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Green Growth Benefits for Climate and Disaster Resilience

Concerns for Urban and Infrastructure Systems

Position Paper

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Authors:

NIDM:

Anil K. Gupta, Head - Division of Environment, Climate and Disaster Risk Management

GGGI:

Shantanu Gotmare (India Country Representative), Unnikrishnan Nair (India Program Lead) and Saurab Babu (Consultant)

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Manoj Kumar Bindal
Executive Director
National Institute of Disaster Management (NIDM)
New Delhi

Foreword

Going forward, Asia is expected to become the economic hub of the world; with India and China driving the growth trends. India is aiming at an ambitious growth to become a USD 5 trillion economy by 2024, from USD 2.8 trillion now (2019). Accompanying this economic growth is rapid urbanization in India; with an expected two-fold increase in urban population between 2014 to 2050. While India is making substantial investments in infrastructure and human resources to fuel growth, it is also important to reduce losses due to disasters.

Disasters - both natural and anthropogenic - are great impediment to sustained growth. Worryingly, climate change induced extreme events raise the cost to the global economy to USD 520 billion per annum, USD 314 billion of which will arise from damage in the urban environment alone. Hence, the need of the hour is for nations to develop means to grow economically while building resilience to disasters and climate change by incorporating disaster risk informed investment decisions. This calls for environmental sustainability-based paradigm to address both, disaster resilience as well as the developmental activities. This paper introduces the option of a Green Growth approach to minimize disaster related risks and disruption to the society in the context of urban and infrastructure growth. Green growth approaches emphasize on economic growth, environmental sustainability, poverty reduction and social inclusiveness to achieve holistic growth.

Case studies have been considered here to highlight successful strategies and tools to fill in gaps in the urban disaster management cycle and theorize the best strategies for implementing green growth interventions in Indian cities. With the high pace of infrastructure and urban growth in India, investing in disaster and climate resilience initiatives will go a long way in achieving the sustainable development goals.

Manoj Kumar Bindal

Contents

1. Introduction

Innovation, disruption and development are driving the world in the 21st century. Various requirements will emerge to cater to a growing population that is expected to be more than 10 billion by the end of the century (Cilluffo & Neil Ruiz, 2019). This is expected to draw investments worth trillions of dollars in every sector of the economy. The services sector continues to become more and more critical, contributing to a majority of the world's GDP as well as becoming a source of employment for millions. USD 3.7 trillion is required in infrastructure investments by the year 2035, which could increase by another USD 1 trillion if we are to successfully achieve the Sustainable Development Goals (SDGs) (Woetzel, *et. al.* 2017). Agricultural yields have slowed in recent years, and it becomes more and more challenging to attain food security as the world population grows. This has triggered investments and research in improved agriculture practices, and it will continue in the coming decades.

Asian, African and Central American countries are expected to drive global economic growth in the coming years. The center of world economy is expected to steadily shift towards Asia with the emergence of China, India and Indonesia as growing markets (Guillemette & Turner, 2018). Manufacturing and services sectors are expected to develop exponentially in the coming decades in this region (Buckley & Majumdar, 2018). Up to 54% of the infrastructure investments are expected to be in Asia (Woetzel, *et. al.* 2017). Agriculture production and trade will be vital to the economic security of Asia, which is expected to see the greatest population growth.

India is aiming at an ambitious growth rate of 10-11% per annum to become a USD 5 trillion economy by the year 2024, from the current economy size of USD 2.8 trillion (Chakrabarti, 2019). This would require investments at 38% of the Gross Domestic Product (GDP) (Anonymous, 2019). Achieving this target requires improvement and investment in transportation, housing and industrial infrastructure. This development is underlined by energy requirements. However, the country is limited by the natural resources it possesses. India relies on over 80% oil imports and over 45% natural gas imports (PTI, 2019). Innovative technological options are required to deliver our economic dreams cost-effectively without depending too much on externalities, which in turn require financial instruments to de-risk investments. Simultaneously, the country will need to improve the economic divide in the country, and lift millions out of poverty and provide the necessary skills to contribute to the GDP.

As India heavily invests in infrastructure and human resources, it is also important to reduce losses. One of the major factors in incurring losses today is disasters; both natural and human-made.

