Building Community Resilience through Modern Model Building Codes

Alliance for National & Community Resilience

ICC INTERNATIONAL CODE COUNCIL®

Building Community Resilience through Modern Model Building Codes

ISBN: 978-1-60983-867-6

Publications Manager:	Mary Lou Luif
Project Editor:	Daniel Mutz
Production Technician:	Beverly Ledbetter
Cover Design:	Duane Acoba

Errata on various ICC publications may be available at www.iccsafe.org/errata.

First Printing: November 2018

PRINTED IN THE USA

T023217

Acknowledgments

The contents of this ICC publication were developed by Brian Meacham, PhD, PE, Managing Principal of Meacham Associates (https://meachamassociates.com/). The author gratefully acknowledges the many photographs by the Federal Emergency Management Agency (FEMA) photographers that are individually cited within this publication, as well as the research undertaken by FEMA, the Multihazard Mitigation Council (MMC) of the National Institute of Building Sciences (NIBS), the National Institute of Standards and Technology (NIST), the National Oceanic and Atmospheric Administration (NOAA), the U.S. Geological Service (USGS), the Institute of Business and Home Safety (IBHS), which underpins this publication. The author sincerely appreciates the helpful input and review by ICC staff, and the extraordinary efforts of the many ICC committee members who draft, maintain, and enforce the International Codes® (I-Codes®).

About The International Code Council

The International Code Council is a member-focused association. It is dedicated to developing model codes and standards used in the design, build, and compliance process to construct safe, sustainable, affordable, and resilient structures.

Most US communities and many global markets choose the I-Codes. ICC Evaluation Service (ICC-ES) is the industry leader in performing technical evaluations for code compliance, fostering safe and sustainable design and construction.

Governmental Affairs Office: 500 New Jersey Avenue, NW, 6th Floor
Washington, DC 20001-2070

Eastern Regional Office (BIRMINGHAM)
Central Regional Office (CHICAGO)
Western Regional Office (LOS ANGELES)

Phone: 888-ICC-SAFE (888-422-7233)
Website: www.iccsafe.org

About the Alliance for National and Community Resilience (ANCR)

The Alliance for National & Community Resilience (ANCR—pronounced "anchor") is an ICC co-founded 501(c)(3) national coalition aimed at improving resilience and implementing good community practices in towns and cities across the United States and helping cities prevent infrastructure failure caused by natural and other disasters, thereby avoiding negative social, economic, and welfare repercussions caused by such damages. ANCR's primary objective is the development of a system of community benchmarks—the first system of its kind in the United States—that will allow local leaders to easily assess and improve their resilience across all functions of a community. When adverse events occur, all gears in the local system must continue to function. ANCR intends to give communities a voluntary, transparent, usable, and easily understandable accredited self-assessment that helps to showcase their whole community resilience and to provide a simple gauge of how their resilience continues to strengthen.

Photos/Images Source: The source for each photo/image in this publication has been identified under each photo/image. Where a source is not identified, the source is Getty Images.

Table of Contents

Introduction

Introduction

Introduction

Over the past twenty years, the United States has experienced a series of natural and human-caused disasters—events that have significantly impacted its society, economy, and culture. Despite the devastating losses, the nation has largely emerged from these events stronger and better able to handle the next. This has been possible because its people are resilient by nature—when disaster strikes, they come together, help those in need, and implement measures to reduce the potential for similar harm in the future. However, as populations grow, urban areas expand, and interconnectedness increases, the potential for a disaster event to have deeper and further-reaching consequences also increases. As a result, there is a need to implement measures that increase societal, economic, and cultural resilience—*community resilience*.

Resiliency is about the ability to plan and prepare for, absorb, recover from, and more successfully adapt to adverse events regardless of whether the subject is an individual or our society, a business or our economy, a single bridge or all critical infrastructure. Each of these components ties together communities: homes, places of employment, utilities and transportation infrastructure, which everyone relies upon, and more. When adverse events occur, all gears in the local system must continue to function. A building constructed to the most current code, that stands tall in a disaster, must be reachable by transportation systems and sidewalks during and after that disaster to be continued to be used. The building must have electrical power and functioning communication systems. If grocery store shelves are bare for extended periods, people may not be able to stay or function at peak efficiency. The resilience of each community function, and how well each function can respond to adverse events, must be well understood for a community to be resilient. Resilience in the built environment starts with strong, regularly adopted, and properly administered building codes. However, to attain whole community resilience,

Figure 1

The remaining section of the World Trade Center is surrounded by a mountain of rubble following the September 11 terrorist attacks.

Photo by Bri Rodriguez/FEMA

Figure 2

Aerial views of flood and fire damage in the Breezy Point neighborhood as a result of Hurricane Sandy. Following the hurricane, a nor'easter struck the area causing more power outages and additional flooding.

Photo by Andrea Booher/FEMA

Figure 3

Interconnection of buildings and infrastructure

Photo by Brian Meacham

communities must look at the resiliency of all interconnected systems and functions of the community as well.

