has decided that waterlogging and flooding will no longer be issues faced by citizens, and to drive economic growth to the city, they have created a resilient and sustainable vision that is currently being carried out. Da Nang has been chosen as Southeast Asia's greenest city and is leading the forefront in green, sustainable urban planning and enterprise development. Population growth is still occurring rapidly, and the cities are still expanding.

Residential and technology hubs have settled in the northeast and southeast of Gorakhpur. The education hub has created great growth in innovation, and spin-off companies have sprouted within the education hub location, causing an employment boom in the southeast of Gorakhpur. Better social cohesion exists between residents and the government, and social accountability has been strengthened. The administration has been held accountable to provide services to its citizens, and due to better access to these services, the pool of tax-paying citizens has increased. As Gorakhpur has grown into a medical and education hub, health care services have expanded to the broader population and are provided at lower rates.

In Da Nang, planning processes have become integrated, and the traditional silo-based approach that had plagued Da Nang earlier is now gone. Key agencies, such as Department of Agriculture and Rural Development (DARD), are critical in the risk planning process of the city and have approval authority over final plans. Leaders are accountable to their constituents, their peers, and their counterparts, ensuring a cohesive and strong voice for progress. Any new land use development must go through environmental impact assessment processes facilitated by a joint agency commission, which works to ensure that environmental rules and regulations are followed.

The private sector in Da Nang can no longer influence government planning to its advantage, as it is accountable to the principles set forth by the leadership of the city and has begun to integrate these principles into its strategic plans. Tourism has grown by 18% per year. Economic planning for the city has occurred in conjunction with other key stakeholders, setting long-term objectives and achieving goals that align with sustainable principles for continued growth and equity. The service industry has become the largest employer in Da Nang, and the city has expanded to house all of its residents, who are now connected by mass rapid transport. Reservoir best management and best practices have been institutionalized, and water resource constraints are no longer an issue.

Resilient Pathways Approach

Building off the examples set by cities such as Amsterdam, both Gorakhpur and Da Nang have adopted a new initiative called Green Roads, which includes waterways for river flow and storm surge that do not disrupt the natural path of nature. Road systems planned for the city integrate a "smart design" that allows water to flow easily, thus eliminating negative flooding impacts. Road materials integrate pervious surface technology that allows rainfall to seep through the structure and recharge the groundwater system. Furthermore, residential areas, office parks, and industrial zones all incorporate green spaces that include waterways and recreational areas. These areas are key icons, creating a sense of place throughout the city. The use of green design has ensured that the upstream and downstream communities that previously experienced major flooding impacts are now far less affected.

In conjunction with green design, the trend toward the construction of high-rise apartment buildings, so prevalent in large metropolitan cities, continues to gain popularity and acceptance in Gorakhpur and Da Nang. Instead of contributing to urban sprawl, multi-storied buildings are under construction within the city limits where there is a shortage of land availability. In Gorakhpur, most of the new houses being built are raised on RCC plinths and have ground floors open for parking. Boundary walls are still found around the houses, but suitable openings have been left to ensure a free flow of water through these walls. A key resilience feature for Gorakhpur has involved steps to ensure that adequate drainage exists and is maintained and connected to all parts of the city. Open space encroachment is under control, as housing programs for low-income groups have been implemented and land has been made available to these vulnerable households. The city has designated more open space to ensure open-water bodies are available for flood retention but also as places for recreation and relaxation. All along Ramgarh Lake, a green recreation zone has been created where people go for walking, relaxation, and general family fun. The waste-to-energy project is fully functional, and Gorakhpur no longer suffers from chronic power outages.

In Da Nang, the EWS that was only partially complete has been fully integrated and the system now reaches all of Da Nang's citizens. In addition, the capacity of key staff of flood and storm control committee and emergency response team at commune level has been strengthened to better disseminate flood early warning information to the remote areas. Better communication facilities have also allowed the development of a communication system that has uses beyond providing early warnings for flooding and other hazards. Pollution is now monitored and has declined, as services have expanded and a citywide door-to-door waste collection system has been fully operationalized.

Overall, under the broad resilient pathway approach, citizens have been empowered, information and EWS have been strengthened, and shelter systems that accommodate floods and storms have been designed. In addition, land use patterns have been made much more compatible with evolving climate conditions through increases in open space, improvements in drainage, and other similar measures.

Scenarios for Economic Analysis

Because the economics of the broad pathway scenarios presented above are impossible to quantify, specific interventions that could be implemented as part of these scenarios are evaluated here. Current conditions and the visioning exercises undertaken in both cities were used to develop a short list of much more specific scenarios (referred to as resilient pathways or RP) as a basis for examining the costs, benefits, and trade-offs of choosing different development pathways.

Gorakhpur, India

In Gorakhpur, where the main hazard is waterlogging in the urban areas, the resilience options identified as a result of the visioning exercises with citizen groups were as follows:

Resilient Pathway 1—Additional open spaces for the free flow of water. Since land for real estate development is at a premium, it is not feasible to create open spaces by reserving undeveloped land for that specific purpose in an urban area. In order to generate additional open spaces, the following measures were considered:

1. *Construct buildings on stilt plinths*: One of the norms in the city is to raise the plinth of buildings above the inundation levels. In areas that are typically not waterlogged, people tend to construct houses on block plinths. The houses thus constructed block the flow of water, leaving only the roads as waterways, where flooding occurs and with higher depths. The RP suggested is that at least 10% of the houses be built on RCC stilts, thus leaving space under the buildings for the free flow of water. This space can be utilized for parking during nonrainy seasons.

2. *Enforce compliance with building bylaws*: It was pointed out that some houses do not comply with the building bylaws that mandate a specific proportion of the total plot area be left open. If this provision was strictly followed for all new houses built going forward to 2041, an additional 875 ha would be available as open spaces.

3. *Include culverts and pavements on both sides of new roads*: Generally, roads are constructed at a higher elevation than the adjacent areas to save them from inundation. But this higher elevation also acts as a barrier to the free flow of water. It is suggested that all new roads should have culverts as part of their design to allow for the flow of water. It is also suggested that at least 1.2 m of space on each side of the road be paved with pervious tiles for better infiltration.

4. *Reserve additional open spaces*: As part of the urban development guidelines, 15% of the total Master Plan area has to be left as open areas (parks, gardens, playgrounds etc.). Because of the acute waterlogging problems in Gorakhpur, one of the hypotheses of this project is that leaving additional open spaces in the (current) peri-urban areas would result in the free flow of rainwater—thereby lowering the levels of waterlogging within the city. About 10% of the land (in addition to the mandated 15%) is proposed to be reserved and maintained without any real estate development.

5. *Other measures*: Most private houses (and even the newer high-rise apartment buildings) have boundary walls on all sides that block the flow of water. A resilient scenario would make it mandatory to leave spaces in the boundary walls for the free flow of water.

Resilient Pathway 2—Implementation of Drainage Master Plan. The Irrigation Department of Gorakhpur has already prepared a Drainage Master Plan, but the city is finding it difficult to implement it due to various reasons. A functional storm water drainage system encompassing the entire city would be the most beneficial measure to reduce vulnerability to waterlogging.

Resilient Pathway 3—Aggregated impact of both of the above scenarios implemented/followed simultaneously.

Da Nang, Vietnam

This analysis focuses on three pathways: housing, roads, and flood risk reduction in the new development area in the southern part of Da Nang. Utilizing the city planning time frame for Da Nang, alternative development pathways are evaluated out to 2030. The city planning process occurs every 20 years, and the planning time frame used here was designed to coincide with that. The BAU scenario takes the current city plan and assumes development continues as it is currently. All Master Plan guidelines for road development, housing, and flood mitigation systems are implemented as defined by the Master Plan. The RP approach takes these key development pathways and adjusts them to allow for living with and integrating the flood regime that is currently being experienced and expected to worsen (see Table 2). All scenarios assume that climate change is occurring and utilize damage estimates that incorporate climate change.