Disasters are already causing great harm to human life and property, and will continue to do so given that most disasters that could happen have not happened yet (UNISDR, Global Assessment Report on Disaster Risk Reduction, 2015). Climate change-related extreme events are expected to further increase disaster risk. Overall, the real cost of disasters to the global economy is estimated at USD 520 billion per annum (CRED & UNISDR, 2016).

Whether or not disaster risk is factored into investment decisions will have a decisive influence on the future of Disaster Risk Reduction (DRR) (UNISDR, 2013). It is estimated that annual investments of USD 6 billion in appropriate disaster risk management strategies could generate benefits in terms of risk reduction of USD 360 billion (UNISDR, 2015).

In this paper, we explore the option of green growth approach to ensure minimal disruption and damage from disasters to society. This is a socially inclusive, environmentally sustainable and flexible development model that will increase disaster resilience without compromising on economic growth. In particular, the paper focuses on urban growth and urban infrastructure. A larger proportion of population growth, economic growth and infrastructure investments are expected to occur in cities in the coming decades, creating the need for greater disaster resilience to safeguard urban development. Green growth can provide additionalities to fill gaps in the existing urban disaster management cycle. Successful cases of green growth in various urban sectors have been analyzed to theorize the best-fit of green growth approaches to Indian cities. Particularly, convergence opportunities with existing Government of India urban development schemes have been noted to help mainstream and scale up green growth for DRR.

2. The Green Growth Development Model

The concept of green growth has gained traction since the Rio+20 conference. It is considered to be a pathway to sustainable development, and emphasizes that strategically crafted policies can achieve environmental sustainability at low cost, and simultaneously help stimulate growth (Toman, 2012). Green growth has been defined in many ways in scientific literature. Organization for Economic Cooperation and Development (OECD) defines it as a "means fostering economic growth and development, while ensuring that natural assets continue to provide the resources

and environmental services on which our well-being relies". **Global Green Growth Institute (GGGI) goes one step further in defining green growth as a form of growth that focusses on "economic growth, environmental sustainability, poverty reduction and social inclusiveness".**

Thus, the green growth option chosen under a set of alternatives may not necessarily be the cheapest alternative, but it would be the best alternative considering social, environmental and economic aspects *together*. Such an approach is critical in the current global scenario of extreme poverty, social inequalities and climate change.

Figure 1. Green growth pillars

In the agricultural sector, this means adopting practices that promote positive environmental impact and social welfare. GGGI, in a study on the small tea growers of Assam and West Bengal, recommends a low-carbon pathway for tea production that adopts rationalization of chemical use, adoption of organic cultivation practices, and use of community solar grids and solar pumps to replace fossil fuel. The study suggests building Self-Help Groups within the small tea growers'

community. Such groups would be formally recognized by the authorities, financial institutions and markets, improving their ability to access resources and overall competitiveness in the market.

In the buildings and construction sector, this means exploring alternative "green" building material, like fly-ash bricks, and promoting energy efficiency through VEE-rated equipment. A barrier to such alternatives would be access to financial resources because green buildings have an incremental cost. Green financing options, like bridge financing from climate finance or subsidized loans, can make such initiatives financially viable and encourage the consumers to adopt green building principles.

In the industrial sector, this means promoting resource efficiency and innovative technology. Due to the growing volume of municipal solid wastes (MSW), GGGI explored the option of utilizing vegetable market waste as an input to produce BioCNG which could replace imported CNG in various domestic and industrial applications (GGGI, 2019). What was once a waste to be disposed of, became an option to solve the twin problems of waste disposal and rising fuel imports.

Green growth is central to the context of urban growth as cities are the drivers of the economy as well as consumers of large quantities of energy, land, food and other resources that place stress on natural capital. Generating green growth action at a local scale in cities can reap considerable positive benefits (Hammer, Kamal-Chaoui, Robert, & Plouin, 2011). In addition to economic growth and environmental sustainability, social equity in urban development and complimenting local policies are important aspects of green growth in urban areas.

