100 Resilient Cities
RESILIENCE POINT OF VIEW SERIES

Buildings and Resilience
Buildings in Yunnan Sheng, China
During its five years of operations, the 100 Resilient Cities program supported the participating city governments to prepare city-wide resilience strategies for each city. During these strategy development efforts, city governments and their stakeholders considered and prioritized a full range of urban risks and vulnerabilities, which spanned each city’s diverse communities, places, economic sectors, and operations.

As the strategy processes established each city’s resilience priorities and action areas, 100RC staff, together with 100RC’s 115 Platform Partners and scores of Subject Matter Advisors, provided further domain specific support to the cities’ relevant technical and managerial counterparts and stakeholders. These focused efforts led to the preparation of domain specific resilience frameworks and approaches. These approaches are now being summarized in this 100RC Resilience Point of View series.
100 Resilient Cities (100RC) works with city governments around the world to build their resilience through the appointment of a Chief Resilience Officer, development and implementation of a Resilience Strategy, and access to a global network of practitioner peers and technical experts. 100RC defines urban resilience as the capacity of individuals, communities, institutions, businesses, and systems within a city to survive, adapt, and grow no matter what kinds of chronic stresses and acute shocks they experience. The need for resilience in cities is heightened every day by the growing and dynamic effects of climate change, rapid urbanization, and globalization. These and other global demographic, technology, and political trends together expose cities and their interconnected built, social, and natural systems to an increasingly complex set of shocks and stresses.

The built environment – housing, schools, hospitals, public and private buildings, and the infrastructure that serve them – is critical in supporting urban resilience. This infrastructure provides the functions and services that support society. Traditional approaches to building planning and construction are not adequate to address the impacts of climate change, rapid urbanization and globalization. Deliberate resilience-based approaches to the planning, design, construction, operation and regulation of buildings are necessary to support the quality of the built environment and the overall resilience of cities and people across the globe.

The topic of resilience in the built environment has focused on the physical performance of buildings in the face of natural events such as severe wind storms or earthquakes and creating robustness and redundancy in building design. In more developed economies, resilience in the building industry is primarily concerned with rapid recovery of a building’s function to minimize economic and social impacts in extraordinary events. In less developed economies, resilience in the built environment is concentrated on improved building construction standards to reduce loss of life in a catastrophic event.

100RC believes that while both objectives are essential components of resilience, a resilience-based approach is one that pursues these objectives while also seeking to improve the quality of life of building users and reduce everyday and long-term social, economic and environmental urban stresses. These outcomes, and the ability of communities to withstand and thrive amid a variety of unforeseen shocks and stresses, are the desired goals of resilience, rather than improved physical performance of buildings themselves. 100RC refers to these types of opportunities as “co-benefits” or “resilience dividends” and support an opportunistic approach of maximizing the co-benefits that are realized from any single intervention or investment. To be successful, such an approach must be holistic, inclusive, integrated across diverse sectors, and forward-looking.
Rapid Urbanization

The rapid pace of urbanization, particularly in primary and secondary cities in the Global South, combined with a lack of planning for where this growth will be accommodated and a lack of capacity in many cities to regulate land use and construction quality, results in a number of negative stresses affecting the built environment such as increased informality and lack of basic utility provision to housing settlements; an increase in the number of human settlements on hazardous land as people seek space to build affordably; and increasingly poor-quality, unregulated building construction which is prone to damage and collapse in the event of earthquakes, floods, and hurricanes. These negative effects have the greatest impact on poor and vulnerable communities and reduce international development and global poverty alleviation efforts.

Why Act Now?

The total area of cities is expected to double by 2070, meaning that half of the urban landscape, which is primarily comprised of buildings, has not yet been built. This presents a huge opportunity to build resilience into these newly developed areas and to also rethink and improve buildings in existing areas of cities.

Climate Change

When not explicitly considered, the increasingly extreme and variable weather that accompanies climate change exposes buildings to greater risk of damage (e.g., flooded basements), shorter life spans (e.g., reduced durability of structural materials exposed to extreme temperatures), increased energy consumption (e.g., energy required to control temperature and humidity), and higher maintenance costs (e.g., crack repair, roof maintenance, etc.). Furthermore, buildings are responsible for nearly half of the CO2 emissions of the United States and account for approximately one-third of global energy use.

Why Act Now?

