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8 Building Urban Resilience in East Asia

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Resilience is a characteristic that gives enterprise buoyancy in the face of any disruption, increasing its day-to-day flexibility to respond to a world that is changing fast and becoming ever less certain[1].

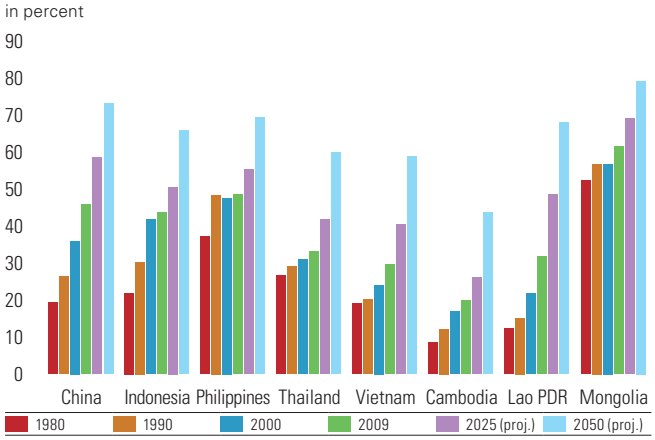
Background and Purpose

The risks of climate change and natural hazards complicate East Asia's quest for continuous rapid growth. The recent tragic earthquake in Japan with a magnitude 9.0—the most powerful in the country's recorded history—and the subsequent tsunami are a stark reminder of the dangers from natural hazards and the key role of careful and thorough investments the authorities have made in seismic safety and emergency preparedness, which undoubtedly saved countless lives and much more widespread loss. This is an important policy takeaway for other parts of East Asia where historically unprecedented rate of urbanization—cities in East Asia absorb 2 million new urban residents every month and are projected to triple their built-up areas in the coming two decades—implies that exposure is increasing and could translate into heavy loss of life and property unless proactive measures are mainstreamed into urban planning processes. These losses may be particularly high in densely populated peri-urban and informal settlements, whose residents live on marginal lands in poorly constructed shelters and lack the financial resources to cope with the loss of property. In the coming decades, policy-makers in the region will need to balance and trade-off infrastructure service provision (access and quality), existing disaster and climate risks and incremental risks from climate change. In this paper we focus on what needs to be done to sustain and develop the hard-fought gains with regard to poverty reduction and economic growth by making urbanization resilient (i.e. be able to adapt and recover from unexpected shocks) to the risks posed by disasters and climate change.

East Asian Urbanization and Its Risks

East Asia is rapidly urbanizing. Figure 1 illustrates the pace at which the countries under study urbanized in the 30-year period 1980–2009 and how this trend is projected to continue through 2050. By 2050, almost 1.5 billion people in these eight countries are projected to be urban dwellers, an increase of more than 640 million from 2009. Figure 2 shows that the total urban population in these countries will more than triple, from 20% in 1980 to a projected level of 70% in 2050. The expected annual growth rate of the urban population in East Asia from the mid-1990s to 2025 will be roughly four times that of the highest income countries.

Figure 1. Percentage of the population by country living in urban areas, 1980–2050

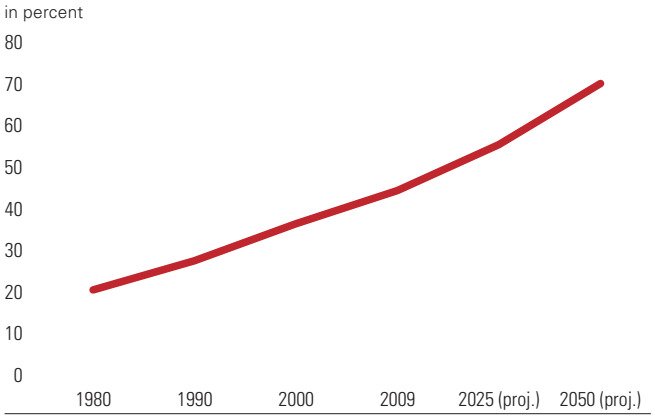


Source: UN World Urbanization Prospects: The 2009 Revision Population Database.

* This note benefitted from inputs from Professor Richard Little.

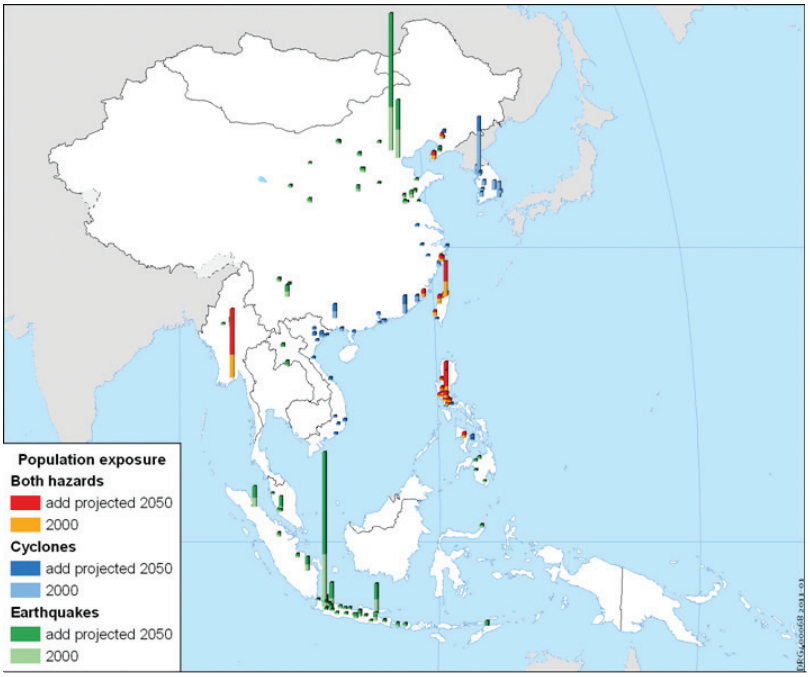
1 Sheffi, Y. 2005. *The Resilient Enterprise*. Cambridge, MA. The MIT Press.

Figure 2. East Asia percentage of the total population living in urban areas, 1980–2050



Source: UN World Urbanization Prospects: The 2009 Revision Population Database.