3. Urban Growth: Trends and Challenges

Growth and development in the 21st century will be concentrated in cities. It is estimated that 68% of the world's population will be living in cities and towns by 2050 (UN DESA, 2018), with 90% of the urban growth happening in developing countries of Asia and Africa (United Nations, 2018). Cities in the Asia-Pacific region is expected to grow by one billion people between 2010 and 2040 (UN-HABITAT & UN-ESCAP, 2015). This growth will be accompanied by investment to the tune of USD 94 trillion in various sectors like real estate, transport, water, energy, sanitation, communication and, production and distribution systems. Asia, Africa and Latin America, is predicted to undergo rapid urban growth on the back of manufacturing prowess, cheaper services and increasing motorization. The level of urbanization in Asia is forecasted to increase from 45% in 2011 to 64.4% in 2050, when about 1.4 billion more people will be living in cities (OECD, 2016). India is expected to dominate this Asian urban growth, jointly accounting for 35% of the world's urban growth by 2050 with China and Nigeria (Prasad S. , 2019). India's urban population is

projected to grow from 410 million in 2014 to over 800 million in 2050 (Tewari *et al.*, 2016), requiring an investment of USD 1.2 trillion in 2016-2030 alone to maintain current growth trajectories (Mathur, 2018). Currently, cities contribute to two-thirds of India's economic output.

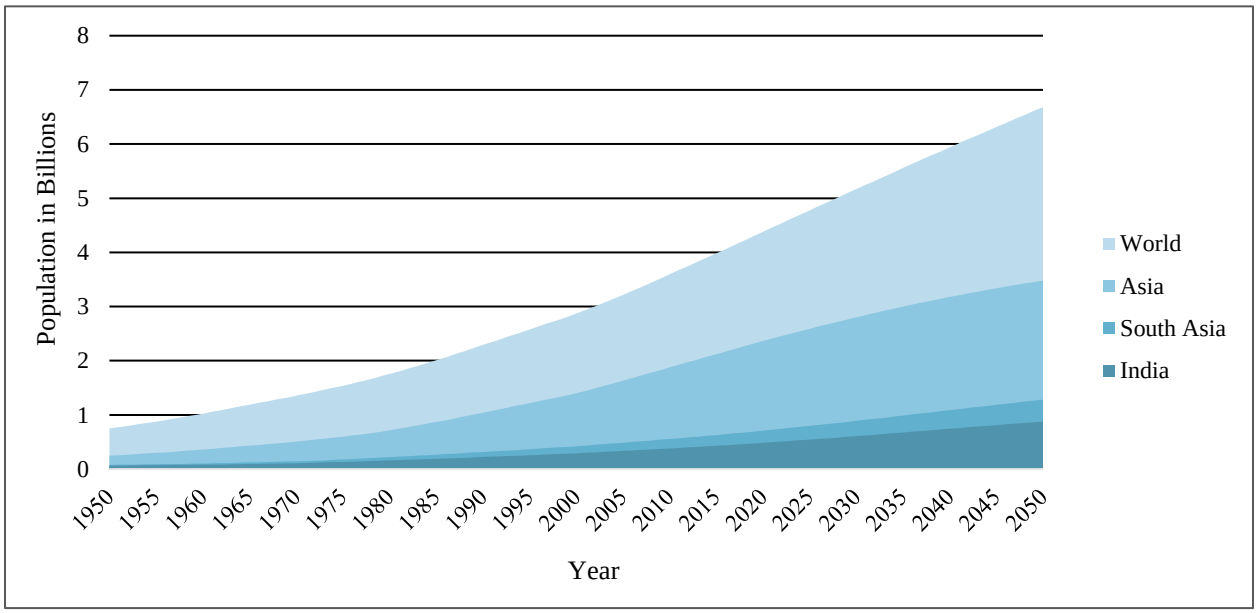

Figure 2. Urban population growth trend from 1950 to 2050. Source: (Ritchie & Roser, 2018)

However, new urban growth and infrastructure development to accommodate this population in the business-as-usual scenario could prove dangerous. Many major cities are presently located in hazard-prone locations (Rumbach, 2017). Economic or political benefits of rapid expansion have outweighed risks (UNISDR, 2009), prompting unplanned growth. Uncontrolled urbanization can exacerbate disaster risk by turning high-frequency, low-severity natural hazards into disasters (UNISDR, Global Assessment Report on Disaster Risk Reduction, 2015). This has been observed as a key factor for recurring and prolonged urban floods in many Indian cities like Mumbai, Chennai, Bengaluru (Gupta & Nair, 2011) and Kolkata (Rumbach, 2017).