Table 2: DEVELOPMENT PATHWAYS SCENARIOS ANALYSED FOR DA NANG

Scenario	Business as usual	Resilient pathway
Housing	In urban areas, townhouses are quite common, have reinforced cement concrete (RCC) structures, are 2–3 stories high, and have heterogeneous architectural styles. This type of housing is relatively good in response to floods due to the RCC structure and usual multi-story height. However, high-density construction reduces open spaces (for water flow and floodwater retention) and hinders the construction of urban infrastructure systems.	Apartment buildings become popular in urban areas to meet the demand of citizens. Townhouses in low-lying areas are constructed with raised plinths to limit flood damage. The first story of the townhouse is designed with materials that respond well to floods; the functionality of the first story is flexible, allowing for water infiltration if necessary.
Transport	National Road 1A and ring roads are planned for construction across flood pathways, limiting available flood drainage. The Hoa Phuoc–Hoa Khuong road project will connect traffic between the southern area and eastern coastal region to the city center; contribute to urban renewal and population distribution; and encourage people to live in new urban areas south of the city, thereby reducing the population density in the center area and increasing the city's economic growth. The road plans include construction in the flood waterways, which will partially block their flow capacity during floods.	The Hoa Phuoc-Hoa Khuong road is built with a high capacity for floodwater to flow, with greater openings for cross culverts and bridges. In some areas, the road is built on stilts to reduce floodwater, especially during large floods such as 1-in-20-year floods or greater.
Early warning system (EWS)	The EWS currently exists but has some limitations (Da Nang CFSC, 2013): (i) machines (e.g., power generators, fax machines) for receiving early warning information are out of date and do not work well during disasters; (ii) the public loudspeakers used for the EWS do not reach the entire population of the city; and (iii) early warning information and response guidelines from city authorities to local communities are transmitted through many intermediate levels, causing warning delays.	The EWS has been improved to increase its effectiveness. The early warning information is broadcast sooner than it used to be and the forecast information is more accurate.

Climate and Flooding Regime

The intensity of rainfall events has increased for both cities. Rainfall intensities and storm intensities are mimicking the projections identified by the climate models years before. However, with the new resilient visions driving the cities' development, the impacts of climate change on urban assets and populations are minimized. Effective strategies for living with the impacts are in place, along with emergency evacuation procedures for times when flooding is extreme. These measures have saved many lives and created vibrant and livable communities. Gorakhpur and Da Nang have become destinations to visit as well as models for similar cities in the region. Donors, nonprofits, and others visit regularly to learn best practices from the cities and their citizens.

Photo by Michelle Fox, ISET-International 2014

5 Resilient Pathways Scenario Comparison

Results From the Cost Benefit Analysis for Different Resilient Pathways

This section presents the findings of the forward-looking climate-based economic analysis of the chosen sectors compared to business as usual development under climate conditions. The results are given for each city and the selected sectors.

Gorakhpur, India

Figures 5–7 illustrate the aggregate damages to the household and commercial sectors in Gorakhpur caused by implementing or following the three previously described RP scenarios in contrast to the business as usual scenario. The economics are estimated to 2041 with and without incorporation of climate change.

Figure 5: GORAKHPUR RESILIENT PATHWAY SCENARIO 1 AGGREGATE LOSS/DAMAGE

Aggregate loss/damage with extra open spaces

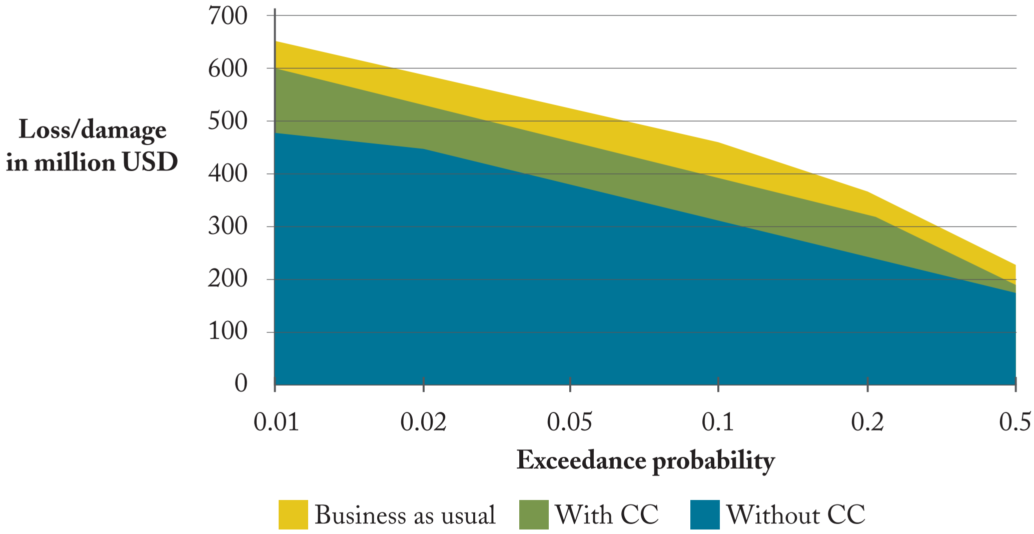


Figure 6: GORAKHPUR RESILIENT PATHWAY SCENARIO 2 AGGREGATE LOSS/DAMAGE

Aggregate loss/damage with drainage system implemented

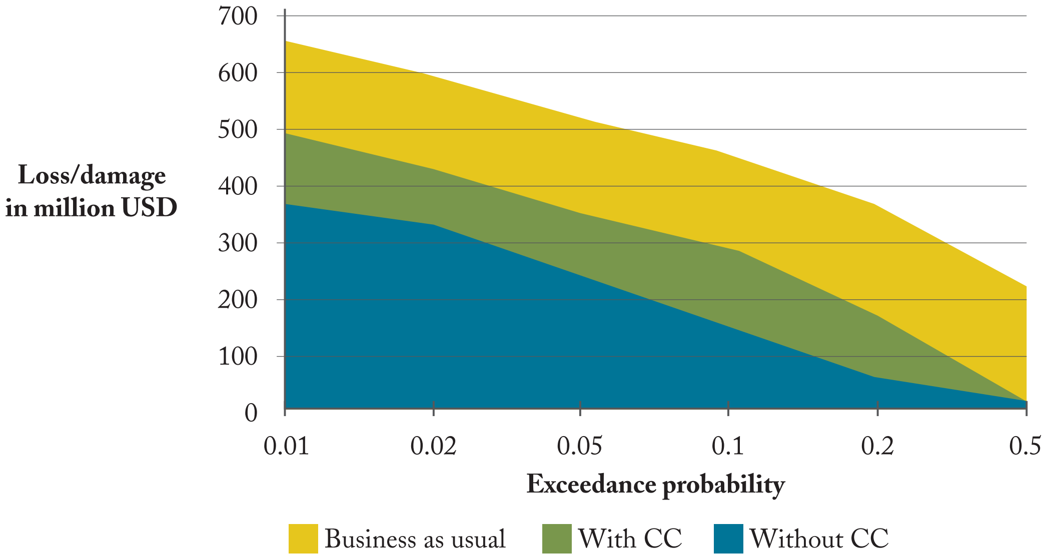
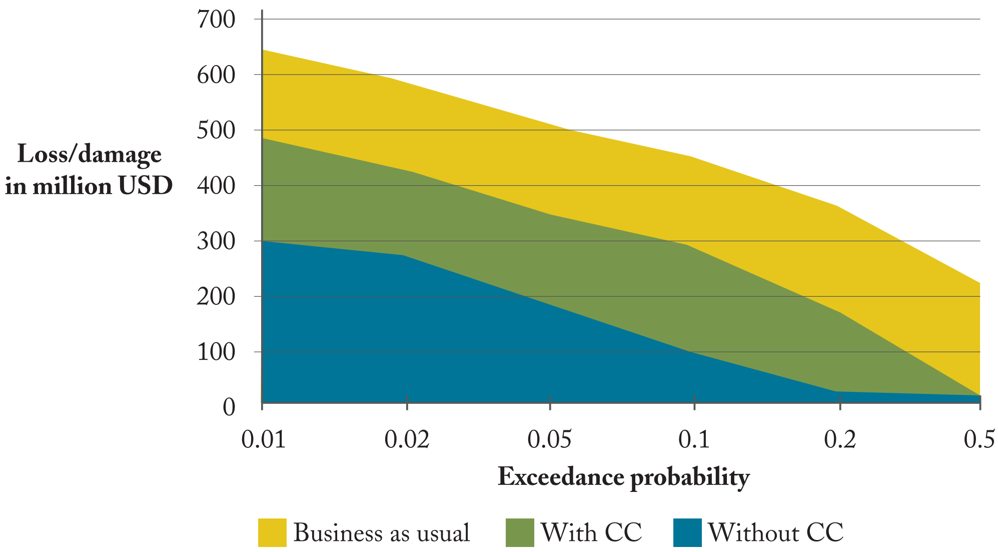