Figure 3. Exposure of people to cyclones and earthquakes, today and by 2050



Source: World Bank and The United Nations (2010), "Natural Hazards, Unnatural Disasters: the economics of effective prevention".

For East Asia as a whole, the urban population will double between 1994 and 2025. The fastest rates of urbanization are taking place in China and Southeast Asia, with cities in Southeast Asia expanding at rates five times faster than those in the OECD countries. Figure 3 combines city-specific population projections to 2050 for cities with significant earthquake and cyclone risks. Globally, the projected number of people exposed to tropical cyclones and earthquakes in large cities is expected to more than double by 2050.

Urban growth in the next few decades will primarily be in small and medium cities; and peri-urban areas along existing and new growth corridors. While the number of East Asian urban agglomerations with a population greater than 5 million will grow from two[2] in 2000 to eight in 2015[3], the lion's share of the increase in urban population over the next 15 years will continue to be in towns and cities with fewer than one million inhabitants. This is true both for high-income countries and for middle- and low-income countries combined. Even in 2015, towns and cities under one million will still account for well over half of the total urban population. Webster et al (2002) estimate that, through the year 2025, up to 40 percent of incremental East Asian urban population (up to 200 million people) will be in transitional peri-urban areas adjoining existing major cities[4]. Moreover, this growth will concentrate in and around regional, metropolitan "growth corridors", either existing like the Pearl River Delta or the greater Mekong Subregion or planned like the multinational regional growth triangle linking Singapore to the Riau Islands in Indonesia and Malaysia's province of Johor or the Southern China growth corridor that incorporates Fujian and Guangdong provinces on mainland China, as well as Hong Kong and Taiwan. The region is also witnessing the formation of ''urban corridors'' that connect cities across the region, the best example of which is the Beijing-Seoul-Tokyo (BESETO) corridor—which stretches 1,500 km connecting 77 cities of over 200,000 inhabitants each[5].

This rapid urbanization will lead to a huge increase in the demand for infrastructure services. As Angel *et al* note anecdotally: "The current pace of urban growth would require the governments of developing countries to provide the necessary public goods for building, on average, a new city of 1 million people every week for the next 40 years."[6] Massive investments in the infrastructure necessary to serve export-oriented manufacturing economies and the commercial centers and burgeoning populations that support them will continue to be needed. The demand for electric power, telecommunications, rail, highway,

2 Bangkok and Metro Manila.

3 Bangkok, Metro Manila, Chongqing, Shenyang, Hanoi, Ho Chi Minh, Yangon, Bandung.

4 Webster, Douglas and Larissa Muller (2004), "The Challenges of Peri-Urban Growth in East Asia: The Case of the China Hangzhou-Ningbo Corridor." in Enhancing Urban Management in East Asia, Mila Freire and Belinda Yeun (Editors).

5 Cohen, Barney (2004), "Urban Growth in Developing Countries: A Review of Current Trends and a Caution Regarding Existing Forecasts" National Research Council, Washington, DC, USA.

6 Angel, Shlomo, Stephen C. Sheppard and Daniel L. Civco (2004), "The Dynamics of Global Urban Expansion", http://web.worldbank.org/WBSITE/EXTERNAL/TOPICS/EXTURBANDEVELOPMENT/0,,contentMDK:20970341~pagePK:148956~piPK:216618~theSitePK:337178,00.html

and seaport connections, and modern water and sanitation facilities has grown enormously. The most recent comprehensive study of East Asian infrastructure needs estimated that the region needed to spend more than $US165 billion per year in the period 2006–2010[7] or roughly 6.2 percent of GDP. Disaggregating these estimates between China and the rest of the region, China would need to spend US$135 billion (6.8 percent of GDP) while the rest of the region $US33 billion of 4.5 percent of GDP. In the five years since *Connecting East Asia* was written, the region has suffered through the global economic crisis and responded with various stimulus strategies, China's being particularly large. However, applying the original percent GDP multipliers to 2009 GDP, China would nominally require about $US340 billion annually while Cambodia, Indonesia, the Lao PDR, Mongolia, the Philippines, Thailand, and Vietnam would require investment of about $US48 billion per year. Although crude, this quick calculation provides a realistic order of magnitude estimate of the annual level of infrastructure investment that will be required to support projected urban expansion. These investments will not all be public nor driven solely by national policy. Increasingly, infrastructure investment in the developing world is underwritten by the private sector through various public-private partnering arrangements and many decisions are made at a local or regional rather than a national level. This suggests that the stakeholder pool needs to be broader and deeper than has been necessary in the past.

East Asia is a region fraught with a high incidence of natural disasters that is aggravated by rapid urban growth under weak regulatory and planning regimes. The Asia-Pacific region comprises covers 52 percent of the earth's surface area, 59 percent of the world's population, and over 70 percent of the world's natural disasters. Most East Asian economies are located in the Pacific Ring of Fire which is home to over 75 percent of the world's volcanoes and the source of 90 percent of the world's earthquakes. The Asia-Pacific region is further affected by weather phenomena such as the El Niño South Oscillation (ENSO) and its contrary weather pattern of La Niña, which have become increasingly apparent in recent decades. Tropical cyclones bring extreme winds and heavy precipitation. In coastal areas, storm surges accompanying these storms have historically killed hundreds of thousands of people.[8] Floods, long a major hazard in China, killed more than 700 people in 2010 and caused $US 20.9 billion in economic losses[9]. Flood flows are often magnified by high percentages of impervious surfaces, in the form of buildings, streets, and other paved areas, clogged drainage ways, and poor planning and other land use controls. Floodwaters also undercut slopes leading to landslides and mud and debris flows. The seismic belt south of Sumatra is one of the most active in the world and also the origin of some of the largest earthquakes in recent history. Earthquakes throughout the region continue to be major killers as evidenced by the 2008 Magnitude 8 Sichuan earthquake in China that killed 70,000, injured 374,000, and caused more than $US85 billion in damage. The combination of highly concentrated populations living in structures not designed and constructed to resist large but reasonably probable hazard events is a recipe for disaster that is played out over the globe but which Asia claims a disproportionate share. This is underscored by figures compiled by Swiss Re, the global reinsurer[10]. In the years 2007-2009, Asia accounted for more than 95% of the 264,100 deaths attributed to natural catastrophes but only 8.4% of the insured losses. This vast disparity between human and economic losses is a direct outgrowth of too many people with too little choice in where they can live. Ultimately, they occupy substandard dwellings on marginal or unsuitable land.