Of the total cost of disasters of USD 520 billion per annum, USD 314 billion is from the urban environment alone (UNISDR, 2015). The proportion of urban losses can greatly increase if disaster resilience is not incorporated into future urban growth. Urban losses can be prevented by incorporating disaster risk reduction principles. Considering that 60% of all urban infrastructure of the year 2030 is yet to be built (United Nations, 2018), this presents a huge opportunity for urban planners and governments to choose a resilient development strategy for all future growth.

The Government of India, led by Prime Minister Narendra Modi, has recognized the need for resilient infrastructure and smart urban design, particularly during Recovery and Reconstruction, to prevent damage from future disasters (Roche, 2019). India, thus, is at a crossroads where it can choose an alternate path of growth where disaster risks are minimized and investments in the economy are secured. We believe that green growth is the appropriate approach to minimize disaster risks. There have been successful cases of implementing DRR in urban development, which can be integrated into the disaster management cycle of the country. Government initiatives like Smart Cities Mission and Atal Mission for Rejuvenation and Urban Transformation (AMRUT) provide an ideal tool to pilot and scale green growth initiatives for DRR.

3.1. Existing gaps in the urban disaster management cycle

Most DRR measures under Mitigation Phase in India are focused on technological interventions and capacity building. Early warning systems with state-of-the-art technology have been developed in India, leading to significant successes in reducing loss and damages from tsunamis and cyclones in coastal cities (Padhy, Padhy, Das, & Mishra, 2015; Aggarwal, 2018). Under the Smart Cities Mission, many cities prone to earthquakes and landslides have incorporated stringent building codes and seismic retrofitting of existing buildings as part of their risk reduction strategy, in addition to improving capacities of citizens and the administration to disaster response.

However, in practice, the close public and media scrutiny in disaster response and relief following a disaster leads to a higher priority being given to response over risk reduction (Bahadur, Lovell, & Pichon, 2016; Jain & Bazaz, 2017). The location-specific nature and cross-sectoral impact of disasters require a highly coordinated micro-scale approach among stakeholders to plan DRR strategies, guided by a large-scale overview. The vulnerability of local populations to hazards is highly dependent on their socio-economic status. This requires an intense mapping of not just locations of vulnerable populations but also the *causes* of vulnerability and the *potential impact* on their socio-economic conditions. An enabling environment for micro-scale development of DRR and Vulnerability Assessments along with specific financial support is absent. Though the Disaster Management Act, 2005 mandates the creation of a National Disaster Mitigation Fund exclusively for risk reduction, the Government of India feels that sufficient funds are available in existing centrally sponsored schemes to incorporate DRR strategies within projects under each scheme (PIB, 2016). This methodology assumes that the implementers of each scheme have the capacity and knowledge to implement DRR activities, which may not always be the case. The lack of stakeholder coordination, absence of micro-scale plans and poor financial arrangements make

Disaster Mitigation Phase the weakest link in the disaster management cycle (Bahadur, Lovell, & Pichon, 2016).

DRR is also a part of the Recovery Phase. The business-as-usual approach in rebuilding and reconstruction leaves the population and infrastructure susceptible to future disasters. Incorporating future climate projects at the micro-scale; covering aspects of exposure, sensitivity and adaptive capacity, is needed to minimize losses from expected climate-related disasters (World Bank & United Nations, 2010). Along with developing resilience, such a recovery approach will also be cost-effective and energy-efficient, leading to a carbon-neutral and sustainable city. Location-specific risk reduction strategies, infrastructure, protocols and associated financial mechanisms can make rebuilding easier, leading to shorter recovery time.

DRR is important in urban areas considering the social, economic and infrastructural risks arising from rapid urban development. Population increase, waste generation, congestion, land-use conversion, intense resource utilization is making cities a disaster hotspot. Cities are particularly vulnerable to water and climate-related disasters, as described in Box 1. Disasters affect the urban poor disproportionately, as they are often marginalized and live highly vulnerable sections of the city with poor housing and utilities (Dickson, Baker, Hoornweg, & Tiwari, 2012; Rumbach, 2017). They are the biggest victims of socio-economic disruption and usually take the longest to recover. The resource-efficient, socially inclusive development approach proposed under green growth models are ideal for DRR in cities. Energy, water, construction, waste management, green space planning and transportation are some of the sectors where green growth can enhance urban development.