There is a significant opportunity to use resilience-based approaches to building design and/or retrofit to simultaneously address risk reduction and sustainability objectives, including interventions that reduce energy consumption, carbon emissions, and waste in building construction and operations. Furthermore, buildings that are designed and built with climate adaptation in mind are more likely to serve their vital functions for their full expected life span – demolishing and rebuilding structures that are damaged from climate impacts and other disasters only further contributes to carbon emissions and climate change.

Globalization

While globalization has had many positive impacts on society, it has also resulted in stresses that negatively impact the built environment and city resilience. The introduction of modern building materials such as reinforced concrete to places with underdeveloped professional design communities and insufficient government capacity to regulate their use has led to significantly elevated risk in the urban built environment, particularly in high seismic zones, as evidenced by the 2010 Haiti earthquake and numerous other recent natural disasters. Globalization has led to the proliferation of new building materials and products which are increasingly difficult for building professionals to test and regulate, leading to man-made tragedies like the 2017 Grenfell Tower fire in London. It also creates more interdependencies across systems and geographies, meaning that the buildings sector around the world is impacted by such disparate effects as changes in the global supply chain of steel, conflict-based migration, and the performance of the stock market.

Why Act Now?

Buildings are ultimately in the service of the people who use them and therefore have profound potential to produce positive impacts to counter some of the stresses that globalization has placed on society. Well-designed housing and social infrastructure can change behavior and reduce the increasing social inequity caused by globalization. Similarly, the thoughtful design of buildings and their connection to communities can reinforce local character and the value of place and community in an era of global homogeneity. Finally, improved regulation and oversight in the buildings sector, particularly around structural, health, and fire requirements, can prevent the “race to the bottom” that is a consequence of globalization and has led to other man-made tragedies like the 2013 Rana Plaza Factory collapse in Bangladesh.
The built environment – housing, schools, hospitals, public and private buildings, and the infrastructure that serve them – is critical in supporting urban resilience.
Current Resilience Practice in Developing Economies

In many parts of the world, the level of building construction quality is not sufficient to provide basic safety to occupants on a daily basis let alone in the event of a storm or an earthquake. In the context of developing economies, therefore, the term ‘resilience’ in the buildings sector is most closely associated with building safety improvements. This is particularly true in places with high concentrations of informal settlements, where housing is oftentimes built in hazard-prone areas such as steep hillsides and low-lying river basins and without regard to formal building standards. Resilience efforts are therefore focused on the development of:

- adequate and appropriate building code and standards that address both modern and vernacular methods of construction
- improved enforcement of building and land use policy and regulation through government capacity-building, operational streamlining and transparency-building
- approaches to support compliance with building regulation through the development of prescriptive design methodologies, builder and engineer training and certification programs, and financial incentives for compliance and safety improvements
- Housing policy approaches specifically addressing low-income and informal housing

Current Resilience Practice in Developed Economies

Over the past 30-40 years, the professional structural engineering community has become proficient in designing buildings to resist extreme loading scenarios without collapse. Building codes in most developed countries are up-to-date, widely used, and enforced. In the past 10-15 years, additional hazards such as floods, tsunamis, fires, blast events, and progressive collapse have been addressed in building codes and standards. Multi-hazard approaches to the physical design of building structures have become prevalent and the engineering community has developed standards supporting life-safety retrofits of existing deficient buildings. As a result of these advances, most buildings built in the last several decades in developed countries will remain standing in the event of a natural disaster and allow occupants to escape safely.

The term “resilience” for most building professionals is associated with the ability to recover essential functionality following a natural disaster.
While the focus of building codes and standards has traditionally been on safety and collapse prevention, building professionals over the past decade have begun to focus efforts on the recovery of essential functionality in buildings following a natural disaster (‘functional recovery’). The sooner a building, such as a home or a school can be re-occupied and serve its original or emergency function following a disaster, the better able it is to support the resilience of its users and its community. This understanding has introduced new considerations into building design and construction, including performance-based design approaches which allow building owners to specify their desired level of building performance in certain types of events above and beyond the code-based safety minimums, measured in “deaths, dollars and downtime.” Recognizing that functional recovery is not only about a building’s structural performance but also the functionality of essential building services such as water and power, building owners and consultants can design buildings to avoid damage to mechanical, electrical, and plumbing equipment from a range of potential hazards and can consider alternative backup sources of essential services such as generators, solar microgrids, and rainwater harvesting.