Rapid, new growth brings new risks (and deepens some old ones). As noted above, the bulk of future urban growth will be in small and medium towns and in peri-urban areas along major urban growth corridors: Often precisely the areas that have the least capacity to manage this explosive growth. Cross-border supply chain fragility will be heightened by increasing metropolitan/regional growth. Shin-Etsu Handotai, one of the world's leading producers of the silicon wafers and ingots that are used in the manufacture of semiconductors. Its Shirakawa plant is located in Fukushima, close to the epicenter of the March 11 Tohoku earthquake and near the site of the nuclear power plant troubles. That plant is responsible for 22% of the world's supply of silicon wafers, and it has been shut down for lack of electric power. Anisotropic conductive film is a key material used in the manufacture of LCD flat panel displays in TV sets, notebook computers, smartphones, and tablets. 70% of the world supply comes from Japan, and as of March 16th, suppliers have stopped taking orders.[11] On April 14, 2010 Iceland's Eyjafjallajokull volcano erupted. Five days later, Nissan Motor shut down three auto assembly lines in Japan. The factories had

7 *Connecting East Asia: A New Framework for Infrastructure*. Asian Development Bank, The International Bank for Reconstruction and Development/The World Bank, and Japan Bank for International Cooperation. 2005.

8 In the deadliest recorded disaster in recent history, a storm surge driven by Super-cyclone Bhola killed more than 300,000 in Bangladesh in 1970.

9 "Flooding in China Kills 701 People This Year, Most in More Than a Decade." Bloomberg News, July 20, 2010.

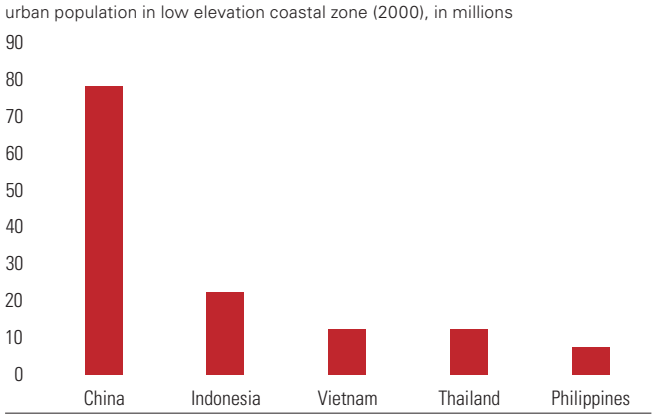
10 Swiss Re (2008, 2009, 2010) "Natural catastrophes and man-made disasters in 2007 (2008) and (2009)." *Sigma*. Zurich, Switzerland. Swiss Reinsurance Company, Ltd.

11 "The Japan Earthquake Rattles Supply Chains, Too", March 23, 2011, http://blogs.hbr.org/hbsfaculty/2011/03/beyond-the-devastating-and-sad.html

run out of tire-pressure sensors when a plane carrying a shipment from a supplier in Ireland was grounded because of volcanic ash.

Climate change makes existing risks much worse. Cities disproportionately face the brunt of climate change impacts due to their concentration of people and physical assets, as well as their geographic location (many cities are coastal, having evolved from historical trading centers). According to an OECD study that looked at 136 port cities around the world with populations exceeding one million, assets exposed in these cities to the potential impacts of climate change amount to $3000 billion (or 5% of global GDP, 2005). By 2070, this could increase to $35,000 billion (or 9% of global GDP). East Asia is home to four of the top 10 most vulnerable cities in terms of exposed population: Guangzhou, Shanghai, Ho Chi Minh City, and Osaka-Kobe. Adding Mumbai and Kolkata, broader Asia has six of the top 10 most exposed cities[12]. McGranahan et al (2007) estimate that Low Elevation Coastal Zone (LECZ), (defined as the contiguous area along the coast that is less than 10 meters above sea level) covers 2 per cent of the world's land area but contains 10 per cent of the world's population and 13 per cent of the world's urban population. In Asia, not only are urban populations more likely to be in the LECZ than rural populations, but larger urban settlements are more likely to overlap with the LECZ than are smaller urban settlements. While only 13 per cent of urban settlements with populations under 100,000 overlap with the LECZ, this rises to 65 per cent among cities of 5 million or more. Perhaps even more striking, of the 183 countries with people living in the LECZ, 130 have their largest urban area extending into the zone.[13] The Economics of Climate Change Adaptation Report estimates that East Asia and the Pacific region has the highest annual cost of adapting to climate change amongst all six geographical regions of the World Bank.[14] As Table 1 below shows, East Asian countries figure prominently in the list of countries most at risk of 4 climate-related risks (Floods, Storms, Sea-level rise 1m and 10m).[15] Figure 4 displays the coastal

Figure 4. Coastal population of select countries that are highly vulnerable to sea level rise



Source: Adapted from Prasad, N. et al., 2009.

Table 1. Countries at risk from climate change effects

Flood	Storm	Coastal 1m	Coastal 5m
Bangladesh	Philippines	All low-lying Island States	All low-lying Island States
China	Bangladesh	Vietnam	Netherlands
India	Madagascar	Egypt	Japan
Cambodia	Vietnam	Tunisia	Bangladesh
Mozambique	Moldova	Indonesia	Philippines
Lao PDR	Mongolia	Mauritania	Egypt
Pakistan	Haiti	China	Brazil
Sri Lanka	Samoa	Mexico	Venezuela
Thailand	Tonga	Myanmar	Senegal
Vietnam	China	Bangladesh	Fiji
Benin	Honduras	Senegal	Vietnam
Rwanda	Fiji	Libya	Denmark

Source: World Bank staff.
Note: Blue shade indicates countries in East Asia and Pacific.