Widespread acknowledgment of the need for community resilience became clear after such events as the Loma Prieta (1989) and Northridge (1994) earthquakes, the terrorist attacks on the World Trade Center and Pentagon (2001), and Hurricanes Katrina (2005) and Sandy (2012). While the United States has long provided support for response and recovery to such events, it has become increasingly clear in recent years that being proactive reaps more benefits than being reactive. By better understanding how hazard events can disrupt communities, and by implementing measures to mitigate the impact of those events in order to quicken recovery, communities become more resilient. In addition, investing in mitigation before an event occurs can significantly reduce losses when the event occurs. With respect to natural hazard events alone, recent studies have demonstrated that for every $1 invested in mitigation from a specific set of hazard mitigation grants, the nation receives $6 in benefits as avoided future losses—a benefit-to-cost ratio of 6 to 1.[1]

Recent studies have demonstrated that for every $1 invested in mitigation from a specific set of hazard mitigation grants, the nation receives $6 in benefits as avoided future losses.

While this return on investment is significant, the picture is incomplete. It does not include the social, economic, and cultural benefits gained by adopting and enforcing the most current building and planning codes, nor does it include benefits derived from private-sector mitigation investments. Each of these benefits is also significant. Considering only the adoption and enforcement of building codes, a recently completed study of the effectiveness of the Florida Building Code[2] (FBC) in reducing

Following the Northridge earthquake in Southern California many buildings with steel frames (structural steel moment frames) and prefabricated walls (tilt-up walls) were severely damaged. Subsequent analyses of the damages resulted in several code changes that:

1. Strengthened wall anchorage requirements;
2. Enhanced observation and testing requirements for key structural connections; and
3. Required seismic strengthening across several building and material types.

1. Multihazard Mitigation Council (2017). Natural Hazard Mitigation Saves: 2017 Interim Report. National Institute of Building Sciences, Washington DC.
2. Simmons, K.M., Czajkowski, J., and Done, J.M. (2017) "Economic Effectiveness of Implementing a Statewide Building Code: The Case of Florida," (July 25, 2017). Available at SSRN: https://ssrn.com/abstract=2963244 or http://dx.doi.org/10.2139/ssrn.2963244, last accessed 4 June 2018).

wind-related losses shows that for the 10-year period from 2001 through 2010, implementation and enforcement of the FBC reduced windstorm losses by up to 72%. Financially, the estimated benefit-to-cost ratio is similar to the effectiveness of hazard mitigation grants noted above: up to $6 dollars in reduced losses for every $1 dollar of added cost of mitigation. In the case of the FBC, a payback period of approximately 8 years was estimated.

This type of loss reduction during future events is indicative of benefits gained when the most current building codes, which include the latest in technologies and methodologies for loss reduction, are implemented and enforced. Similar outcomes in terms of loss reduction associated with building codes have been observed as associated with earthquake, tornado, and other natural events. Unfortunately, building codes have not been regularly adopted and implemented in every state and local jurisdiction. Furthermore, in some jurisdictions that have adopted a building code, it may be based on a model code that is 10 years or more behind the most recent edition, therefore without the benefit of the 10 years plus of enhanced mitigation data, technologies, and methodologies. To increase community resilience to hazard events, particularly natural hazard events, more extensive adoption, implementation, and enforcement of the most current model building codes is needed.

The ICC goal of building safety and resiliency supports making our nation's communities more resilient, and the ICC is a founding member of the Alliance for National & Community Resilience (ANCR).[3] ANCR aims to provide the information that communities need to understand and benchmark their current level of resiliency, identify and understand options available to fill gaps and increase resiliency, and to understand the future benefits to be gained by

Figure 4

A lone, mitigated home stands in Long Beach, Mississippi. Hurricane Katrina caused extensive damage all along the Mississippi gulf coast.

Photo by Mark Wolfe/FEMA

Figure 5

Complete destruction in Bay St. Louis, Mississippi, three weeks after Hurricane Katrina.

3. http://www.resilientalliance.org/

Figure 6

Downed power lines in a neighborhood devastated by Hurricane Irma in Ramrod Key, Florida, on September 21, 2017.

Photo by J.T. Blatty/FEMA

investing in advance of the next hazard event. Helping communities to understand the measurable benefits of adopting the most current building and planning codes, as an important component of community resilience, is a particular focus of this initiative.

In addition, the ICC works with other countries, including high-, middle-, and low-income countries, to bring these concepts into play. Low- and middle-income countries have the least capacity to cope with disasters. In many of these countries, the populations of urban centers are rapidly expanding, and the existing building regulatory infrastructure and capacity is struggling to keep up. As a result, many are living in low-quality housing with limited access to stable utilities and public services, which puts them at higher risk of being exposed to an extreme hazard event. The implementation of better building regulatory systems will help reduce the devastation of natural hazard events and increase community resilience.