**Current Community Resilience Approaches**

While the buildings sector has focused for the most part on improving the safety and performance of individual buildings in the event of a disaster, there has been a growing recognition over the past decade of the value of ‘community resilience’ approaches. Recognizing that the individual performance of buildings in a disaster does not equate to the recovery of a community following a disaster, these approaches first focus on community priorities and available resources and translate this information down to the necessary building and infrastructure performance requirements in terms of the social and economic services they provide. Community resilience is also very much focused on the interdependencies between the built environment and human systems. The importance of inter-organizational collaboration, emergency preparedness and operational procedures, and funding availability are emphasized in addition to building codes and standards. Two examples are the National Institute of Standards and Technology’s Community Resilience Planning Guide for Buildings and Infrastructure and the Alliance for National and Community Resilience which aims to develop a set of community resilience benchmarks organized by individual sectors. Many of these efforts were initiated by members of the earthquake engineering community but developed with a multi-hazard approach that applies to hazards such as floods and wildfires which are increasingly the focus of resilience conversations.

The evolution of resilience in the buildings sector as described above – from asset-specific to community- and systems-based thinking, from physical to human dimensions, in both developing and developed contexts - illustrates a continually broadening approach. However, there remains an opportunity to leverage investments in new building construction and improvements to the safety and performance of existing buildings not only to reduce risk and the potential for physical and economic loss from an acute shock, but also to create broader social, environmental, and economic benefits that lessen the impacts of everyday chronic stresses and

**The sooner a building can be re-occupied and serve its original or emergency function following a disaster, the better able it is to support the resilience of its users and its community.**
allow communities to better handle all sorts of un-anticipated shocks and stresses. The RELi Standard, a certification standard for buildings, infrastructure, neighborhoods and communities focused on extreme weather hazards, is a new effort that emphasizes both physical and social factors and provides guidance on seeking opportunities for co-benefits. It also integrates disaster management objectives with sustainability objectives, which have traditionally been kept distinct.

A resilience-based approach requires more integrated and complex partnerships across professions including planners, architects, engineers, policy makers, sociologists and emergency management specialists. The Earthquake Engineering Research Institute is an example of a professional organization that has begun a dialogue and learning opportunities across these diverse groups of professionals on the topic of earthquake resilience, and similar approaches could be taken for resilience more broadly.
While the term “resilience” is used widely and incorrectly in the buildings sector to refer to materials (e.g., resilient wall cladding), to components within buildings (e.g., a resilient structural system), to individual buildings (e.g., a resilient hospital), and to groupings of buildings (e.g., resilience districts), none of these elements alone is resilient. Rather, collectively, and in concert with other natural and human systems, these elements may support urban resilience if they are carefully and intentionally integrated. A resilience-based approach to the built environment requires an understanding of the components of the building industry’s “ecosystem,” the key actors involved, and the processes that link them. It requires coordination across different physical and social domains as well as timescales. In other words, resilience-based approaches to the built environment require new and different modes of collaboration and decision-making.

Figure 1. Schematic of actors in the building industry ecosystem and resilience influencers
3.1 Systems-Based Frameworks for Resilience in the Built Environment

Figure 1 below is a schematic that begins to identify key actors involved in this work. The arrow indicates the direction of potential resilience influence. For example, academia and research play a role in determining government policies and regulations on land use and construction codes and standards. These regulations, in turn, influence the work of consultants and building contractors who are responsible for the end product. Similarly, banks issuing debt to building developers have influence over the criteria and performance standards for the asset and could therefore influence the work of the design consultants. In many cases, the arrows flow in both directions. While division of responsibility is necessary for industry efficiency, having a shared understanding of this landscape, regardless of one’s individual role, is important for collectively assessing the risks and opportunities for resilience-building within the buildings sector across various interconnected human systems of finance, governance, etc.

Whereas Figure 1 considers the various actors and disciplines contributing to resilience in and through the built environment, Figure 2 begins to identify the scales of intervention involved, starting first at a country’s administrative structure, laws, and policies and continuing through local-level policy and program-level practices to individual project approaches. Within each scale and each phase, there are opportunities to reduce risk, improve performance, and add greater value to building projects. For example, to support economic development objectives, a city could decide to leverage the construction phase of a building program or project to engage the local construction community. Implementation at a project or program level might present certain requirements on the physical design of the buildings in terms of preferred materials and construction techniques. Such an approach may also require special approvals or exceptions, or changes to standard procurement practices. It also might require modified material supply chains and new builder training programs. These factors must be considered and addressed simultaneously in the decision-making process.

Figure 2. Scales of built environment interventions
Figure 3 below begins to identify the subsystems that comprise the built-environment system and in concert with human and natural systems have the potential to achieve resilience outcomes. Not only do the nested subsystems each in sequence serve higher-level systems, but also the identification of resilience objectives at a community or city-scale should inform the requirements of each subsystem. At each level in the diagram, in order to mitigate risks and unlock additional benefits, it is necessary to consider the systemic relationships and interdependencies that might impact performance or whose performance might be impacted.