12 Nicholls, R.J., S. Hanson, C. Herweijer, N. Patmore, S. Hallegatte, J. Corfee-Morlot, Chateau, J. and R. Muir-Wood (2007). Ranking Of The World's Cities Most Exposed To Coastal Flooding Today And In The Future. Paris, France: OECD publishing, http://www.oecd-library.org/docserver/download/fulltext/5kzssgshj742.pdf?expires=1285190021&id=0000&accname=guest&checksum=1EAA040044DB6464A51E74AFE061F915

13 McGranahan, G., D. Balk and B. Anderson. 2007. The rising tide: assessing the risks of climate change and human settlements in low elevation coastal zones. Environment & Urbanization 19(1): 17-37 (2007). International Institute for Environment and Development (IIED). http://eau.sagepub.com/cgi/content/abstract/19/1/17

14 World Bank (2010), "The Economics of Adaptation to Climate Change: Synthesis Report".

15 World Bank (2008), "Development and Climate Change: A Strategic Framework for the World Bank Group". http://siteresources.worldbank.org/EXTCC/Resources/FullFrameworkDocument1212008Book.pdf

population of five of the countries under discussion that are highly vulnerable to sea level rise[16]. As more poor people seek better lives in Asian cities of all sizes, the number of the people at risk will grow at an even faster rate.

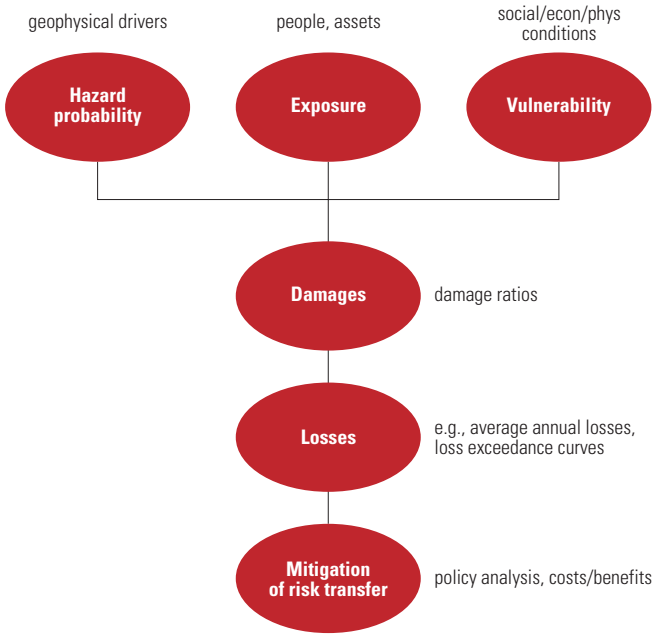
A Framework for Understanding Risk and Building Urban Resilience

Understanding risk is critical to building more resilient communities. In simple mathematical terms, risk (*R*) can be expressed as the probability of the hazard (*P*), multiplied by the exposure of people and assets (*E*) and the vulnerability (*V*) of the population or place where it will occur, or $R = P \times E \times V$. For example, in the case of rising sea level, the risk is far greater for people living in coastal areas than for those at higher elevations because coastal populations are more vulnerable to lowland flooding and storm surge and will suffer greater consequences if those events should occur. Figure 5 shows the standard risk assessment model.

In essence, the assessment of risk answers the following questions.

1. What is the likelihood of the event?
2. Who and what is in harm's way?
3. What are the projected losses due to disaster and climate change impacts?
4. What social, economic and physical conditions reduce or amplify the impact?[17]

Figure 5. The standard risk assesment model applies across spatial scales



Source: Diechmann, Uwe (2008), "Spatial ICTs for risk identification and risk reduction: Three geographic scales and three challenges", World Bank."

Quantifying risk and expected future losses is not only the first step in a disaster risk reduction program; the impact scenarios of a risk assessment are now also increasingly incorporated in other sustainable development approaches in order to climate- and disaster-proof infrastructure and development efforts in general. Once severity and geographical extent of risks have been assessed, appropriate and cost-effective countermeasures can systematically be identified. Risk assessments serve as input, for example, for investment prioritization, land use planning, building codes, and catastrophe risk insurance schemes. In short, they support a wide range of decision-making processes for different actors from the public to the private sector.

From the general risk equation it can be seen that the risk from natural hazards can be effectively reduced by reducing one or more of the three factors that contribute to it. While the Hazard component can usually not be changed and the Exposure component can only be partially influenced through land use planning, the Vulnerability component is crucial to reduce risks. This implies that reducing the risk from natural hazards embodies four sequential actions:

1. **avoid** the hazard if possible,
2. Invest in **generating** and **disseminating** credible information on hazard risk in cities
3. **Withstand** the effects of the hazard, and
4. **Prepare for and recover** from its impacts.

16 Prasad, N., F. Ranghieri, F. Shah, Z. Trohanis, E. Kessler, and R. Sinha. 2009. *Climate Resilient Cities: A Primer on Reducing Vulnerabilities to Disasters*. Washington, DC. World Bank.

17 Adapted from Kaplan, S. and B.J. Garrick. 1981. "On the Quantitative Assessment of Risk," Risk Analysis 1(1):11–27.

Avoid the Hazard

Natural hazards cannot be prevented but every hazard does not need to translate into a disaster with loss of life and property. One practical way to avoid them is not to be there when one occurs. In the case of coastal areas, for example, living outside the possible inundation zone associated with rising sea level or storm surge is perhaps the wisest choice, though certainly not a short-term option for the many people already living in flood-prone areas or for those who depend on the sea for their livelihood. However, as a longer term strategy, better identification and delineation of floodways and flood-prone areas, and the implementation of appropriate land use planning and regulatory tools could lead to development patterns where less of the population, building stock, and supporting infrastructure were at risk. New facilities and infrastructure would also benefit from this approach and as facilities age and major reconstruction becomes warranted, consideration could be given to relocating those facilities that could be moved to elevations above expected flood levels. A good example of a (non-structural) relocation program is the US floodplain voluntary buyout program run by the Federal Emergency Management Agency (FEMA). The program acquired about 17,000 structures at a cost of approximately US$ 473 million. FEMA estimates that the 1993 flood voluntary buyouts in the 30 top repetitive loss communities cost $1 for every $2 saved in future insurance claims.[18] In the medium-long term, risk based planned investment in trunk infrastructure that guides city expansion to exclude risk-prone areas, while ensuring a supply of suitable land for new and affordable development is a very effective policy for avoiding hazards. The impacts of the flooding witnessed in the mountainous areas around Rio de Janeiro, Brazil in January 2011 offers a tragic example of the consequences of the poor disproportionately residing in the most hazardous and vulnerable parts of the city. Therefore, a focus on the poor through voluntary in-city relocation of existing informal settlements/slums in high-risk areas is especially important. The city of Bogota provides a good example of the development of an inclusive, voluntary resettlement policy for families living in high-risk areas.[19]