This publication has been created to help policy makers, and those who are responsible for enhancing community resilience, better understand the fundamental components of community resilience and the critical role that regularly updated, adopted, and properly administered modern building codes serve in facilitating community resilience. The concepts noted above are explored in more detail throughout this publication. Also provided are examples that illustrate the benefits to be gained from making this a national, state, and local priority.

The I-Codes are developed by a public-private collaboration that provides modern model codes to government jurisdictions. As a result, government does not have to take on the high cost of developing its own codes and benefits from the code uniformity among adopting jurisdictions.

Defining Resiliency

Whole Community Resilience

The terms *resilient* and *resiliency* come from the Latin word to rebound or bounce back. The terms are widely used to describe the ability to return to normal after suffering some type of loss. The concept applies to individuals, society, ecologies, economies, physical infrastructure, and more.

In applying the concept of resiliency to the built environment—the building stock that houses people, businesses, government, and utilities—the ICC considers four primary components:[1]

- efficient disaster mitigation and recovery,
- ensuring mental and physical health and well-being,
- improving building life cycles, and
- creating a sustainable community.

These components are intertwined in a way that is not easy to separate. People own, rent, live, and work in buildings. These buildings have power, water, heating, cooling, and sanitary systems that make them safe and comfortable to occupy. The buildings are connected by transportation infrastructure for moving people, goods, and services. Buildings and infrastructure that are not resilient to adverse events do not promote or facilitate mental and physical health and wellbeing. Buildings that must be torn down after a hazard event are not sustainable.

When considering what it takes to create resilient communities, it is important to understand that communities function as complex, interconnected "systems of systems," and that individual systems rarely, if ever, operate in isolation from one another. When an adverse event occurs, all gears in the local "system of systems" must continue to function: this is *whole community resilience.*

Definition
ICC considers the definition of *resilience* as the ability to prepare and plan for, absorb, recover from, and more successfully adapt to adverse events.

ICC Vision
Protect the health, safety, and welfare of people by creating safe buildings and communities.

1. See https://www.iccsafe.org/about-icc/safety/resiliency/ for more discussion.

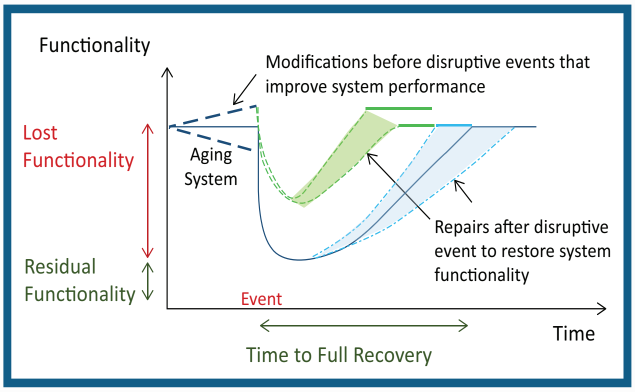
Figure 7

Representative critical infrastructure components within a community

Adapted from Cauffman, 2014 [2]

Figure 8

Representation of response and recovery from an adverse event



Adapted from Cauffman, 2014 [2]*;*
Bruneau et al., 2003 [3]*; McDaniels et al., 2008* [4]

Whole Community Resilience

Whole community resilience means that a building constructed to the most current code, that stands tall in a disaster, must be reachable by transportation systems and sidewalks during and after that disaster to be continued to be used. Furthermore, the building must have electrical power, functioning communication systems, and sanitary facilities to continue to be used. For the occupants of the building to remain nourished and functional, grocery store shelves must continue to be refilled. To attain whole community resilience, a community must understand the interconnections between its critical systems, how they might be impacted by adverse events, and how they can make the systems and the community stronger, more adaptable, and more quickly able to recover when disaster strikes.

Whole community resilience starts with strong, regularly adopted, and properly administered building and planning codes. Where buildings are located—and how they are constructed and maintained—are fundamental components of resiliency. If buildings are located in areas of susceptibility to natural hazard events, or if buildings are not constructed with sufficient strength to resist natural hazard forces, they may not be able to absorb, recover from, and return to normal operation after an adverse event.

A graphical representation of the resiliency concept is provided in Figure 8. From the perspective of the normal life cycle of a building, a building is at its best the day it is completed and occupied. This is the starting point on the vertical axis. With regular maintenance, the functionality (blue line) remains

2. Cauffman, S.A. (2014). “Community Disaster Resilience,” presentation at *Mpact Week 2014*, University of Maryland, 22 October 2014 (available at https://eng.umd.edu/html/mpact/oct22-session1.html, last accessed 1 August 2018).
3. Bruneau, M., Chang, S.E., Eguchi, R.T., Lee, G.C., O’Rourke, T.D., Reinhorn, A.M., Shinozuka, M., Tierney, K., Wallace, W.A., and von Winterfeldt, D. (2003). “A Framework to Quantitatively Assess and Enhance the Seismic Resilience of Communities,” *Earthquake Spectra*, Volume 19, No. 4, pages 733–752.
4. McDaniels, T., Chang, S., Cole, D., Mikawozc, J., and Longstaff, H. (2008). “Fostering resilience to extreme events within infrastructure systems: Characterizing decision contexts for mitigation and adaptation,” *Global Environmental Change*, Volume 18, Issue 2, May 2008, Pages 310–318.

consistent with time. If proper maintenance does not occur, the functionality decreases (declining blue dotted line). If enhancements are made to the building, functionality can increase (rising blue dotted line).