Figure 7: GORAKHPUR RESILIENT PATHWAY SCENARIO 3 AGGREGATE LOSS/DAMAGE

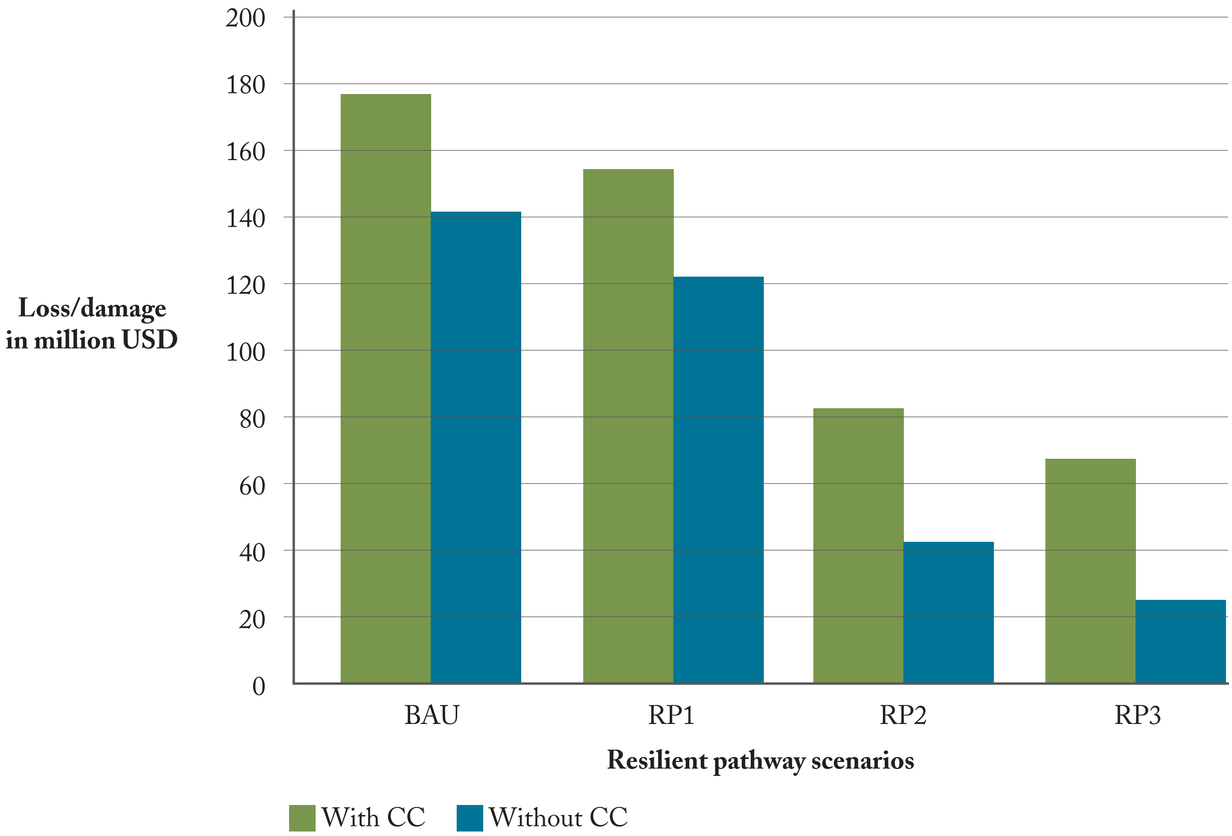
Aggregate loss/damage with open spaces and drainage plan implemented



The loss/damage in all three resilient pathway scenarios and the business as usual scenario were estimated for two sectors in the city, households and businesses/enterprises, by calculating the area under the curve for each scenario. The area under the curve indicates the gross probabilistic damages that would be incurred due to any given rainfall return period in any given year. In this case, return periods of 2-, 5-, 10-, 20-, 50-, and 100-year rainfall events were used. The gross damages to the household and commercial sectors in Gorakhpur caused by implementing/following the three resilient pathway scenarios as well as the BAU development scenario are shown in Figure 8.

Figure 8: GORAKHPUR GROSS LOSS/DAMAGE TO VARIOUS SECTORS BY SCENARIO

Aggregate annual loss/damage to various sectors in Gorakhpur (2041)



A CBA was undertaken for the three resilient scenarios. The results reflect a comparison between the resilient pathway scenarios (1, 2, and 3) and the BAU development scenario (Table 3).

TABLE 3

CBA Results of the Three Resilient Pathway Scenarios as Compared to the Business as Usual Development Scenario

	BAU vs. Resilient Pathway Scenario 1		**BAU vs. Resilient Pathway Scenario 2**		**BAU vs. Resilient Pathway Scenario 3**	
	With CC	Without CC	With CC	Without CC	With CC	Without CC
NPV	(11,964)	(12,527)	56,575	60,629	30,950	35,807
IRR	-	-	39%	41%	18%	19%
BCR	0.5	0.4	9.3	9.9	1.7	1.8

As expected, the Resilient Pathways Scenario 1 option of having more open spaces (a combination of actual open spaces, houses built on stilt plinths, and other measures) results in a negative NPV and a BCR of much less than one. With the demand for land, and hence the cost, being high in expanding urban areas, the benefits of having open spaces for the free flow of water are not adequate to cover the costs.

Resilient Pathway Scenario 2 of having a functional drainage system yields benefits that are about nine times the cost of implementing and maintaining a storm water drainage system in the city. This option has limits because the current standards dictate that storm water drainage should be built with a capacity for 2-year return period rains only. Rainfall above this return period will cause inundation. However, having the system functional will greatly reduce the waterlogging period.

Resilient Pathway Scenario 3 option of having open spaces as well as a functional storm water drainage system still shows a positive BCR, albeit a much smaller figure than for option 2. Again, the additional costs of having open spaces draw down the BCR as compared to having only a functional storm water drainage system in the city.

Da Nang, Vietnam

Cost and Benefits of Household-Level Interventions

Through the use of visioning exercises with key stakeholders, options were identified that could reduce the overall risk of flooding, both now and in the future, in the area of the city selected for study. Raising house plinths was one of the options put forth. The cost associated with raising house plinths includes the investment cost that private developers and households would pay to avoid flooding in the new development area. The benefits associated with raising plinths are reducing the asset losses and minimizing the structural damage that would otherwise occur to the house due to floodwater penetration and waterlogging.

Estimates of flood damage to housing and flood damage reduction in 2030 and 2050 under the BAU and RP scenarios are reported in Table 4.

Table 4: ESTIMATED ANNUAL FLOOD DAMAGE TO HOUSING IN NEW DEVELOPMENT AREA WITH AND WITHOUT RAISED PLINTH (UNIT: MILLION USD)

	Flood damage to housing (BAU)	**Flood damage to housing following plinth raising (RP)**	**Average annual damage reduction due to raised plinths**
Base case	0.53	0.26	0.27
2030	0.87	0.30	0.56
2050	1.20	0.32	0.88

Source: City's statistics (2012) and authors' calculations.

Figure 9 presents the flood damage curve and damage reduction (i.e., the benefit) due to raised house plinths curve for the base case (2013). Figures 10 and 11 present the flood damage and damage reduction curves for the 2030 and 2050 scenarios, respectively.