Invest in generating and disseminating credible information on hazard risk in cities

Mandatory disclosure of risks is very effective in changing consumer behavior. Lall and Deichmann find that, for the city of Bogota, households and businesses value the disamenity of natural hazard risk in deciding where to locate as reflected in a negative capitalization of hazard risk in property values. As a result they find that the poor live overwhelmingly in higher risk areas. They also find that earthquake risk has a negative association with land values and that individual investment in mitigation increases with economic density as people have more to lose with disruptions due to natural hazard events. Similarly, flood zone disclosure is mandatory in some areas of North Carolina, so buyers are aware of flood risk before buying a property. Bin et al. (2008) find that the property market reflects geographic differentials in flood risk, reducing property values on average by 7.3%[20]. A comprehensive web-based risk information disclosure system like HAZUS[21] that gives precise and clear risk information like flood plain maps, fault lines, is made simpler through technological advances—such as the abundance of free, simple, and open source software (for example, PostGIS, Geoserver, Mapserver, the GeoNode.org project). The exponential drop in the cost of acquiring data and resulting explosion in data availability (e.g. the Haiti post disaster needs assessment acquired 2.3 TB of data) implies the need for effective data visualization tools that convey policy options and trade-offs to decision-makers.

Early Warning Systems save lives and have huge paybacks relative to cost. If people are aware of a risk ex ante, and receive a credible and trusted warning in sufficient time to evacuate to a place of safety, many lives can be saved. Weather forecasts, warnings, and emergency responses associated with hurricanes in USA are valued at $3 billion per year (2/3 of this from reduced loss of life). The value of public weather forecasts to households in Ontario, Canada is estimated at US$ 1.26 billion per year. A pilot study in Russia finds a payoff of $4–$8 for every $1 invested in modernization of hydro-meteorological

18 "Higher Ground: A Report on Voluntary Property Buyouts in the Nation's Floodplains A Common Ground Solution Serving People at Risk, Taxpayers and the Environment", http://www.nwf.org/News-and-Magazines/Media-Center/Reports/Archive/1998/~/media/PDFs/Water/199807_HigherGround_Report.ashx

19 Resettlement of Families Living in High Risk Areas and Environmental Rehabilitation of "Altos de la Estancia" In Bogotá, http://emi.pdc.org/soundpractices/Bogota/SP6-resettlement-high-risk.pdf

20 Bin, O., J. Brown Kruse, and C.E. Landry (2008), "Flood hazards, insurance rates, and amenities: Evidence from the coastal housing market," Journal of Risk and Insurance, 75, 1: 63-82.

21 http://www.fema.gov/plan/prevent/hazus/ The HAZUS program, developed by the U.S. Federal Emergency Management Agency, is probably the most comprehensive multi-hazard identification and loss estimation tool currently available. See *Multihazards Loss Estimation and HAZUS* (2006) Natural Hazards Review, Special Issue, vol. 7 for more information.

services in Russia[22]. After Super-cyclone Bhola killed more than 300,000 people in 1970, the Government of Bangladesh in partnership with the Bangladesh Red Crescent Society established the Cyclone Preparedness Program in 1972. Working with local communities, a system appropriate to the area was developed to transmit hazard warnings—radio broadcasts complemented by flags of various colors, hoisted for all to see. This, as part of a comprehensive, end-to-end mitigation, warning, evacuation, and sheltering system has led to a dramatic drop in deaths and property loss from cyclones in the country. Another good example is the China Meteorological Administration's Weather Alert Service via SMS that reaches more than 90 million users[23]. The urban poor are more likely to take increased risks to secure housing/property during disasters in spite of functioning early warning systems (this was observed, for example, in the Philippines Post-Ondoy/Pepeng Social Impacts Assessment). Therefore, cities are likely to require targeted communication strategies to reach out to these communities. A good example is the Jakarta Flood EWS which has a strong focus on community capacity building element and ensures the coordination of activities between front line providers (NGOs, community organizations) and local governments[24].

Withstand the Hazard's Effects

From "optimal" to "robust" design "Today's" risks are often significant and this pre-existing adaptation deficit—that exists either by choice or implicit practice—needs to be addressed. At the same time, today's urban investment decisions have tremendous inertia. The Resilience Alliance evocatively defines this as "We live in "yesterday's cities".[25] Many of the urban patterns we see today—roads, buildings, land ownership, etc—reflect decision making periods of the past. Policy-makers face a seeming trade-off in terms of service provision and access to quality basic services while trying to account for risk and uncertainty (e.g. an earthquake or flood that may or may not happen in the foreseeable future). And while decision-makers may or may not take into account the impact that future risks like climate change (with deep uncertainty around its actual impact) may have on service provision in the future, policy inertia means that they are often unable to rationally deal with existing vulnerabilities and today's risks. e.g. the joint World-Bank-ADB-JICA study on climate change and coastal cities found that land subsidence caused by poor groundwater management will be a bigger cause of flooding in coastal cities than storm surges and sea-level rise caused by climate change.[26] For this reason, policy-makers need a decision support tool to make "robust" investment choices under uncertainty. Lempert et al (2010)[27] contrasts "optimal" solutions with "robust" ones thus: "An optimal solution is that it is only optimal for the predicted future and may be poor otherwise. A robustness criterion, in contrast, seeks solutions that are good (though not necessarily optimal) no matter what the future."