4. Green Growth in Urban DRR

Green growth principles and approaches can be incorporated in various activities along the disaster management cycle to improve resilience. It ensures that sustainability and risk reduction measures do not hamper the economic growth and output. Green growth strategies provide specific additionalities that improve the process of incorporating disaster management strategies in the development of a city and fill the existing gaps of the disaster management cycle (Table 1).

Various DRR initiatives with green growth narratives have been applied in India and the world. The Climate Smart Cities Assessment Framework developed by Ministry of Housing and Urban Affairs (MoHUA) assesses Smart Cities on climate-relevant parameters to ensure that development is climate-resilient (Puri, 2019). Pre-defined methodology to disburse finances, like the parametric Caribbean Catastrophic Risk Insurance Facility, are innovative instruments to limit the financial

impact in affected areas (CCRIF, 2018). Off-grid energy infrastructure can support disaster-affected populations, particularly the urban poor, in recovering from disasters faster and maintain communication channels with the world, as seen post the Hurricane Maria in 2017 (Love, 2018) or Assam floods of 2019 (Karmakar, 2019). These initiatives cater to location-specific needs and involve various stakeholders in the public and private sector in the DRR process, leading to greater climate and disaster resilience.

Box 1: India's drowning cities

The Mumbai floods of 2005 brought the phenomenon of urban flooding to national attention. The floodwaters persisted for a week, affecting close to 20 million people, including killing 1200 people and 26,000 cattle. It destroyed more than 14,000 homes, and damaged more than 350,000; about 200,000 people had to stay in relief camps. The agricultural sector was heavily hit as 20,000 ha of farmland lost the topsoil and 550,000 ha of crop was damaged (Gupta & Nair, 2011).

Since then, urban floods have continuously struck Indian cities. Parts of New Delhi face urban flooding every year due to inadequate drainage, uncontrolled development and land-use changes, particularly in the Yamuna Flood Plain. The Surat flood of 2006 inundated 75% of the city area with a very high cost to the population, the city economy and the municipal corporation (ICLEI-South Asia, 2015). The Chennai floods in 2015 was caused by unusually high rainfall due to climatic variation, but poor management and city development were blamed for increasing the scale of the disaster to huge proportions, causing damages of billions of dollars. Growing Tier I and II Indian cities like Jamshedpur, Rohtak and Gorakhpur have also faced urban flooding events in recent years. UNDRR considers floods as the single most widespread disaster risk to urban settlements globally (ICLEI-South Asia, 2015).

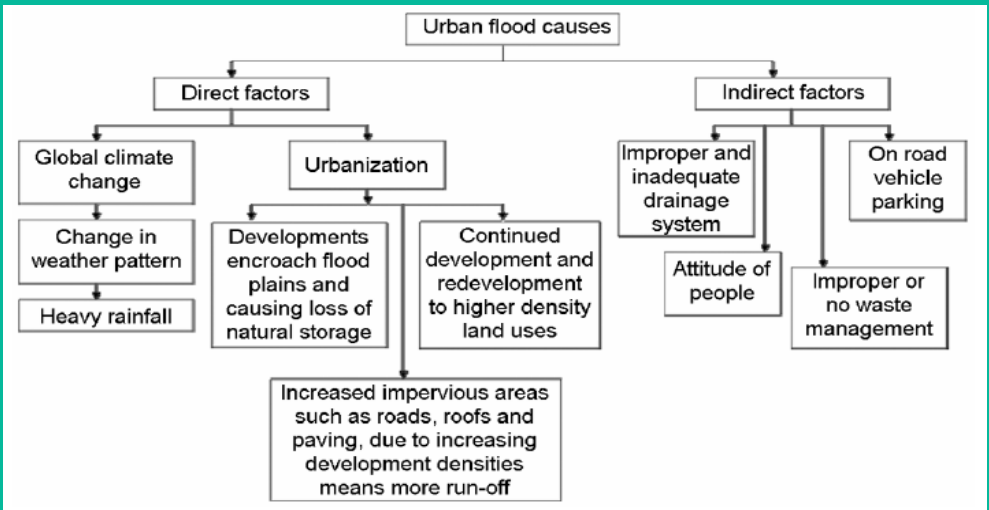

Figure 3. Causes of urban floods in India (Gupta & Nair 2011)