Figure 9: FLOOD DAMAGE AND DAMAGE REDUCTION (DUE TO RAISED HOUSE PLINTHS) CURVES FOR THE BASE CASE (2013)

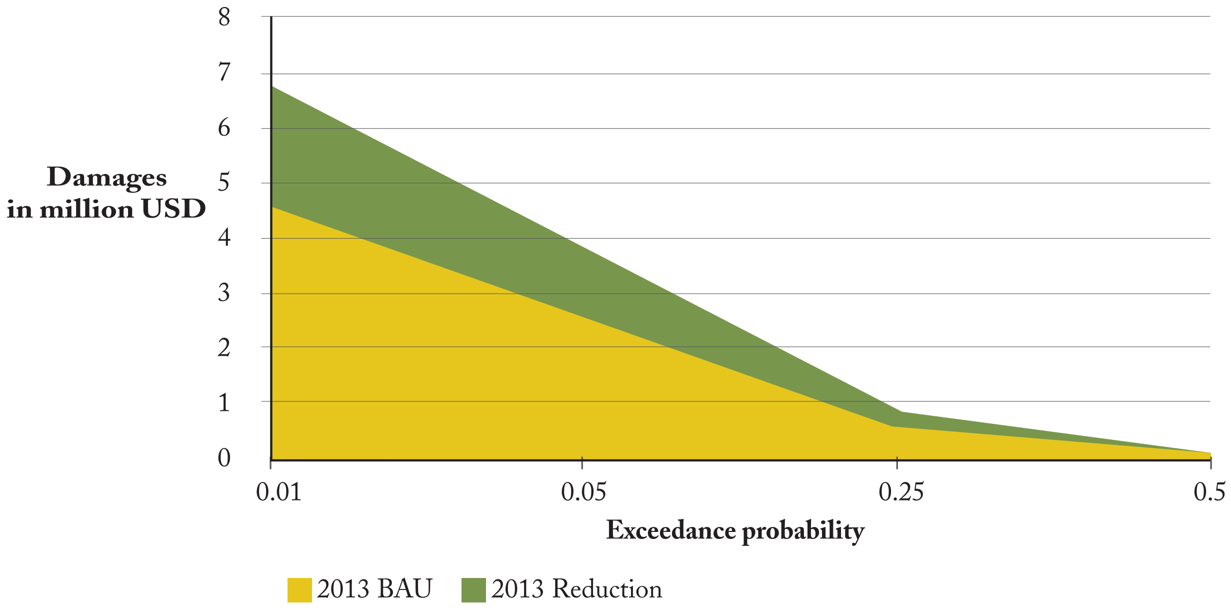


Figure 10: FLOOD DAMAGE AND DAMAGE REDUCTION (DUE TO RAISED HOUSE PLINTHS) CURVES FOR THE 2030 SCENARIO

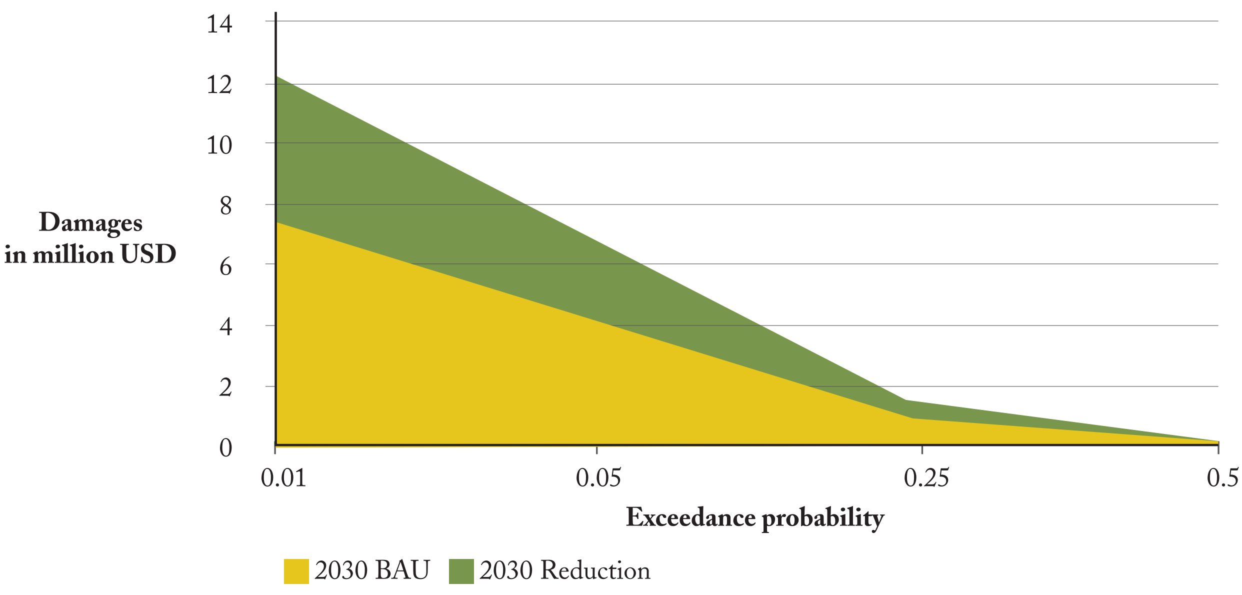
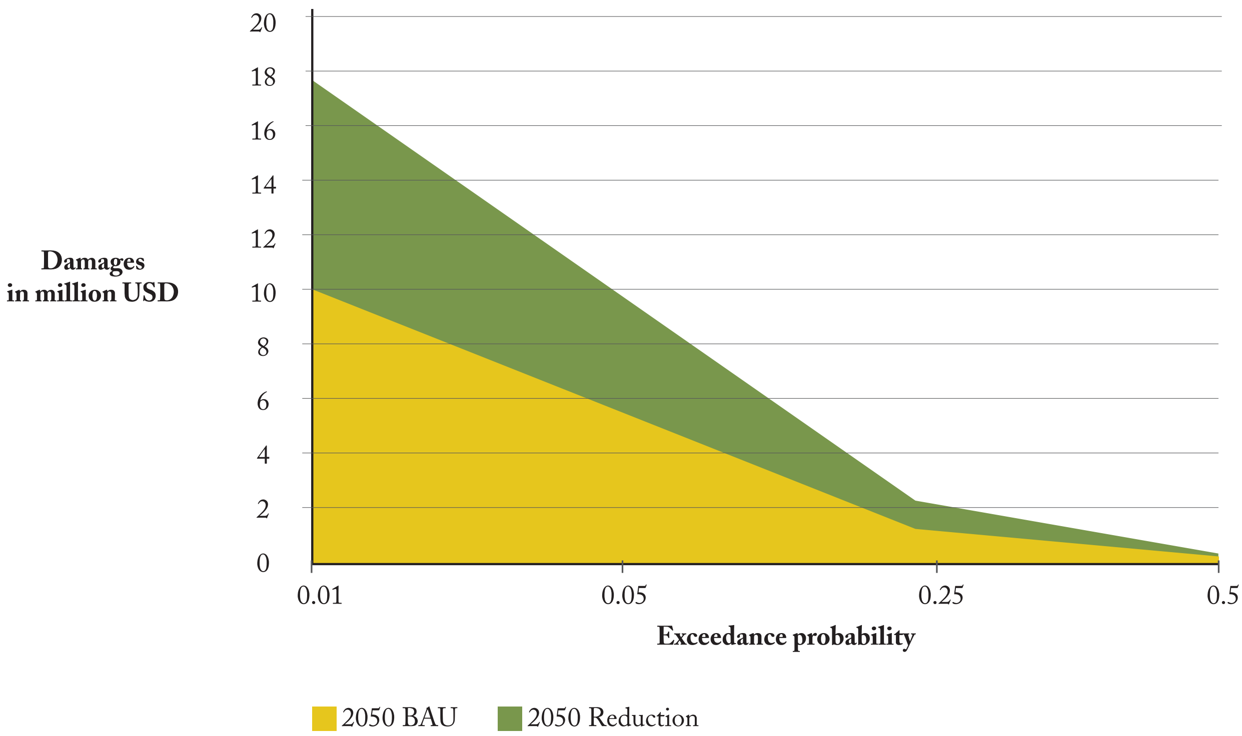


Figure 11: FLOOD DAMAGE AND DAMAGE REDUCTION (DUE TO RAISED HOUSE PLINTHS) CURVES FOR THE 2050 SCENARIO



Calculation of the BCR. To calculate the BCR for raising house plinths in the base case (2013), several assumptions were made, as presented in Table 5. The BCR for the raised house plinths in the base case is reported in Table 6.

Table 5: ASSUMPTIONS FOR RAISED HOUSE PLINTHS

Assumptions	
Lifetime in years	**30**
Annual benefit (annual damage reduction)	**0.27**
Investment costs (million USD)	**-1.52**
O&M costs: 8% of investment cost	**-0.12**
Discount rate	**10%**

Table 6: BCR FOR RAISED HOUSE PLINTHS

Economic return	
NPV (million USD)	**0.12**
IRR	**11%**
BCR	**1.04**

Cost and Benefits of Resilient Road Construction

The flood risk reduction option for road construction is based on the Hoa Phuoc–Hoa Khuong road project. If the Hoa Phuoc–Hoa Khuong road is built as planned, with little provision for drainage (BAU), it will cause flooding in upstream areas. To reduce flood damage in upstream areas and allow water to flow, the option of raising the road (RP) on plinths and incorporating additional drainage was proposed. In this section we compare raising the road (RP) to building the road as planned (BAU), with the cost of raising the road based on the project proposal for the Hoa Phuoc–Hoa Khuong road. More specifically, we compare the cost of raising the road and increasing drainage through it (RP) to the cost of building the Hoa Phuoc–Hoa Khuong road (BAU) as currently planned. The benefit of raising the road (RP) is a reduction in damage in upstream areas.