One of the most effective means to achieve a robust strategy is to explicitly design it to evolve over time in response to new information. Robust decision making (RDM) can highlight policies that provide an effective hedge against undesirable future outcomes.RDM has been used in a variety of long-term urban planning contexts such as the design of El Dorado Irrigation District's (California) Urban Water Management Plan and the design of the Thames Estuary Flood System Model. RDM also has the benefit of "unbundling" the complexity of urban infrastructure and by isolating the most critical elements of resilience/vulnerability. Robust solutions also recognize how technological factors interact with institutional (including community-level coping and adaptation mechanisms) and environmental factors in a cycle that can be virtuous or vicious, depending on the overall policy context. e.g. good risk-based land-use planning can include building up of urban green space and environmental buffers such as green roofs, downspout disconnections, rain harvesting/gardens, planter boxes, and permeable pavements that are designed to mimic natural hydrologic functions and decrease the amount of impervious area and stormwater runoff from individual sites. These applications and approaches can keep stormwater out of the sewer system to reduce overflows and to reduce the amount of untreated stormwater discharging to surface waters. Poor land use planning that ignores the role of green-spaces and environmental buffers leads to a huge increase in overall vulnerability. Hurricane Katrina and the land-use planning in city of New Orleans is a good example: Every hour a parcel of wetlands the size of two football fields is lost. Every

22 Tsirkunov, Vladimir (2005), "Evaluating Economic Benefits of HydrometServices", http://siteresources.worldbank.org/CMUDLP/Resources/Tsirkunov_Presentation.pdf

23 http://www.wamis.org/agm/meetings/walcs10/S2-Chen.pdf

24 Many partners, one system: An integrated Flood Early Warning System (FEWS) for Jakarta (UNISDR, 2010), http://www.unisdr.org/preventionweb/files/13627_LocalGovernmentsandDisasterRiskRedu.pdf

25 Resilience Alliance (2007), "A Resilience Alliance Initiative for Transitioning Urban Systems towards Sustainable Futures", http://www.resalliance.org/files/1172764197_urbanresilienceresearchprospectusv7feb07.pdf

26 http://siteresources.worldbank.org/INTURBANDEVELOPMENT/Resources/336387-1265151743414/Bojo.pdf.

27 Lempert, Robert, , Nidhi Kalra, and Jordan Fischbach (2010), "Developing Robust Flood Defenses for Ho Chi Minh City Project Concept." (Mimeo).

2.7 miles of marshland that a hurricane has to travel reduces the storm-surge by a foot. If Katrina had struck in 1945 instead of 2005, the surge that reached New Orleans would have been as much as five to ten feet shallower (Tidwell 2005).[28] Box 1 details a good example of such a comprehensive, iterative strategy in the city of Rotterdam.

Box 1: Adapting to Climate Change Risks in the city of Rotterdam

The City of Rotterdam started the "Rotterdam Climate Initiative" to develop Rotterdam into a climate-neutral city. The focus of this plan is on mitigating the emission of greenhouse gases and on strengthening the city's economy through innovative solutions to save energy and store CO_2. The goal is to achieve a 50% reduction in CO_2 emissions by 2025 (compared to the level of emissions in 1990), in conjunction with economic growth. The Rotterdam Climate Proof (RCP) plan focuses on adaptation, and is complementary to the Rotterdam Climate Initiative. There are three main challenges in the RCP plan related to water and climate change:

(1) Flood protection

Sea level rise will increase flood risk. According to Dutch law, flood defenses will have to be reinforced. All quays and levees that are not yet high enough will be reinforced in the coming years. However, in the long term additional reinforcement may be needed. For this reason, space needs to be reserved now for the possible upgrading of flood defenses in the future.

(2) Architecture and spatial planning

One of the challenges is to find alternative options that both enhance flood protection and add value to the attractiveness of the city. To achieve this, spatial planning, architecture and flood protection should join forces in looking for alternative adaptation options. Traditional solutions are inadequate in this respect. In the city center and the old neighborhoods, for example, it is not possible to tackle the problems of water storage by constructing extra facilities. The costs are exorbitant and existing buildings cannot simply be demolished. Innovations such as green roofs, "water plazas", alternative forms of water storage and the like, are therefore essential for the further development of the city. The city also plans to develop new suburban centers outside the levee system. The challenge for spatial planners and architects is to find areas that are able to absorb high flood levels.

(3) Rainwater storage, updating sewage system

The severity and frequency of extreme rainfall events will increase in the future; there is a risk that the current sewage system may not be able to treat and drain the surplus of water. In practice, rainwater usually drains away via the sewers; increasing amounts of rainfall already lead to problems with the existing sewage system. One possible way to avoid these problems is to collect the rainwater and allow it to drain away in a system other than the sewers, separating the dirty "black" wastewater from the relatively clean "brown" wastewater. However, this system must not be allowed to affect public health, the quality of the groundwater or groundwater levels. Sewage pipes generally last for about fifty years; the reconstruction would take several decades. One option is to look for locations for the (temporary) storage of rainwater. The Rotterdam Water Plan 2030 is looking for an additional 600,000 m^3 of water storage space. At least 80 hectares of extra lakes and canals would be needed to provide this storage in open water. Another important aspect of adaptation planning in Rotterdam is to understand how the regional and national government plans for adaptation intersect, and hence the requirements and boundary conditions that they set for the City of Rotterdam. In 2008, for example, the "Veerman Committee focused on reducing the probability of flooding through the use of flood defenses such as levees, beach nourishment and storm surge barriers. The plan has implications for adaptation planning in Rotterdam: should the city invest in additional storm surge barriers?; or should the city invest in adaptive architecture and become a more open city where water can move around freely?

Source: Coastal Cities, Flood Risk Management and Adaptation to Climate Change (2009). VU University Press. Aerts, J., Major, D.C., Bowman, M.J., Dircke, P., Marfai, M.A., http://climateinitiative.eu/nl/delta_cities_website/documents, www.rotterdamclimateinitiative.nl, accessed on January 3, 2011.

Retrofitting public buildings is a cost-effective way to ensure resilience. Many major cities (San Francisco, Berkeley in the US, Bogota in Colombia and Istanbul in Turkey) have undertaken systematic, phased and fully-funded programs to retrofit critical public building like schools, hospitals, fire-stations etc. based on well-known, simple and cost-effectives measures. These include:

- Prepare a risk scenario of losses to cities: Following two destructive quakes in 1999 near Istanbul, the Turkish Government, supported by the World Bank, did a systematic risk audit beginning with schools.