Table 1. Additionality of green growth approach in the disaster management cycle

Stage of Disaster Management Cycle	Needs	Green Growth additionality
Hazard Risk Vulnerability Analysis (HRVA)	Stakeholder coordination	Green growth provides a multi-stakeholder approach by developing specific vehicles with representation from all stakeholders (ex. Surat Climate Change Trust)
	DRR strategies across spatial and temporal scales	Comprehensive hazard mapping at multiple scales; this allows generic overview at the macro-scale as well as specific strategies at the micro-scale
	Social Inclusion	Comprehensive socio-economic vulnerability assessment
Disaster Mitigation	Diversified approaches to DRR	Green urban design, Nature-based Solutions (NbS), decentralized utilities, specialized and targeted financing for DRR
	Climate risk assessment for economic growth	Consideration of climate risks in business development to ensure sustained economic growth
	Financial safety nets for poor	Financial tools like insurance products, specific redressal mechanisms and facilities (like green housing under PMAY-U) for urban poor to reduce socio-economic disruption
	Specialized capacity building for DRR	Specific capacity building for Green Growth approaches in DRR
Disaster Response	Socio-economic stability for the poor	Trigger financial tools through pre-determined protocols
Disaster Recovery	Pre-determined response measures and associated financial mechanisms	Specialized vehicles comprising of protocols and associated financial mechanisms to trigger fast and strong recovery
	Resilient reconstruction of the city	Sustainable Consumption and Production (SDG 12) through use of debris and recycled materials for reconstruction Recovery through new urban design with green and smart elements for future infrastructure resilience
	Climate change considerations in design	Incorporating climate data and climate projections in redevelopment will create climate-resilient cities

5. Strategies and Tools for Green Growth in Urban DRR: Case studies

Case 1: Post-disaster debris management and recycling in Italy (Furcas & Balletto, 2012)

In the earth that struck a zone between Umbria and Marche, Italy, 70,252 buildings were damaged. More than 1580 demolitions were issued in the worst affected municipalities as these buildings were deemed unfit for reconstruction. The total amount of waste generated from the earthquake was estimated at 903,000 cubic meters, which included debris from demolished buildings and waste from reconstructed buildings. About 20-25% of the volume of the full building that was demolished was recovered as usable debris.

Post the collection, quantification and separation of debris, the following three years lead to the production of 189,362 cubic meters/year of recycled aggregates among which 55% was sold. The recovery rate of materials like inert materials and iron was ranging from 96%-98%. The collection and reuse of debris supported many entrepreneurial activities dedicated to recycling.

Such efforts were possible because of overarching policy directives, like the Regional Directive on Removal of debris, demolition of buildings and materials recovery 1998, which directed roles of authorities and targets for demolition and reuse. In addition to this directive, it was mandated by the region that municipalities must reuse at least 50% of the materials recycled from earthquake debris in the reconstruction of public and/or private civil works. The basis for such decisions was a far-reaching policy passed by the regional government in 1987 called Plan for waste management, which focused on the recovery of "mixed waste resulting from demolition". The aggregates generated were typically used for road filling, railway ballast and armor stones for flood control.

Application in India: Using debris in reconstruction to promote disaster resilience, circular economy and resource efficiency

Salvaging debris from disasters can be an extremely valuable resource in reconstruction. For example, it was possible to salvage enough material to build three new homes out of four destroyed ones after Hurricane Katrina in New Orleans (Denhart, 2010). India currently manages Construction and Demolition (C&D) waste as per the Construction and Demolition Waste Management Rules, 2016. These Rules mandate that up to 10-20% of materials in municipal and Government contracts must be from C&D recycled material, monitored by strict

quality control. Bureau of Indian Standards (BIS) and Indian Roads Congress (IRC) will develop the quality control guidelines for the use of such materials in construction activities.

However, there is no specific mention of the use of waste generated from disasters under these Rules. Debris management is mentioned as a key thematic area in Disaster Recovery under the National Disaster Management Plan 2016. There is a potential to link NDMP 2016 and the C&D Management Rules, 2016 in order to specifically target the use of debris in reconstruction. Even with high levels of risk reduction, some amount of damage to infrastructure is expected. Reconstruction with fresh materials is an expensive affair and is economically and environmentally unsustainable (World Economic Forum, 2018). Urban Local Bodies, with the help of National Disaster Management Authority (NDMA) and BIS can come up with debris management plans to ensure that usable materials are recovered, recycled as aggregates and utilized in various development activities. This is a form of circular economy that is promoted by Smart Cities around the world. Buildings being constructed under the Smart Cities Mission can be designed in such a way as to maximize the reusability and recyclability of materials after demolition. This will promote resource efficiency during the rapid urban development in the country.