Table 7 presents the flood damage and damage reduction accruing in upstream areas as a result of changing the road (raising plus drainage) for the base case and the 2030 and 2050 scenarios.

Table 7: FLOOD DAMAGE AND DAMAGE REDUCTION IN UPSTREAM AREAS DUE TO A RAISED ROAD (UNIT: MILLION USD)

	Damage (BAU)	Damage (RP)	Average annual damage reduction due to raised road
Base case	**15.61**	**14.31**	**1.29**
2030	**24.99**	**22.92**	**2.07**
2050	**34.03**	**31.21**	**2.82**

Figure 12 presents the flood damage curve and damage reduction (i.e., the benefit) due to a raised road curve for the base case (2013). Figures 13 and 14 present the flood damage and damage reduction curves for the 2030 and 2050 scenarios, respectively.

Figure 12: FLOOD DAMAGE AND DAMAGE REDUCTION (DUE TO A RAISED ROAD) CURVES FOR THE BASE CASE (2013)

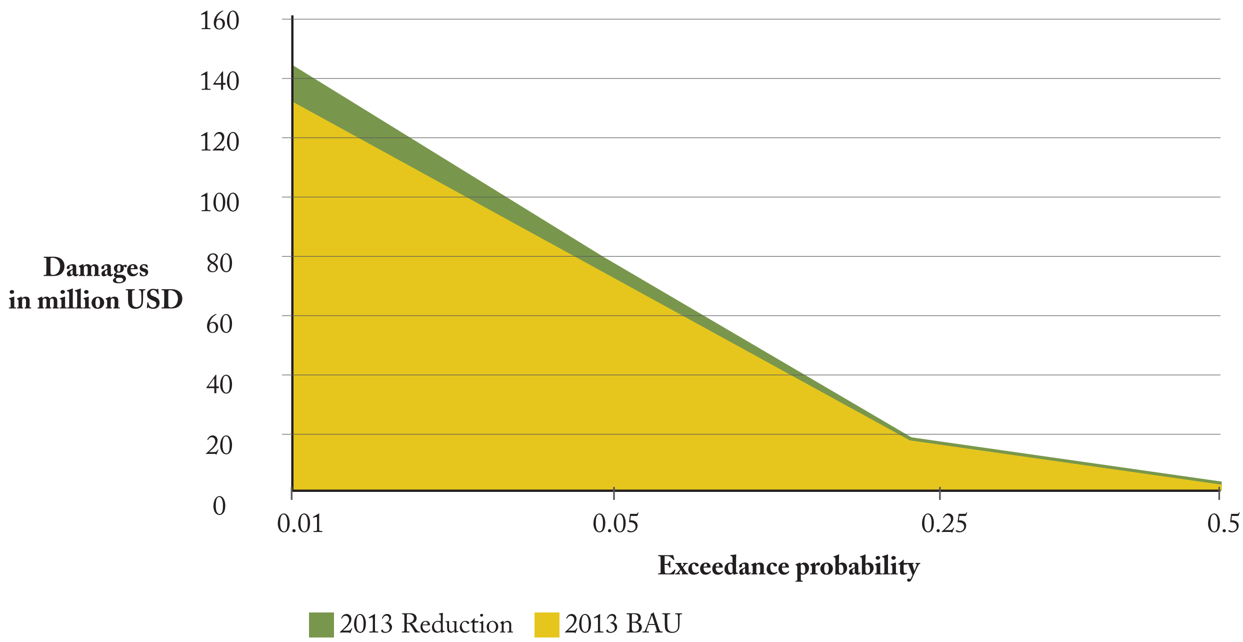


Figure 13: FLOOD DAMAGE AND DAMAGE REDUCTION (DUE TO A RAISED ROAD) CURVES FOR THE 2030 SCENARIO

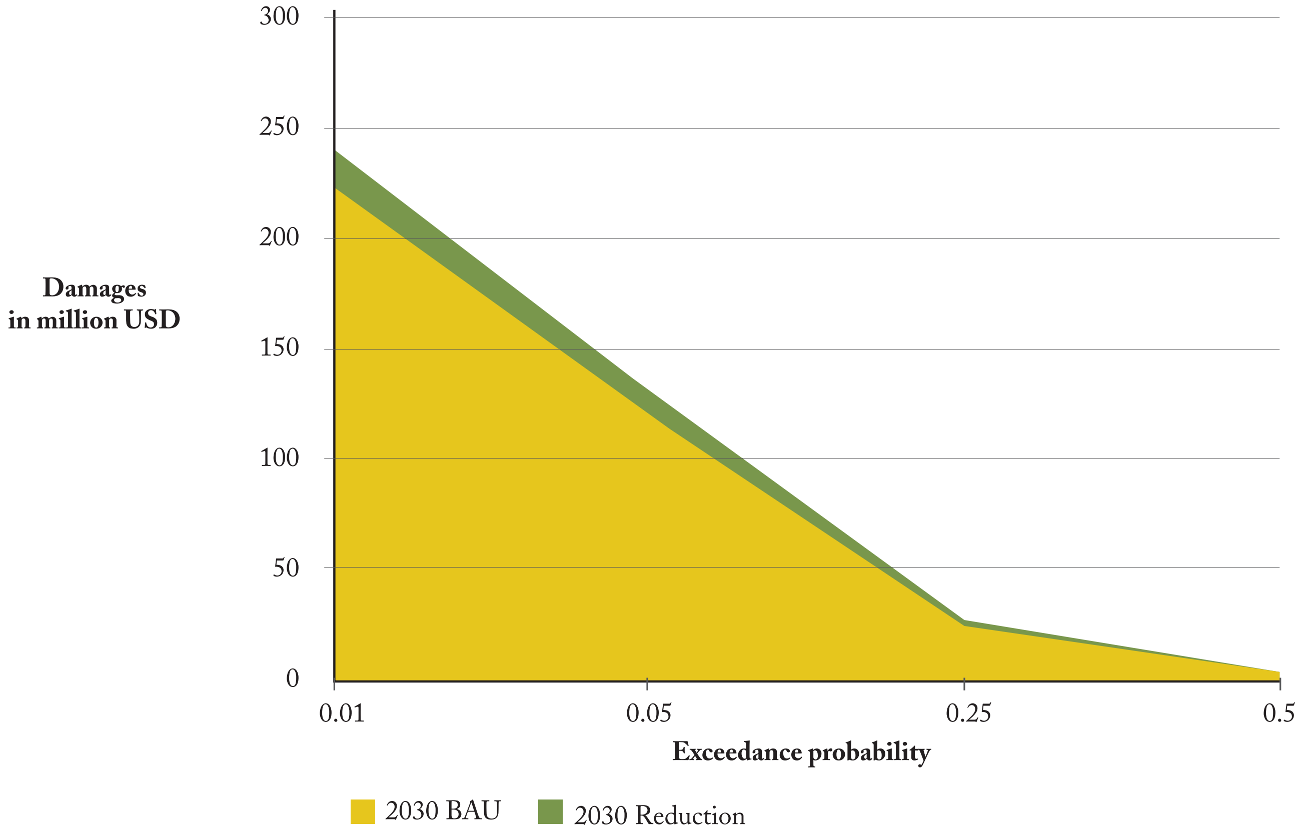
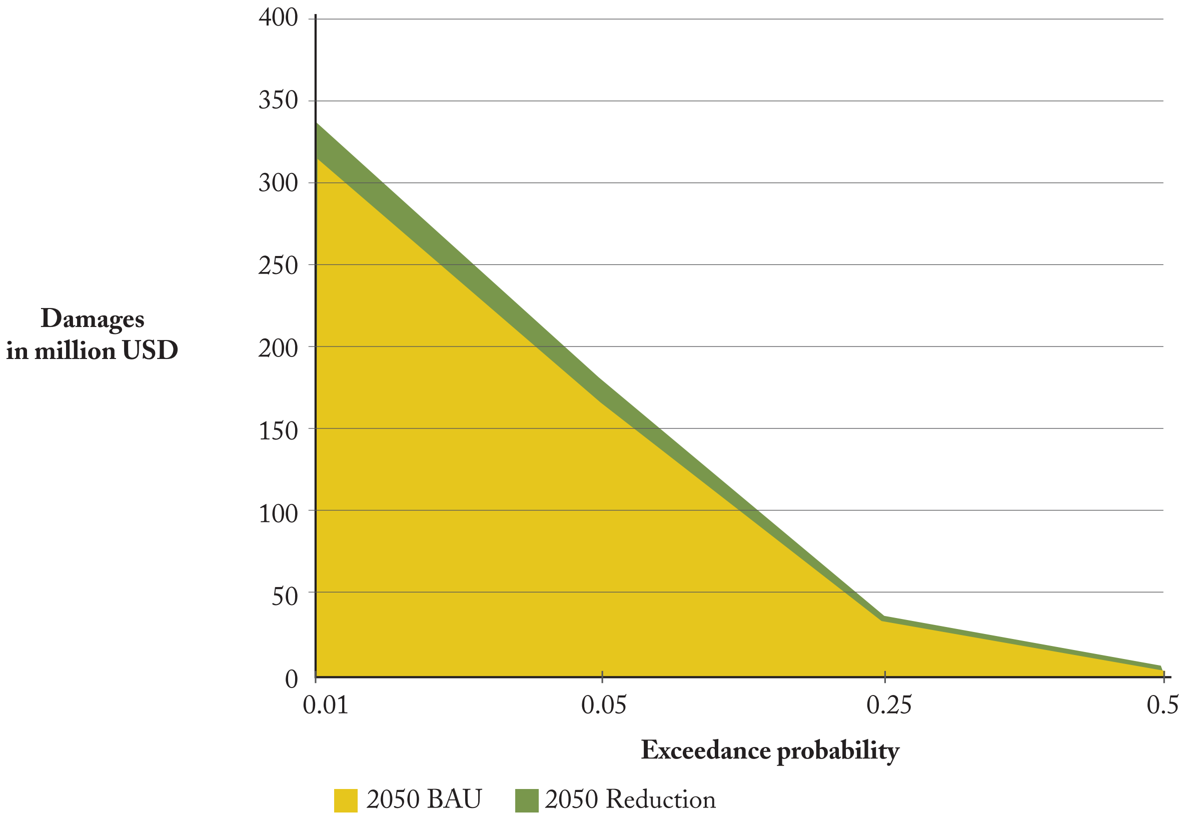