Chapter 16 of the IBC and Chapter 3 of the IRC address earthquake design and seismic design categories for the design of safe buildings.

When an adverse event occurs, the magnitude of the immediate impact, as well as the time until full recovery, depends on the level of resiliency of the building and its systems. A building that has not been adequately maintained, for example, is likely to suffer greater initial impact, and requires more extensive repairs, which increases time and cost (blue line and blue shading). If a building has resiliency built in, the initial impact is generally much lower, as are the repair and replacement time and cost (green line and green shading). The resiliency of the building also has a direct impact on business operations because the downtime of operations, impact to contents, and other related factors will be reduced as well. Having a *business continuity plan* (BCP) is important.[5]

Figure 9

Earthquake damage in Pioneer Square, a part of Seattle's historic district

Kevin Galvin/FEMA

In Figure 9 it is easy to see that the brick building in the foreground suffered significant damage in the earthquake, whereas the neighboring buildings did not. One could see where businesses in the undamaged building could be up and running as soon as the street is cleared and power is operating, but those in the damaged building would be forced to wait until the building was repaired, or in the worst case would have to relocate if the building would need to be demolished. The business impacts could be significant.

As noted earlier, ensuring mental and physical health and wellbeing of the members of communities is an important component of resiliency as well. In the case above, the building owner, business owner and employees, and business customers would all be impacted. Temporary or permanent loss of employment

5. Many resources for business continuity planning (BCP) are available. A good starting point is FEMA, https://www.ready.gov/business.

imposes significant stress on individuals and families. Loss of business, or worse yet, being forced out of business, can have devastating emotional impact in addition to the financial losses. Losing one's home can also take an unimaginable toll.

It is well known that impacts of disasters can be devastating to our communities: the people who live and work there, the businesses, and the local economy. The good news is that meaningful steps can be taken to mitigate the impact of disasters before they occur. It is not possible to stop natural hazard events from occurring. It is not possible to reduce their frequency or severity. It is not possible to eliminate the threat of deliberate acts of terrorism. However, it is possible to make communities, businesses, society, and the economy more resilient by reducing the impact of such events when they occur and by implementing plans that get everyone back on their feet more quickly. This starts by increasing the resiliency of the built environment, then expanding to increase the resiliency of all interconnected systems and functions. The end result is whole community resilience.

Figure 10

Residents of a Staten Island neighborhood look at properties destroyed by Hurricane Sandy.

Photo by Andrea Booher/FEMA

Figure 11

Interconnections of a resilient community[6]

6. Cauffman, S.A. (2014). "Community Disaster Resilience," presentation at *Mpact Week 2014*, University of Maryland, 22 October 2014 (available at https://eng.umd.edu/html/mpact/oct22-session1.html, last accessed 1 August 2018).

Why Resiliency of the Built Environment Is Important

- Natural Hazard Events
- Human-Related Events
- Hazards Are Common: Disasters Do Not Need to Be
- Well-Constructed Buildings Suffer Less Damage from Hazard Events
- Well-Constructed Buildings Enhance Well-Being, Health, and Sustainability
- Resilient Buildings Facilitate Adaptive Reuse and Recovery from a Range of Events

Natural Hazard Events

Natural disaster events exact a devastating toll on society. Looking around the world just in this century alone, natural hazard event-related fatality estimates include some 250,000 from the Indian Ocean earthquake and tsunami in 2004; 180,000 from Cyclone Nargis in Myanmar in 2008; 300,000 from the Haitian earthquake in 2010; and some 70,000 and 56,000 deaths from the heat waves in Europe (2003) and Russia (2010), respectively. Droughts, flooding, wildland fire, tornados, and more add significantly to the overall totals. Looking to the United States over this same period, people lived through such events as Hurricane Katrina in 2005, which killed more than 1,800; several devastating tornado seasons, including 2011, which resulted in more than 500 fatalities; the devastating hurricanes and wildland fires of 2017; and the expansive wildland fire season to date in 2018. Each of these events, and the many others that occurred, have impacted the collective psyche of the nation, its communities, and the multitude of families and individuals involved. They have the potential to significantly disrupt our economy. They have severe direct and indirect economic impacts.