Case 2: Disaster-resilient infrastructure through innovative financing in United States of America (USA)

The Property Assessed Clean Energy (PACE) Financing or PACE Loan is a means of financing energy efficiency upgrades, disaster-resilient improvements and retrofitting, water conservation measures and renewable energy installations in the USA, developed and run by the US Department of Energy. The financing provided is state-specific; depending on the state legislation this financing can be used for various purposes among residential, commercial and industry owners in either new construction projects or upgrading existing projects. The program is active in various forms in 20 states of the USA.

In this type of financing, the property itself serves as the collateral and the debt is tied to the property, not the owner (Segal, 2019). Governments issue municipal bonds or private lenders provide financing to property owners for the retrofitting. The amount of loan is typically 15% of the cost of the property (Pritchard, 2019). The loan received by the owner is repaid with interest as an additional line item in the annual assessment of property tax. The repayment period is spread out over 5 to 25 years, based on the amount of financing involved. The benefits of this approach are; 100% up-front financing of the project, no down payment required, and a long repayment period which is flexible. The cost savings generated from retrofitting can be earned right from installation, increasing the potential to achieve net financial gains even though property tax increases. This financing scheme is a form of public-

private partnership (PPP) model designed to raise private investments in disaster resilience of private residential and commercial properties in the USA.

This financing scheme has been used in the San Francisco Seismic Retrofitting Financing Program in collaboration with Alliance NRG/Counterpointe Sustainable Real Estate (CounterpointeSRE) to provide owners 100 % financing for seismic retrofitting of their property (ESIP, 2013). CounterpointeSRE Program provides terms up to 30 years, fixed interest rates, and no balloon payment. The program is designed to help real estate owners free cash flow so they maximize investment in their future and the resilience of San Francisco.

As of February 2019, the residential PACE (R-PACE) market was worth USD 5.172 billion and the commercial PACE (C-PACE) market was worth USD 893 million for 1866 projects (Segal, 2019).

Application in India: Need for innovative financing in disaster-resilient infrastructure

As people and enterprises, with their assets, increasingly concentrate in cities, they become highly dependent on infrastructure networks, communications systems, supply chains, residential spaces and utility connections for their well-being (World Bank & GFDRR, 2015). Most of the growth in Indian cities is expected to occur in peri-urban areas, which are usually located in low-lying areas or slopes or floodplains, where disaster risk is high (Gillard, Datey, Sudmant, Oates, & Gouldson, 2018). This threatens the vast economic investments and past economic growth.

At present, the traditional sources of finance to cities from national government grants and existing budgets for city development is unlikely to sufficiently meet the incremental cost for disaster-resilient infrastructure and/or retrofitting (Prasad, et al., 2009). Therefore, specific financial instruments and incentives are needed, along with supporting policies and awareness generation, to reduce incremental cost and/or show future savings from disaster resilience.

A subsidy-based financing structure like the Credit-Linked Subsidy Scheme under the Pradhan Mantri Awas Yojna Urban (PMAY-U) (MoHUA, 2015) may not be able to cover large and diverse infrastructure projects envisioned in the Smart Cities Mission or AMRUT. Unorthodox measures have been applied for disaster management in India, most notable when Kerala Infrastructure Investment Fund Board (KIIFB) issued masala bonds of INR 2,150 Crore in March 2019 to finance recovery and reconstruction after the Kerala Floods of 2019 (Bhaskar & Kelkar, 2019). A PACE financing-like scheme, customized and backed by creditworthy Special Purpose Vehicle (SPV) of Smart Cities Mission, could boost incentives for residential complexes, businesses and industries to incorporate disaster-resilient reconstruction, install decentralized

utilities or retrofitting. Commercial entities may be particularly interested in accessing such finance as many of them recognize the potential for losses in case disasters occur.