For example, at a building materials level, the use of precast concrete panels for walls and floors might provide benefits in terms of sustainability, cost and construction efficiency; however, they could also present risk related to seismic performance if connection design and associated construction and inspection processes do not explicitly consider potential vulnerabilities and human error.

Desired outcomes for resilient urban community: Reduce shocks and stresses.

Figure 3. Systems and subsystems of the built environment contributing to urban resilience
3.2 Characteristics of Resilience in the Built Environment

1OORC characterizes “resilience infrastructure” as infrastructure that:

1. Is conceived and developed through an inclusive and integrated process with inherent flexibility built into design and operations and data-driven monitoring that allows for learning and adaptation over time to manage uncertain and dynamic future conditions (i.e., resilience-based process)

2. Provides reliable physical performance in both routine and extraordinary situations by factoring direct impacts of shocks and stresses and indirect impacts resulting from interdependent infrastructure and social systems into the design, construction, and long-term operations of the project (i.e., reliable performance and intended outcomes)

3. Is conceived, designed, built, and operated to appropriately minimize and/or mitigate potential negative impacts based on its necessary function and to maximize, based on financial constraints, social, economic, and environmental benefits to the poorest and most vulnerable populations (i.e., co-benefits)

Each of these characteristics can be applied to the buildings sector using the frameworks described above to begin to establish practical guidance and policy for government, building owners, and industry practitioners to better address today’s complex and dynamic challenges. It should be noted that this type of holistic approach is nascent, and while components of this approach are common in the industry, gaps remain. Very few current projects can be pointed to that have taken a comprehensive resilience-based approach. This section, therefore, provides practical suggestions for how this approach can become more mainstream and embedded in traditional industry practices.

3.2.1 A Resilience-Based Process

A resilience-based process in the buildings industry includes the following characteristics applied across the ecosystem, scales of intervention, and systems identified in Figures 1-3 above:

- Building design must put users and other beneficiaries at the center of the design process, with an emphasis on the least advantaged members of society. This can be done through ongoing and substantive consultation and engagement with target beneficiaries and impacted communities. Successful engagement processes meet people where they are in the community and often find creative ways to surface input throughout the life span of the project.

- Planning and design processes must be better integrated across technical and functional disciplines within the built environment sector and over the life cycle of a project’s design and implementation. At a city scale, and for city-led projects, this must include better integration across agency functions and budgets (recognizing mutual benefit), and new approaches to procurement that favor more integrated and multidisciplinary contractor teams and focus on desired outcomes. It also must include a deliberate strategy for linking individual building projects to a city’s strategic and long-term development objectives.

- Building projects must consider both current conditions and a range of possible future environmental, social, demographic, and market scenarios in their programming, design, and performance objectives to ensure reliable performance in a variety of conditions; safe failure when thresholds are exceeded; and value and usability over the full life cycle of the project.

- Whether through smart technologies, building management systems, or more basic operational procedures, buildings and building systems should have mechanisms in place to
collect data, understand performance over time, and adjust accordingly to ensure intended resilience value is delivered over the life span of the asset and to improve performance where possible. The role of a Building Commissioning Authority in verifying an owner’s program of requirements as implemented by the design team is key; however, the commissioning process could expand beyond technical performance verification at the completion of construction to also include social and environmental performance evaluation as well as ongoing evaluation over the life span of the project. An effort to collect and share the data from such a process would also support research and development within the building design community.

3.2.2 Reliable Performance and Intended Outcomes

Adoption of the resilience-based approach described in the previous section by the public and private sector supports achieving reliable performance in both routine and extraordinary situations; however, there must also be a deliberate focus on the desired outcomes of this process to ensure it is a means to an end.

• A building’s design, construction and long-term operations must factor in the acute shocks it could be subjected to over its useful life and the desired performance it must achieve in each of these scenarios, whether that is strictly life-safety or a higher performance level. In addition to the shocks that could directly impact the building structure and services, one should also consider the impacts from other types of shocks that indirectly impact a building’s ability to function as intended resulting from systemic interdependencies across physical, human, and environmental domains. These include power outages, loss of water supply, cyberattacks, inability of staff to access the building, and so on.

• A building’s design, construction and long-term operations must also account for the chronic stresses that could, over time, reduce the building’s performance such as chronic lack of funding for maintenance and upkeep or increasing demands on capacity from population growth. Additionally, there may be indirect stresses, such as a poor regulatory environment, which should be factored into and mitigated by the project approach.