One needs only to look at four events that occurred in 2017 to understand the

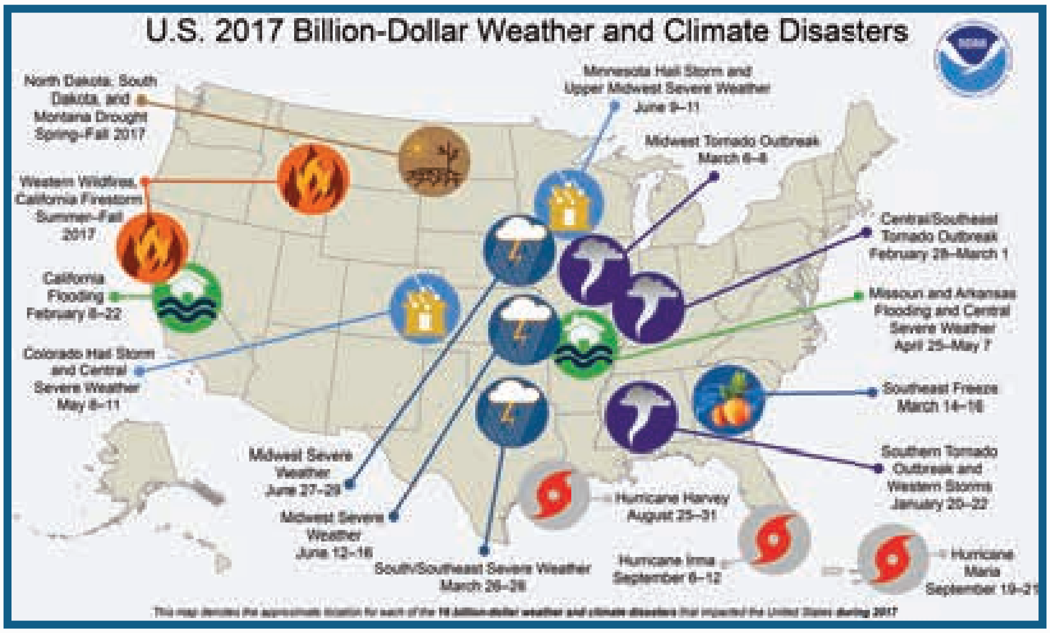
Figure 12

Aerial view of New Orleans and the surrounding area showing the flood waters and damage caused from Hurricane Katrina.

Photo by Jocelyn Augustino/FEMA

Figure 13

Billion-dollar weather and climate disasters in 2017[1]



NOAA National Centers for Environmental Information (NCEI) U.S. Billion-Dollar Weather and Climate Disasters (2018). https://www.ncdc.noaa.gov/billions/

1. National Centers for Environmental Information (NCEI), National Oceanic and Atmospheric Administration (NOAA), 2018 (https://www.ncdc.noaa.gov/billions/, last accessed 5 June 2018).

Figure 14

View from FEMA's Urban Search and Rescue Virginia Task Force Two, which is searching neighborhoods inside Houston for survivors after flooding caused by Hurricane Harvey

Photo by FEMA News

magnitude of the social and economic consequences of natural hazard events: Hurricanes Harvey, Irma, and Maria, and the wildfires and subsequent mudslides in California. From an economic perspective, 2017 was an historic year in terms of natural hazard events, with 16 separate billion-dollar disaster events, which together totaled $309.5 billion—a new US annual record—that obliterated the previous record of $219.2 billion set in 2005 from the impacts of Hurricanes Dennis, Katrina, Rita, and Wilma.[2] The death toll in Puerto Rico could likewise eclipse past human losses from natural hazard events.

Historically, the United States spends billions of dollars in disaster response and recovery. This is understandable: we want to help rescue people who are trapped and injured; we want to restore power, water, and other utilities to get people and businesses back in operation; we want to help those significantly impacted to recover emotionally, physically, and financially.

However, significant social and economic gains can be made by investing in mitigation to reduce the human and financial losses associated with such events—to make communities safer and more disaster resilient. While we cannot prevent rain from falling, wind from blowing, or earthquakes shaking us about, we can look to reduce rebuilding in hazard-prone areas, and we can increase the resistance of our buildings to these natural forces.

Investing in mitigation to reduce the human and financial losses associated with natural disasters can provide significant social and economic gains while also making communities safer and more disaster resilient.

Human-Related Events

Much like natural hazard events, human-related events—fires, explosions, accidents, poor construction, and deliberate events—can lead to devastating losses. The 2013 collapse of the Rana Plaza in Bangladesh resulted in some 1,300 deaths. A 2004 supermarket fire in Paraguay killed almost 400 people, and the 2013 Kiss

2. National Centers for Environmental Information (NCEI), National Oceanic and Atmospheric Administration (NOAA), 2018 (https://www.ncdc.noaa.gov/billions/, last accessed 5 June 2018).

Nightclub fire in Brazil killed some 250. The Grenfell Tower fire in London killed more than 70 people. The economic impacts can be significant as well. According to Allianz, fires and explosions in the built environment accounted for 59% of 1,807 business interruption claims globally, according to data analyzed over a five-year period, with losses in 2015 in the billions of US dollars.[3] In addition to this, the losses associated with terrorism, civil unrest and similar deliberate events can be staggering.