Figure 14: FLOOD DAMAGE AND DAMAGE REDUCTION (DUE TO A RAISED ROAD) CURVES FOR THE 2050 SCENARIO



Calculation of the BCR. To calculate the BCR for a raised road in the base case (2013), a number of assumptions were made, as presented in Table 8. The BCR for a raised road in the base case is reported in Table 9.

Table 8: ASSUMPTIONS FOR A RAISED ROAD

Assumptions	
Cost of building road as planned: without resilience (million USD)	**53.60**
Cost of raised road: with resilience (million USD)	**-61.79**
Cost: incremental costs (million USD)	**-8.18**
Benefit: annual damage reduced (million USD)	**1.29**
Interest rate	**10%**
Annual O&M cost: 5% of extra construction cost (million USD)	**-0.41**
Lifetime of the project in years	**70**

Table 9: BCR FOR A RAISED ROAD

Economic return	
NPV (million USD)	1.95
IRR	13%
BCR	1.16

Cost and Benefits of Improving the Early Warning System (EWS)

In 2013, Da Nang's Committee for Flood and Storm Control (CFSC) proposed to implement an improved EWS in order to enhance the capacity of the existing EWS in the southern area of the city.

This section compares the costs and benefits associated with implementation of the improved EWS. The cost to improve the current EWS includes both investment costs and the operation costs of the system selected as appropriate by the local authority (i.e., Da Nang's CFSC, 2013) in the study area. The benefits of implementing the improved EWS are the flood damage reductions achieved. These reductions are the difference between flood damage without an improved EWS (BAU) and flood damage with an improved EWS (RP) in the impacted area.

Table 10 presents the flood damage and damage reduction due to an improved EWS in the study area for the base case (2013) and the 2030 and 2050 scenarios.

Table 10: FLOOD DAMAGE AND DAMAGE REDUCTION (DUE TO AN IMPROVED EWS) IN THE IMPACTED AREA (UNIT: MILLION USD)

	Damage (BAU)	Damage (RP)	Average annual damage reduction due to improved EWS
Base case	27.70	24.04	3.66
2030	44.36	38.82	5.54
2050	60.41	53.04	7.59

Figure 15 presents the flood damage curve and damage reduction (i.e., the benefit) due to an improved EWS curve for the base case (2013). Figures 16 and 17 present the flood damage and damage reduction curves for the 2030 and 2050 scenarios, respectively.

Figure 15: FLOOD DAMAGE AND DAMAGE REDUCTION (DUE TO AN IMPROVED EWS) CURVES FOR THE BASE CASE (2013)