• These shocks and stresses should be clearly identified and defined at the start of the project and desired performance levels for each potential scenario articulated. Performance-based design methodologies which define a series of physical performance objectives for buildings subjected to varying hazard or threat levels are one common approach; similar approaches could be considered for social shocks and longer-term social and environmental stresses resulting from factors such as urban growth and climate change. Additionally, where a project’s scope does not provide the ability to address indirect stresses (for example the lack of a qualified construction labor market) it may be necessary to pursue or advocate for parallel projects or programs to address these risks.

3.2.3 Co-Benefits

100RC uses the City Resilience Framework (CRF) as a tool for articulating the drivers of resilience and the complex interactions and interdependencies across them. The CRF can also be used as a means of identifying co-benefits or “resilience dividends” to built environment programs or projects that can be deliberately incorporated with limited additional resource allocation, cost, or disruption. For example, a well-conceived building project has the potential to not only provide shelter or services, but also foster economic prosperity; ensure social stability, security, and justice; and promote cohesive and engaged communities; and in doing so, allows urban communities to better handle all sorts of shocks and stresses. A similar approach can be
taken to identify and deliberately eliminate or minimize potential unintended negative consequences to programs or projects. The incorporation of green or sustainable features into the design and operations of buildings is one common example of creating co-benefits (or minimizing unintended consequences, depending on how you view it).

A recommended approach to deliberate incorporation of co-benefits and minimizing of negative consequences includes the following:

- In the same way that a project should identify and respond to the shocks and stresses it faces, it should also identify and attempt to respond to the shocks and stresses that the community or city in which it is located faces. At the conception of a project, the shock and stress profile of the community should be determined and kept as a guiding feature throughout the project life cycle (see Figure 3).

- This local profile as well as relevant needs, sensitivities, and risks will also naturally emerge if inclusive and integrated planning and implementation processes as described in Section 3.2.1 are used. Impacted communities and direct and indirect beneficiaries of projects should be given a voice in project planning from its conception.

- Cost-benefit and triple-bottom-line analyses should be leveraged to fully articulate the added value from resilience-based approaches and interventions within a project versus the added cost. When avoided losses as well as social, economic, and environmental benefits are factored into a financial and economic analysis of various project schemes, it provides an objective means of decision-making and drives political and community support for more resilient alternatives.

Flooded street in Vejle, Denmark
Following a resilience-based process and achieving resilience-based outcomes may sound straightforward in concept but is difficult in practice for a number of reasons including those articulated below. New tools, procedures and, most importantly, policies are needed to overcome these hurdles.

- There is cost associated with resilience approaches to building projects compared to traditional, business-as-usual approaches. Engaging stakeholders in a substantive way in the planning and design process adds time and cost; building flexibility, robustness, and redundancy into building systems beyond immediate, basic functional needs adds to cost; adding quality assurance measures in design and construction increases cost. To counter the natural tendency to race to the bottom, there must be both policies and incentives in place to require and/or encourage these values to be upheld. Cities, as building developers and owners, should also ensure that they are favoring resilience-based approaches in their procurement practices.

- The integration of community benefits into a building project may create broad social, economic, or environmental returns over time but no direct or immediate revenue streams to finance the additional upfront cost. The same inclusive and integrated planning processes that identify co-benefits can also support the identification of funding and financing strategies for resilience projects. Project owners should identify public and/or private sector partners who would benefit from a project, engage them in project planning, and pool resources to provide enhanced resilience benefits within a project. Innovative financial approaches and products are needed to support this type of effort. Automated cost-benefit analysis tools should be more commonly used by project owners and designers to understand the full implications of design decisions beyond direct cost.

An integrated resilience-based approach requires a coordinated effort across various governance scales, time scales, and disciplines.
siloed and there are multiple owners of “resilience value” at any point in time in a project’s execution and multiple handovers over a project’s life span. This lack of coordination can lead to missed opportunities and the degradation of resilience value over time. In response to this, the building industry, including governments investing in new building and infrastructure projects, could consider a new role termed “resilience advocate” tasked with ensuring that resilience-building opportunities are maximized and maintained across the life cycle of a project. This could be an evolution of the commissioning authority. Furthermore, building professionals and practitioners should as part of their education and training be taught and encouraged to think more systematically and understand the interdependencies across systems, scales, and disciplines in the building industry so that there is a common understanding of the risks, opportunities, and levers that must be considered.

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