Fires and explosions in the built environment accounted for 59% of business interruption claims globally, according to data analyzed over a five-year period.

Looking at the United States over this same period, the terrorist attacks on the World Trade Center and Pentagon in 2001 resulted in more than 3,000 deaths and some $44 billion in direct and indirect economic impact; the 2003 Station Nightclub fire in Rhode Island resulted in 100 fatalities; and several large-scale industrial facility fires, including the 2005 Texas City Refinery fire and explosion and the 2013 fertilizer plant explosion in West, TX, have resulted in hundreds of millions of US dollars in direct and indirect economic losses, in addition to fatalities and injuries.

Hazards Are Common: Disasters Do Not Need to Be

Natural and human-related hazards will always exist. While one can often take steps to mitigate the impact of hazard events when they occur, it can be difficult or impossible to prevent the events from occurring—especially natural hazard events.

From 2016 though 2018 more than 100 million people in the United States, a third of its population, suffered in some way from natural disasters, including tornados, hurricanes, earthquakes, wildfires, and flooding.

When one thinks of disasters, one often thinks of, and refers to, natural hazard events, such as hurricanes, tornados, floods, earthquakes, and wildland fires. These events are viewed as wreaking havoc on homes, businesses, communities, and lives. However, these natural events have been happening throughout the life

3. https://www.agcs.allianz.com/assets/PDFs/Reports/AGCS-Global-Claims-Review-2015.pdf (accessed June 2018).

Figure 15

View of Hurricane Katrina from space

of the planet, and many, like wildland fire, serve useful purposes in making the ecosystem more resilient. While some of these natural events may be getting more intense, that is not the sole problem: the problems develop when these events occur in locations where people live and work.

While some might say "just move out of the hazard-prone area," in most cases there are limited choices—the decisions were made decades or centuries ago. The cost to relocate would be prohibitive. If cost were not an issue, the physical land area needed for relocation may not be available. One also must be careful about trading one type of hazard event for another, since it is hard to find places that are not exposed to some type of extreme event over time. There are few options other than making our built environment more resilient to these natural events, as well as to the deliberate attacks that we have witnessed in recent years.

The good news is that because the changing patterns of weather events and their attributes are studied—wind speeds, rainfall rates and potential, snow and ice potential—the forces developed by earthquakes centered at different depths through different soil types—the factors contributing to wildland fire development and spread—informed decisions about how to mitigate the effects through better building design can be made.

ICC's Wildland-Urban Interface Code

The intent of this code is to mitigate the risk to life and structures from intrusion of fire from wildland fire exposures, including fire exposures from adjacent structures, and to mitigate structure fires from spreading to wildland fuels.

Well-Constructed Buildings Suffer Less Damage from Hazard Events

Well-constructed buildings suffer less damage from hazard events, which means lower costs, faster recovery, and less social and economic disruption. This has been known for centuries. So too have been the benefits of appropriate building regulation. Some of the first building regulations in the Western world were imposed following the Great Fire of London in 1666 to mitigate the impact of fire in London. Similarly, building codes were developed and implemented in the United States following the various conflagrations of the late 19th century, the 1906 San Francisco earthquake and fire, and numerous other natural and human-related events. The building code system in the United States developed out of this recognition to design buildings to safeguard the health, safety, and welfare of the occupants and the community.

Figure 16

An aerial view showing damage from Hurricane Harvey

FEMA News Photo—Bob Epstein

From a large-scale natural hazard event and community resilience perspective, the benefits of adopting and enforcing current building codes, with up-to-date technology, hazard data, and more, was highlighted in the 1989 Loma Prieta earthquake and the 1992 Hurricane Andrew. As a result of Hurricane Andrew, for example, more than 125,000 Florida homes were damaged or destroyed, and about 250,000 people were left homeless in south Miami-Dade County. Overall, the financial impact was more than $24 billion (in 2016 dollars), ranking amongst the nation's most costly disasters.[4]

However, this level of loss did not need to have occurred. If the existing building codes were enforced, the Insurance Information Institute observed that 25% of the insured losses from Hurricane Andrew could have been prevented.[5]

Hurricanes and Tornados

The structural provisions of the IBC and IRC address construction in high-wind areas subject to hurricanes and tornados.

In response to the widespread damage, the Florida Building Code was updated, with many additions including mitigation measures for resistance to high wind speeds. The value of these code changes was seen in 2004, when Hurricane Charley hit Florida. A study conducted by the Institute of Business and Home Safety (IBHS) following Hurricane Charley[6] found that improvements to the codes adopted in 1996 and enforced in Florida, as

4. Insurance Information Institute, *Facts + Statistics: Hurricanes*, https://www.iii.org/fact-statistic/facts-statistics-hurricanes, last accessed 7 June 2018.
5. Kunreuther, H. 1996. Mitigating disaster losses through insurance, *Journal of Risk and Uncertainty* 12:171–187.
6. IBHS, 2004. *Hurricane Charley: Nature's Force vs. Structural Strength*, http://disastersafety.org/wp-content/uploads/hurricane-charley-report.pdf (last accessed 7 June 2018).