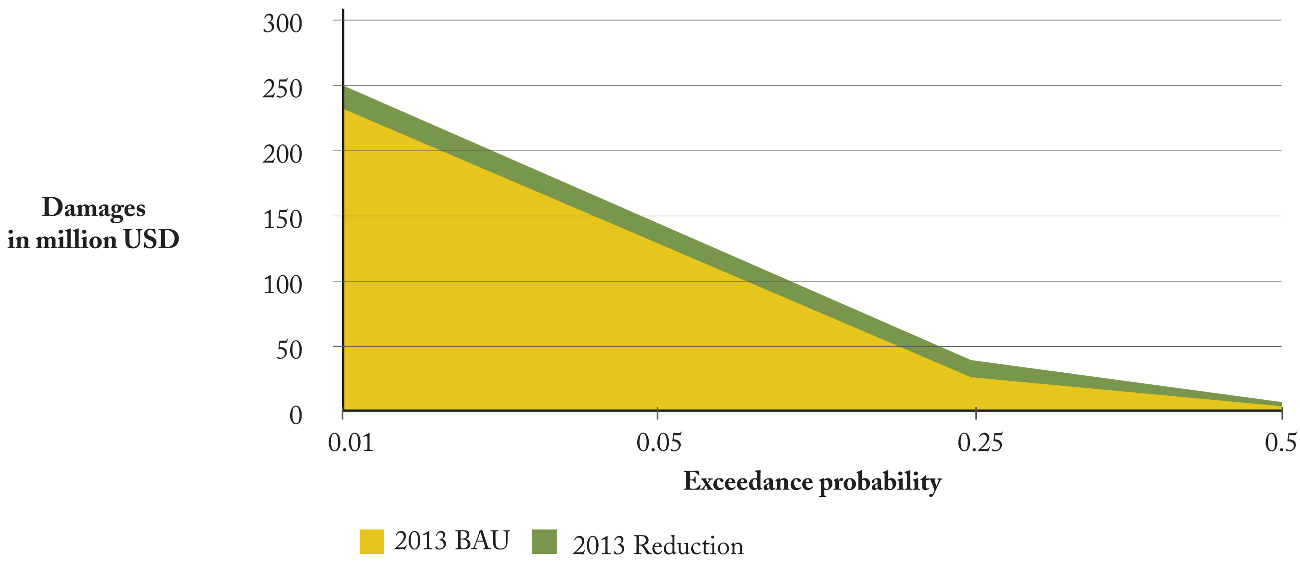


Figure 16: FLOOD DAMAGE AND DAMAGE REDUCTION (DUE TO AN IMPROVED EWS) CURVES FOR THE 2030 SCENARIO

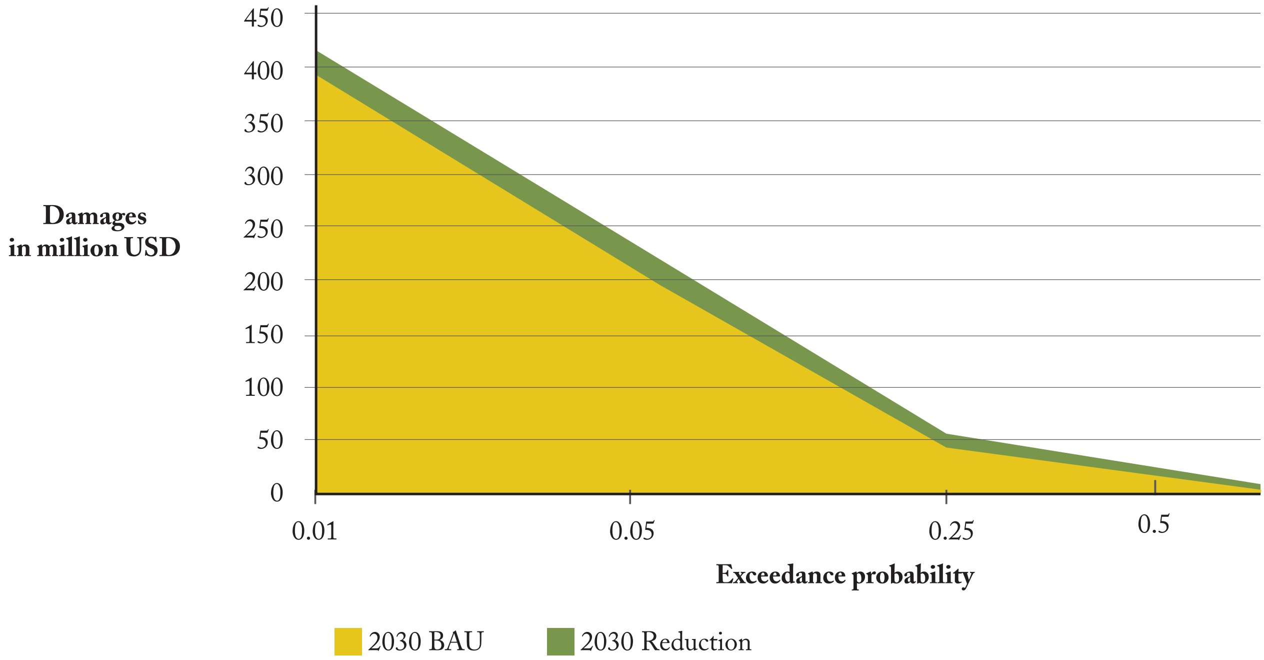
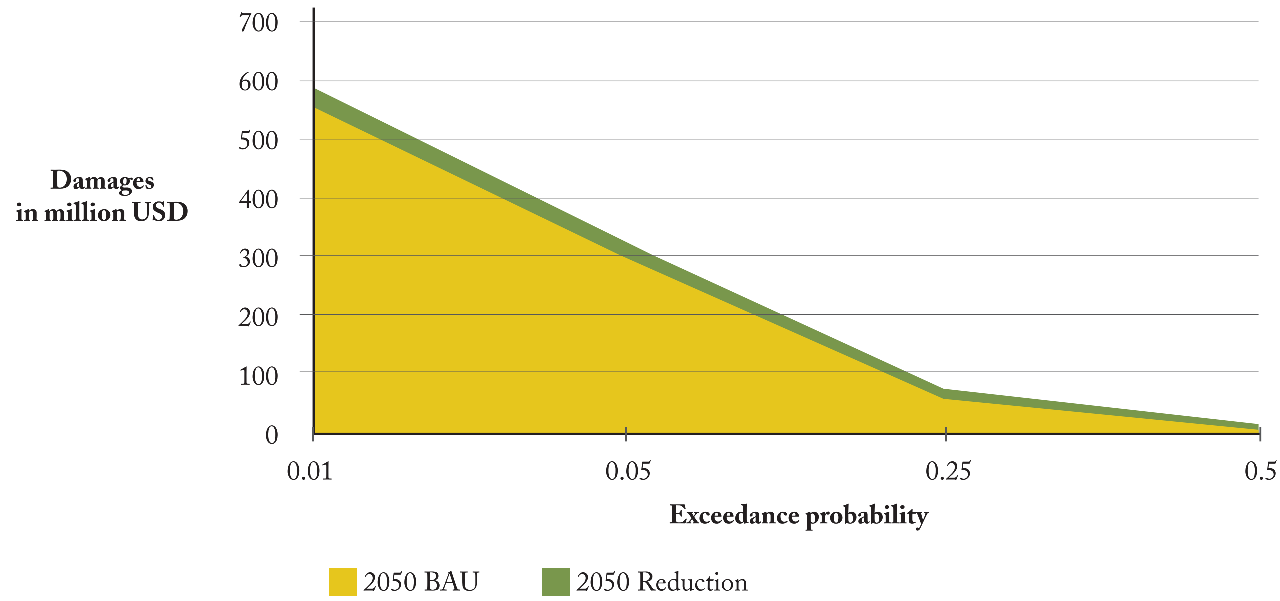


Figure 17: FLOOD DAMAGE AND DAMAGE REDUCTION (DUE TO AN IMPROVED EWS) CURVES FOR THE 2050 SCENARIO



Calculation of the BCR. The assumptions made for the calculation of the BCR for an improved EWS in the base case are presented in Table 11. The BCR of the EWS in the base case is reported in Table 12.

Table 11: ASSUMPTIONS FOR AN IMPROVED EWS

Assumptions	
Lifetime in years	20
Annual benefit (million USD)	3.66
Cost (million USD)	-1.10
O&M costs per year (20%)	-0.22
Discount rate	10%

Table 12: BCR FOR AN IMPROVED EWS

Economic return	
NPV (million USD)	24.15
IRR	–
BCR	9.13

Due to the low cost of implementation and large area covered by the EWS, it provides the best return on investment of the three options considered. But there are limits to its effectiveness. When fully operational, it can save lives and reduce the damage to movable assets because it provides time for people to respond. However, the EWS cannot prevent inundation, disruption, and damage to immobile infrastructure, which is the largest capital asset of the city, both in the private and public sectors.

Photo by Michelle Fox, ISET-International 2014

6 Discussion & Conclusions

Key Findings from the economic analysis are discussed in this section. The results, once again, are presented by city and selected sector. Wider implications and conclusions from the research are presented at the end of the section. The following are the key results of our economic analysis based on the development scenarios and climate modeling.

Gorakhpur, India

Implementation of a storm water drainage system (and maintaining it) would provide the best results in terms of BCR. The cost of implementing (and maintaining) a comprehensive storm water drainage system is much lower than the benefits it would provide in the form of reduced losses and damage to households and businesses. This does not even take into account the reduction in losses to public infrastructure, such as office buildings and roads, through reduction in maintenance and repair costs, or, in the case of schools, loss of days of education.

The reduction in inundation due to maintenance of open space does not compare favorably with the cost of land. Overall, the reduction in losses and damage to households and businesses through maintaining open space is lower than the losses and damages avoided in the BAU scenario. The cost of land reserved for open space and use as a flood buffer is high due to competing demands in growing urban centers, which create economic incentives that encourage the development of such land. Municipalities like Gorakhpur have strong incentives to overlook the conversion of open space and its use for construction. Similar pressures exist in other regions. In the case of Da Nang, for example, the same demand pressures on open space provide a strong incentive for municipal authorities to sell such land to developers as a major source of revenue.

There are co-benefits to resilience measures that have not been monetized. Qualitative insights were collected during the survey process and SLDs. However, due to the challenge of quantifying these benefits, the research team has not included them in the overall analysis. For example, flood risk reduction measures create safer environments for households as well as businesses. This provides immense psychological benefits related to an increased sense of safety and security. Furthermore, greater open spaces within a city provide co-benefits in the form of more greenery (or playgrounds for children), improved air quality, a reduction in the heat island effect, and an overall healthier population. Since none of these benefits have been monetized, however, the study underestimates the overall benefits of flood risk reduction.

Da Nang, Vietnam

The development of Da Nang in the floodplain areas of the lower Vu Gia-Han basin creates a bottleneck in the flow of water into the east and reduces retention capacity. This causes increased flooding in vulnerable communities in the upstream areas of Quang Nam province and in the existing flood-prone areas in Da Nang. With extreme rainfall, floodwaters back up behind roads and overtop the residential areas within the floodplain. To reduce the current flood risks and increase resilience to future climate change, this analysis suggests resilient pathways for three sectors: housing, roads, and flood risk reduction.

Detailed analysis of the costs and benefits of these three pathway sectors in the new development in the southern part of Da Nang show significant differences in economic returns. However, in all cases, the results show that investment in resilient pathways is socially desirable.

Among the three resilient pathways, the BCRs reveal that an improved EWS is the most economically efficient option (BCR = 9.13), followed by raised road (BCR = 1.16) and then raised house plinths (BCR = 1.04). These findings suggest that investment in soft resilience measures, or nonstructural interventions, is more economically efficient as compared to investment in hard resilience measures.

Improving the EWS is economically the best option for increasing the resilience of development in the city and should be considered the highest priority. In practice, in order for the EWS to work effectively, it requires an integrated flood management perspective, involving the participation of different stakeholders and the coordination of actors across different sectors in the decision making process. Areas for discussion could include the integration of land and water management; the integration of dams, dikes, and reservoirs management; the integration of forecasting and warnings; a review of housing and building codes; and the preservation of the natural resources of the floodplain.