28 Tidwell, Mike (2005), "Goodbye, New Orleans: It's time we stopped pretending.", *Orion*.

- Update earthquake mapping and zoning for adequate building codes. One of the key lessons of the 2008 Wenchuan earthquake in China (70,000 dead, US$122 billion in real estate losses) is the importance of constantly updating earthquake mapping and zoning for adequate building codes. Although L'Aquila in Italy, is a city in an area with well known high seismic risk, it had building specifications for a much lower risk scenario.
- Do a cost-benefit analysis for quake-proofing buildings. In Istanbul, the rule was if the cost of reinforcing a building was more than 40 per cent of constructing a new one, then it's better to tear it down and build a bigger, stronger one. Retrofitting programs are remarkably cost-effective. For instance, in Istanbul, five schools could be reinforced for the price of building one.
- Develop a prioritized building strengthening and renovation program. In Turkey buildings nearest to the fault were prioritized.
- Develop performance criteria: Do we want a school that will fully withstand quake impacts (expensive) or schools that may have masonry damaged (less expensive). Reinforced concrete walls provide protection but so do much cheaper confined masonry walls, as was demonstrated by many 1930s houses that withstood the 2010 Chile quake. Newer is not always better.

Box 2: Retrofitting public buildings in Istanbul

Following the destructive 1999 earthquakes in Turkey, the government of Turkey embarked on an ambitious program to address the vulnerability of public buildings in Istanbul under the Istanbul Seismic Risk Mitigation and Emergency Preparedness Project (ISMEP). The primary objective is to improve the safety performance of public buildings using cost-effective retrofitting techniques. Other goals of the project include:

- Strengthening/Reconstruction of priority public buildings
- Studying the inventory and the vulnerability of cultural and historical heritage structures and strengthening a few
- Providing support for the efficient implementation of real-estate development laws and building codes.
- Setting up training programs for structural engineers in earthquake engineering, and particularly for the strengthening of existing structures.

The project developed (1) standards for the selection of structures to be strengthened, (2) procedures for the design and third-party review of the structural designs, (3) detailed procedures for quality assurance of design and construction quality, etc. In order to ensure successful strengthening and the use of state-of-the-art procedures from around the world, a collaborative effort between domestic (Turkish) and international engineering firms (New Zealand, USA, etc.) was established. This arrangement took advantage of the strengths of both groups. The local engineers are familiar with local design and construction practices and can readily identify vulnerable structures. The international consultants are much more experienced with strengthening of existing buildings and are better versed in the art of earthquake strengthening and can more readily identify deficiencies in proposed retrofits, given their experience with many diverse projects elsewhere.

The project also included the development of (1) comprehensive structural engineering strengthening guidelines and (2) guidelines for their implementation. The guidelines are based on the provisions of the Turkish code with input from ASCE 41(U.S. guidelines). While the Turkish code is written for new construction, the Guidelines are intended for strengthening work. In order to ensure the strengthening encompasses as many structure as possible, the Guidelines are less stringent than the Turkish code and a certain level of damage is deemed acceptable in the provisions.

By the end of calendar year 2010, over 620 schools, hospitals and other buildings have been evaluated and strengthened or reconstructed. That number will go up to about 1,100 buildings by the end of 2014. The bulk of the effort has been and will continue to be concentrated on schools and hospitals. If it is assumed that the schools have roughly 2,000 students and staff per building that means that already the project has protected the lives of more than 1,200,000 students and their teachers. If it is assumed that each family of a student has four people, then the project has already affected directly the lives of about 5 million people in Istanbul.

Particularly noteworthy is that roughly five to seven school buildings can be strengthened in Istanbul for every single building that is rebuilt completely. So, strengthening has proven to be very cost effective. Also, in a typical strengthening of a school about 50% of the budget goes into the actual strengthening (structural work) and 50% is expended on reconditioning the school. Thus, at the end, the schools are effectively new buildings with new plumbing, electrical and mechanical systems, new bathrooms, mostly new architectural finishes, new exterior thermal insulation, etc.

Source: Peter Yanev (2010): "It Is Not Too Late: Preparing for Asia's Next Big Earthquake", http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2010/11/23/000333038_20101123230355/Rendered/PDF/576830WP0REVIS1AVOID1EARTHQUAKE1web.pdf

Box 2 gives more details of the Istanbul retrofitting program.

Ensuring the survivability of infrastructure is critical to improved resilience. Because infrastructure plays such an important role in delivering vital services before, during, and after a hazard event, ensuring its survivability is critical to improved resilience. Typically, this has focused on first order effects. That is, designing the physical elements to resist stresses imparted by gravity, deterioration (corrosion), and ground movement and high winds. However, despite the best efforts of engineers to predict and design for a worst case scenario, failures occur. At such times, redundant back-up systems can prove invaluable but their value must be assessed against their cost. Providing redundancy specifically for back-up purposes can be enormously expensive, particularly for countries that can barely afford basic services. What can serve essentially the same purpose but at much lower marginal cost is the creation of dense service networks. By their very nature such networks provide multiple redundant paths so that if a portion of the system is compromised, some functionality is maintained. This argues for bringing services to all urban residents, not just isolated enclaves of the well-to-do which are vulnerable to the failure of a single element. Landau provides an excellent discussion of the role redundancy and reliability play in improved resilience[29].

An additional vulnerability of infrastructure that needs to be addressed is the interdependent nature of these systems. For example, almost all infrastructure systems depend on electricity. The delivery of electric power is dependent on a variety of other systems ranging from the railroads and pipelines for fuel deliveries, to cellular and digital communications for system control, to the public transit and highways that workers take to the generating plant. A failure in any of these subordinate systems can cause disruptions in the electrical system with spillover effects on the others. Because of this, interdependency itself becomes a potential cause of failure and vulnerability in and of itself[30]. In fact, a report on the 2010 Chilean earthquake noted[31]: "*Infrastructure interdependence among power, transportation, telecommunication and water systems increased their loss of functionality or delayed the restoration processes. This additional loss of functionality reduced regional resilience, and it was triggered by physical and cyber interaction among lifeline systems, as well as by co-location, and by relational and logistical coupling among infrastructures and institutional entities.*"

Prepare for and Recover from the Hazard

We live in a world where, even with the most through preparation and planning, surprises and shocks are inevitable. This implies that, as part of the design of a comprehensive resilience strategy, cities and national governments need to put in place a framework for preparation and robust recovery after the event. This implies first and foremost the need to systematically invest in building institutional capacity in areas highlighted above like risk based land-use planning , emergency preparedness and early warning systems but also, *inter alia*, ex-ante investments in areas like emergency communication systems (taking into account issues like lack of interoperability, damaged or failed network infrastructure, and systems overwhelmed by simultaneous communication between superiors and subordinates) and urban search and rescue equipment. Given the metropolitan, regional nature of current urbanization trends, investments in capacity to manage across multiple jurisdictions and complex authority will be particularly important.