ICC Standards
ICC 500 and ICC 600 address construction of storm shelters and residential construction in high-wind areas.

updated after Hurricane Andrew, resulted in a 60% reduction in residential property damage frequency (number of claims) and a 42% reduction in damage severity (cost of claims) as compared with Hurricane Andrew. For example, claims that resulted from homes built between 1996 and 2004 resulted in:

- 44% fewer total roof covering replacements compared to homes built before 1996. Instead, homes built between 1996 and 2004 most often required only partial roof covering replacements.
- 38% fewer homes had window glass and/or frame damage compared to homes built before 1996. Instead, homes built between 1996 and 2004 had a higher frequency of window screen damage only.
- 32% fewer total garage door replacements compared to homes built before 1996. Instead, the majority of homes built between 1996 and 2004 required only minor garage door repairs, such as track adjustments or dent repairs from debris impact.

Figure 17

Remains of one house in front of an undamaged house after Hurricane Charley

Photo by Andrea Booher/FEMA

More recently, researchers looked specifically at the benefits gained in hurricane damage loss reduction by adoption and enforcement of the Florida Building Code (FBC) with changes since Hurricane Andrew.[7] In this study, they considered hurricanes and associated losses over a ten-year period. The results show that statewide adoption and enforcement of the FBC resulted in having actual losses reduced by as much as 72% as compared with Andrew. Furthermore, based on the benefit-cost analysis that was conducted, compliance with the FBC results in $6 in reduced loss to $1 of added cost, with a payback period of approximately 8 years. This benefit-to-cost ratio of 6 to 1 is consistent with findings presented by the Multihazard Mitigation Council (MMC) in their recent assessment,[8] as well as with prior studies.[9]

Studies such as the above are supported by research conducted by FEMA. For example, a 2014 FEMA analysis estimated the approximately $500 million in annualized losses could be avoided in eight southeastern states due to the adoption of modern building codes.[10] This included potential losses from flood, wind and earthquake. A number of FEMA studies on loss avoidance have been conducted related to flooding, tornado, and hurricane,[11] and a wide range of helpful mitigation/loss avoidance guidance is available through FEMA as well.[12] These include several documents on how adoption and enforcement of the latest building codes helps.

The key point is that well-constructed buildings, designed to the latest building codes, are a significant

Figure 18

A town employee shows the hurricane shutter system that was installed on the town hall after Hurricane Wilma. The town used money from a FEMA Mitigation Grant for the shutters. Since the shutters were installed, no damage has occurred to this building in Brevard county.

Photo by Liz Roll/FEMA

The benefit-to-cost ratio of 6 to 1 is consistent in various studies, including findings presented by the Multihazard Mitigation Council.

7. Simmons, K.M., Czajkowski, J. and Done, J.M. (2017) "Economic Effectiveness of Implementing a Statewide Building Code: The Case of Florida," (July 25, 2017). Available at SSRN: https://ssrn.com/abstract=2963244 or http://dx.doi.org/10.2139/ssrn.2963244, last accessed 4 June 2018).
8. Multihazard Mitigation Council (2017). *Natural Hazard Mitigation Saves: 2017 Interim Report*. National Institute of Building Sciences, Washington DC.
9. Multihazard Mitigation Council (2005). *Natural Hazard Mitigation Saves: An Independent Study to Assess the Future Savings from Mitigation Activities*. National Institute of Building Sciences, Washington DC.
10. FEMA, Phase 3 National Methodology and Phase 2 Regional Study, *Losses Avoided as a Result of Adopting and Enforcing Hazard-Resistant Building Codes*. (See http://www.floods.org/Files/Conf2015_ppts/A4_Laatsch.pdf for an overview, last accessed 1 August 2018)
11. https://www.fema.gov/hmgp-loss-avoidance-studies
12. https://www.fema.gov/building-science-publications

Figure 19

A well-designed interior space

factor in avoiding and reducing potential losses when disaster strikes. When buildings are resilient, the community is resilient, leading to faster recovery and less overall economic and social disruption.

Well-Constructed Buildings Enhance Well-Being, Health, and Sustainability

Indoor environments have strong positive effects on occupant well-being and functioning, as well as on occupant health.[13] If people are comfortable in the building—temperature, air quality, connection to the outdoors—they feel better and are more productive. However, poor indoor environments can lead to a variety of adverse health effects that result directly in increased physician visits and medical treatment, which can lead to increases in health insurance costs, both for institutions and for individuals. For example, a 1997 study reported that the cost to the nation's workforce due to upper respiratory diseases in 1995 was $35 billion in lost work plus an additional $29 billion in health care costs.[14] This study estimated that more healthful indoor environments could reduce these costs by 10% to 30%.