Case 3: Stormwater Management using green roofs in Auckland, New Zealand (Fassman-Beck, Voyde, Simcock, & Hong, 2013)

Roofs form 40-50% of the impervious layer of urban centers (Mentens, Raes, & Hermy, 2006), but are often overlooked from the stormwater runoff point of view. Green roofs, also called eco-roofs, are roofs with a vegetated surface designed to manage stormwater runoff from roofs. A green roof reduces the peak discharge volume and retains water on the roof for a longer period, which is critical to prevent disasters like urban flooding. The nature of substrate, plant species, age of the roof, roof slope and roof type have a role to play in the amount of water retained by the green roof.

In Auckland, New Zealand, several green roofs have been designed with the support of the Auckland Council and other stakeholders. The experiments run by Fassman-Beck, *et. al.* 2013 studied green roofs in multiple locations in Auckland. The green roofs differed in age, substrate depth as well as areal extent. The results of these experiments generate strong evidence for green roofs to mitigate runoff related urban disasters. Peak flows from the living roofs were 62-90% less than a corresponding conventional roof's runoff, while the green roofs retained up to 56% more runoff than a conventional roof on a long-term basis.

The use of green roofs as part of a green infrastructure system is promoted under The Auckland Plan 2050 to "deliver greater resilience, long-term cost savings and quality environmental outcomes" with a strong emphasis on community-level awareness generation and participation. Such a policy initiative is important to drive the use of green roofs in urban spaces, because roofs are private spaces and proper incentives need to be generated to promote green roofs adoption.

Application in India: Retrofitting and early-stage integration of green roofs in urban infrastructure to prevent urban flooding

Urban flooding is a cause of major concern for Indian cities like Mumbai, Chennai and Bangalore, (Gupta & Nair, 2011). Increasing urban flooding instances in the country is directly attributed to increasing intensity rainfall events driven by climate change combined with increasing impervious area, with a reduction in natural infrastructure and inadequate drainage systems identified as indirect causes. The amount of economic and opportunity costs is staggering (see Box 1).

Retrofitting existing roofs in metropolitan cities with green roofs, and mandating green roof construction in early-stage development of Tier I and II cities of India can significantly reduce urban flooding risk. It can also free up valuable ground space for other forms of land-use. At present, green roofing is a voluntary practice, undertaken in isolation by environmentally-conscious individuals. For an impactful DRR for urban flooding, green roofs need to be promoted at a city scale, with strong incentives provided to homeowners and building managers to adopt this measure. Since green roofs provide co-benefits of thermal cooling, energy usage and energy efficiency ratings for buildings could rate green roofs highly. A PACE financing-like scheme can be promoted under Smart Cities Mission, PMAY-U or AMRUT to incentivize green roof construction in new buildings. Stormwater Management to reduce urban flooding is a key thrust area under AMRUT. An endorsement of green roofs by the City Development Plan like The Auckland Plan 2050 would be a strong policy directive.

6. Lessons and Way Forward

Cities are going to face significant challenges from climate change, population growth, migration and land constraints in the coming decades. But cities are also the drivers of current and future economic growth. DRR in urban planning will safeguard the investments made in urban centers of India. 70% of India's built environment for 2030 yet to take shape (Prasad S. , 2019), which presents a huge opportunity to adopt a disaster-resilient, resource-efficient and smart growth trajectory. Particular attention needs to be given to climate change mitigation and adaptation. Mitigation is important considering that more than half of the carbon emissions are from urban centers, according to the United Nations. Cities contribute to significant indirect emissions as well because of their resource requirements and utilization. The large population with significant social inequalities creates the need for adaptation measures. Such measures require a multi-stakeholder approach where Urban Local Bodies (ULBs), DRR experts and Climate Change Adaptation (CCA) community work together. The case studies demonstrate that the green growth approach has proved to be an effective way to attain economic growth, promote stakeholder interactions, explore resource-efficient strategies and provide the right incentives to enhance the resilience of cities. We see an opportunity to integrate green growth-based DRR strategies within existing urban development schemes of the government of India like Smart Cities Mission and AMRUT. Both these schemes emphasize investments in smart infrastructure development. The Smart Cities Mission specifically mentions the need to make the Area under development less vulnerable to disasters, making DRR a strong component of its Area-Based Development (ABD) model. The strong policy support for sustainable urban development and growing recognition of threats to urban centers makes this an opportune moment to mainstream an alternative approach to urban planning and development.

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