One of the major obstacles to rapid response and recovery following a natural hazard event is immediate access to liquidity. Often national and local budgetary processes are not flexible and agile enough to respond effectively to financing needs in the aftermath of a disaster, despite resources being available. Even though often massive assistance is eventually provided by the international donor community, the lag time between the event and the flow of aid can determine whether the event will spiral into a disaster. Cities and national governments need to design comprehensive catastrophe financing strategies that includes multiple sources of financing (both "on-balance sheet" including the design of rapidly disbursing post-disaster social safety nets-used effectively in Pakistan and Sri Lanka after the 2005 earthquake and 2004 tsunami respectively[32], procedures for rapid disbursing funds including contingent lines of credit; and "off-balance sheet" risk transfer to the private sector through

29 Landau, M. 1969. "Redundancy, Rationality, and the Problem of Duplication and Overlap." *Public Administration Review*. 29(4):346-358.

30 Little, R. G. 2009. "Managing the Risk of Cascading Failure in Complex Urban Infrastructures" in *Disrupted Cities: When Infrastructure Fails*. London, UK. Routledge.

31 EERI. 2010. "The Mw 8.8 Chile Earthquake of February 27, 2010." *EERI Special Earthquake Report* – June 2010.

32 Vakis, Renos (World Bank , 2006), "Complementing Natural Disasters Management: The Role of Social Protection", http://siteresources.worldbank.org/SOCIALPROTECTION/Resources/SP-Discussion-papers/Social-Risk-Management-DP/0543.pdf)

mandatory insurance programs like the Turkey Catastrophe Insurance Pool and catastrophe linked securities like the World Bank platform for a multi-country, multi-peril cat bond that transfers diversified risk to private investors. Remittances often play a crucial role as a coping mechanism for households after disasters. Governments can facilitate assistance to embassies and migrant associations to channel contributions after disasters, and ensure quicker restoration of financial infrastructure and money transfer facilities that may have been disrupted so as to facilitate uninterrupted flow of remittances by family and friends.[33]

Recommendations—A Plan for Action

With this in mind, the following actions are recommended as basic elements of a comprehensive strategy to build resilience. Some are long term goals that should be pursued for their own sake. Others are more specific but still generic for the most part. As mentioned above, they will ultimately need to be customized to address the political, social, and economic realities of the countries where they will be implemented.

Short-term (1 year)

1. Perform a risk-audit of critical infrastructure and a detailed risk assessment including cost-benefit analysis for the particular sector and prioritization of the assets to strengthen. A risk assessment is not only the first step in a disaster risk reduction program; the impact scenarios of a risk assessment are also increasingly incorporated in sustainable development approaches in order to climate- and disaster-proof infrastructure and development efforts in general.

2. Assess the integration of risk assessments and risk reduction into all major infrastructure investments.

3. Carry out a critical review of city-level disaster risk management policies and laws.

4. Review and update building codes and their enforcement. Hazard proofing of infrastructure is effective, especially where warning times are short. Appropriate codes can reduce the debilitating impacts of disasters on human safety and welfare.

5. Carry out a fiscal risk audit to assess the fiscal impact of natural disasters and existing budget instruments.

6. Develop multi-media communication strategies for natural hazards that are ethnically and culturally appropriate so that all stakeholders are aware of the risks and of measures to reduce the risks.

Medium-term (5 years)

1. Strengthen Early Warning Systems. Studies have shown that, apart from the incalculable benefits to human well-being, every dollar invested in meteorological and hydrological services produces a significantly greater economic return.

2. Adopt and enforce land use planning. Controlling development in hazardous zones, like floodplains, combined with providing incentives for development to take place elsewhere is crucial for effective disaster risk management.

3. Develop the capability for comprehensive, end-to-end, emergency preparedness that includes pre-event mitigation, emergency warning, evacuation, and shelter areas.

33 Mohapatra, Sanket, George Joseph and Dilip Ratha (2009), " Remittances and Natural Disasters: Ex-post Response and Contribution to Ex-ante Preparedness", http://siteresources.worldbank.org/INTPROSPECTS/Resources/334934-1110315015165/Remittances_and_natural_disasters_May_15.pdf

4. Green your city. Rapid expansion of metropolitan areas, and the impervious cover that accompanies such expansion, impedes rainwater from recharging aquifers and contributes to flooding and polluted run-off. Permeable pavements and green spaces reduce run-off and flooding.

5. Ensure resilience of existing public buildings (especially hospitals and schools) through a phased and fully funded retrofitting program. Improving the resilience of schools and hospitals will not only save lives and property but will also enable a more effective emergency management since the role of schools and hospitals goes beyond a structural facility that offers healthcare and educational services: they can serve as community shelters during a disaster or as centers to coordinate post-disaster response and recovery efforts.

6. Redesign the urban drainage infrastructure, taking into account the future impacts of climate change through sea-level rise, storm surge, and stronger rainfalls.

7. Develop a comprehensive disaster risk financing and insurance strategy, with a particular focus on the protection of public budgets against natural disasters (reserves, contingent credit, aggregate insurance).

Long-term (5-10 years)

1. Implement a comprehensive range of Catastrophe Risk Financing Products and Services to alleviate budgetary shocks of disasters and to pool risks. The strategies should involve public and private sectors.

2. Implement long-term risk reduction programs with components on infrastructure and capacity building. Infrastructure helps to keep hazards and people separated, for example through flood control structures. Invest in building human capital and institutional competence is necessary to identify and take appropriate actions.

3. Develop term and private property cat insurance markets with vehicles such as catastrophe insurance pools.

4. Invest in building regional and metropolitan capacity for urban governance across multiple jurisdictions and stakeholders.

5. Work to reduce poverty. Being poor is probably the greatest vulnerability to natural hazards.

Conclusions

Resilience in the face of multiple hazards is a global challenge; one in which rich as well as poor nations will struggle to make their way. Obviously, to the extent that wealthy nations have the resources to address issues of monumental scope and scale, they will have an advantage. However, this paper has attempted to illustrate that although many of the nations of East Asia are particularly vulnerable to natural hazards because of geography, the rapid pace of urbanization, limited resources, climate and large numbers of poor people, there is much that can be done, based on good practice in the region and globally that can protect people and assets from the worst impacts of natural hazards.

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