The BCR for raised house plinths is marginal. It is worth noting that raised house plinths in the new development area did not cause external flooding in other areas because the proportion of households implementing this option is small. However, in the future, when more households adopt this option, negative externalities of flooding cannot be avoided. Therefore, for future developments, it is recommended that raised plinths should allow for the flow of floodwater. As we have seen in Gorakhpur, however, this will increase the cost and reduce the BCR even further. Regarding solutions for the housing sector, during the process of scenario development, we realized that soft measures such as the use of flood-resilient materials in first-floor housing that allow it to be used flexibly during floods either for living or, if the flood is high, for floodwater retention seemed to be more effective in dealing with flooding.

Other Findings

Resilience measures are cost-effective. The scale and quantum of disruption and damage to public and private life and property due to the impact of hazards such as waterlogging in Gorakhpur are such that simple urban measures (basic services) like storm water drainage are important in improving the resilience of the city and can be achieved in a cost-effective manner. This finding is supported by research produced by the World Bank, as well as the United Nations (Leoni, Radford & Schulman). Similarly, the EWS in Da Nang is a very cost-effective resilience measure. Other interventions are also cost-effective, but various economic incentives, such as those presented by high-cost land, make resilient planning and implementation very difficult.

Costs and benefits have a distributional aspect. Since this analysis is area based, it does not explicitly identify how costs and benefits are distributed among the population. Most of the flood damage affects households that are predominantly poor, especially those inhabiting low-lying areas. In the case of Da Nang, the damage to areas upstream of the development area extend to a neighboring province. Because this province is under a different administration, the losses experienced there provide little disincentive for the conversion of the floodplain into housing for sale.

Planning processes are time consuming. The planning process for urbanization and expansion of urban areas via the Master Plan is well entrenched. However, the process of developing a master plan takes a considerable amount of time, and it has been observed that by the time the plan is ratified and accepted by the government, the information upon which the plan is based is no longer valid. For example, the spaces that are identified as green, or open, have often been usurped by developers, and the Master Plan has to be amended to change the land use of that area. To develop urban areas while keeping in mind hazards and exposure, the planning process needs to be completed in a timely manner and the plan should be revised periodically (such a provision exists but is followed only occasionally). Additionally, the inclusion of various stakeholders in the visioning and planning process is also important, so as to incorporate the concerns of all segments of the society.

The planning process does not consider future climate hazards. While the Master Plan does take into account demographic and economic development projections, the use of climate information is limited to historical information/data. The impact of future climate changes that would affect and dictate land use is still not incorporated in the Master Plan. In the case of Da Nang, both road and housing development projects contribute to increased flooding.

Master Plans are not made or not followed. In India, many cities have yet to embrace the master planning process. According to reports, only 24% of India's cities and towns have a Master Plan (Staff Reporter, 2012, August 30). However, in many cases, even the cities that have a Master Plan, especially tier II and III cities, do not follow or implement it, as observed in Gorakhpur. This tendency results in an increased exposure to hazards and risks.

Suggestions for Potential Ways Forward

Since the demand for real estate is quite high in a growing city like Gorakhpur, increasing infiltration by utilizing additional techniques, such as rainwater harvesting, is needed. Building bylaws mandate that a roof area greater than a specific size must have a rainwater harvesting system installed (GoI, 2013). But this bylaw is rarely observed in the city. The resources available for this research did not allow for a query into this topic, but given that the total additional built-up area in Gorakhpur will be more than 7,500 ha by 2041, it is estimated that the implementation of rainwater harvesting (a green roof) on only about 50% of residential properties and 50% of government and institutional buildings would provide a significant reduction in flood depth, especially during lower return period events (1 year—about a 20% reduction; 2 years—about a 10% reduction).[1] However, for larger precipitation events, such as 50-, 100-, and 200-years events, the reduction would not be as significant.

The promotion of high-rise apartment buildings versus row houses or individual houses by the city development agency would result in additional open spaces being created, leading to increased infiltration.

Low-lying and flood-prone areas should be demarcated, and construction activity should be discouraged in these areas. Low-lying areas should be kept open so as to assist with better infiltration of rainwater, thus reducing the inundation levels in other parts of the city.

Wider Implications & Conclusioans

The research results presented in this report illustrate both the economic importance of tangible measures to influence the risks urban areas will face as climate evolves as a result of alternative development pathways and the difficulty in developing quantitative estimates regarding the costs and benefits of such measures. In the case of Da Nang, for example, large areas in the flood plain have already been raised. As a result, elements of Da Nang's development pathway have already been set in place. That specific area will benefit and this benefit could be increased in a relatively small way by activities to further raise the plinth level of buildings in that area. At the same time, the costs that will be incurred due to additional flooding in other areas, some of them upstream in another province, have in effect already been incurred. Additional measures, for example, to implement an EWS, can reduce losses but they don't alter the overall development pathway in a way that avoids exposure to anticipated hazards.

1 Information obtained from consultation with expert hydrologist on March 10, 2015.

The above situation is far from unique to Da Nang. Throughout the world, urbanization in coastal deltaic regions involves decisions to protect specific areas. Once hard protective measures, such as dikes, sea walls or landfill, are in place, a pathway has been set. The costs to other areas when water or the force of storm surges, are displaced, have already in effect been incurred. Measures to mitigate such costs or provide additional protection to the area that already benefits from the protection can still make economic sense—but the returns are likely to be lower because the broad patterns influencing hazard exposure have already been set.

The situation in Gorakhpur and probably Da Nang as well, illustrates another issue. Land in urban areas is valuable and it can be extremely difficult to make an economic case for the preservation of large open areas for flood mitigation alone. Other benefits from the maintenance of open space may be large but are often even more difficult to quantify from an economic perspective than potential flood losses. Furthermore, the economic value of land in urban areas reflects deeper factors that from the perspective of urban inhabitants probably outweigh flood risks. For poor immigrants to urban areas, proximity to jobs, medical facilities, and educational opportunities depends heavily on proximity. For them, transportation from distant, but safer, locations is both expensive and time consuming. As a result, meeting their immediate livelihood needs may necessitate living in a location, such as an urban flood plain, that provides immediate access to the benefits of urban living. This is also often the case for corporations and more wealthy groups. Da Nang's port and access to major river ways conveys unique advantages for many businesses. This nexus underlies a development pathway that provides very strong incentives for settlement in the floodplain. Such locational advantages have been recognized as a fundamental economic feature driving patterns of development at least since the early 1800s (Thünen 1826). The advantages conferred by location and settlement density are also strongly recognized as a fundamental driver in recent research on the evolution of urban areas (Bettencourt 2010).

This has important implications for attempts to manage the risks urban areas will face as a consequence of climate change through measures to influence development pathways. Because the factors driving urbanization in areas, such as urban flood plains, reflect such fundamental economic and behavioral elements, avenues that support the ability to "live with water" or design cities, buildings and other infrastructure in ways that are compatible with regular flooding, may have more success than attempts to preserve large areas of natural floodplain in rapidly urbanizing areas. This raises profound questions regarding the ability to design urban systems that are compatible, not just with flooding, but also with the maintenance of dynamic riverine, coastal and estuarine ecosystems. Living with water isn't just about the economics of flood risk mitigation, the focus of this report, but must also address challenges associated with the co-location of urban systems in areas of high environmental value and productivity.

As a final point, the cases presented in this report highlight numerous issues related to the process by which urbanization occurs. Planning is often weak, particularly in rapidly urbanizing areas. Local communities often lack a voice in decision-making processes. The decisions themselves are rarely neutral and tend to represent the interests of more wealthy sections of the population while distributing large amounts of the cost to poor and marginalized groups. Data are often lacking or don't address key areas where information is required. At the same time, because development pathways contain large irreversible elements, economic analyses are likely to be most effective when done well in advance of the many major development decisions that influence and limit future options.

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This report evaluates the economics of development choices in relation to risks from flood events under current conditions and those projected as a consequence of climate change. The research undertaken in two mid-size cities—Gorakhpur (India) and Da Nang (Vietnam)—illustrates the need for robust economic analysis and the crucial role it can play in influencing the complex processes through which more equitable development pathways shape exposure to future climate related risks. In a very tangible manner, this research highlights the limitations and strengths of pure market forces in fuelling urban growth through day-to-day development choices and the nearly irreversible pathways that result.

For more information, please see:

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