When buildings are resilient, the community is resilient, which leads to faster recovery and less overall economic and social disruption.

These issues can be addressed, and the well-being and health of occupants can be increased, by integrating a few key concepts into buildings. If moisture control is in place within the building envelop and interior sources of water, it will help reduce the formation of mold. This will reduce health effects related to mold, in addition to reducing the potential for water- and mold-related damage. If building materials do not contain highly toxic materials, occupants will not be exposed. If ventilation is adequate, it will help with moisture and indoor air quality, and people will be healthier. Each of these

13. *Whole Building Design Guide*, https://www.wbdg.org/design-objectives/productive/promote-health-well-being, last accessed on 7 June 2018.
14. W.J. Fisk and A.H. Rosenfeld, 1997. "Estimates of Improved Productivity and Health from Better Indoor Environments," *Indoor Air*, Vol. 7, pp. 158–172.

aspects is addressed in building codes—and more. This helps create healthier and more comfortable conditions. Furthermore, as new information becomes available about how to increase health and well-being in buildings the codes are modified, test methods to look for precursors of problems are developed and referenced in the codes, and better performing buildings are built as a result.

The same is true for sustainability. Sustainability is largely about not using more of the Earth's resources than needed and not causing damage to the environment through our use of these resources in supporting our daily lives. Sustainable design merges natural, minimum resource-conditioning solutions (e.g., daylight, solar heat, natural ventilation) with innovative technologies into an integrated system that can result in environmental quality and resource consciousness.[15] Buildings with inadequate insulation, poor-performing heating, cooling and lighting are not sustainable. In addition, buildings that suffer significant damage in hazard events are not sustainable—demolition and rebuild significantly contributes to Carbon load across life cycle (i.e., extraction, fabrication, operational, demolition, and disposal). In these ways and more, sustainability and resiliency are strongly linked.

Figure 20

A green building

Photo by Brian Meacham

Resilient Buildings Facilitate Adaptive Reuse and Recovery from a Range of Events

The ability to withstand a wide range of hazard events is of course an important aspect of resiliency; however,

15. Loftness, Vivian et al. "Elements That Contribute to Healthy Building Design." *Environmental Health Perspectives* 115.6 (2007): 965–970.

adverse events can manifest in other forms as well. Economic downturns can devastate communities, especially if companies close down local operations that employ large numbers of people and provide critical economic infrastructure, or if large numbers of the community move to other places in search of new job opportunities. Whole community resilience must include consideration of these types of adverse events as well—planning to mitigate, respond, and successfully recover from them and to adapt to the new needs of the community is essential.

40% to 60% of small businesses never reopen their doors following a disaster, and 90% of smaller companies fail within a year after the disaster unless they can resume operations within five days.

According to FEMA, 40% to 60% of small businesses never reopen their doors following a disaster and 90% of smaller companies fail within a year after the disaster unless they can resume operations within 5 days.[16] A 2017 study by the National Bureau of Economic Research shows that severe disasters increase out migration rates and lower housing prices, especially in areas at particular risk of disaster activity.[17]

ICC's Existing Building Code

The intent of this code is to provide flexibility to permit the use of alternative approaches to achieve compliance with minimum requirements to safeguard the public health, safety, and welfare insofar as they are affected by the repair, alteration, change of occupancy, addition, and relocation of existing buildings.

For many communities, much of their building stock for the next generation is already built. In some cases, these buildings have been an essential part of the community for 100 years or more. These might be old brick factories and warehouses from the industrial revolution and the block housing where the factory workers lived. They might include a wide range of downtown buildings that housed dozens of small shops before large malls were built outside of town. Some may be office buildings or other commercial spaces that are being converted to lofts and other living spaces for people moving back into city centers. In many of these cases, the aim is to reuse as much of the building as possible, while meeting the objectives for health, safety,

16. FEMA, Make Your Business Resilient: Infographic (Sept. 2, 2015), available at https://www.fema.gov/media-library-data/1441212988001-1aa7fa978c5f999ed088dcaa815cb8cd/3a_BusinessInfographic-1.pdf
17. Boustan, L.P. et al., *The Effect of Natural Disasters on Economic Activity in US Counties: A Century of Data,* Natural Bureau of Economic Research, (May 2017 (https://www.bls.gov/opub/mlr/2017/beyond-bls/the-effect-of-natural-disasters-on-local-economies.htm, last accessed 15 August 2018.

sustainability, and resiliency built into the most recent building regulations.

If a robust and resilient building regulatory system is in place within a community when disaster strikes—be it a natural hazard, accidental or deliberate human event, or economic downturn—it can be a driver for rebuilding to be more resilient to future events, a driver for adaptive reuse of existing buildings, a driver for increasing the environmental, societal, and economic sustainability of buildings and of the community, and a driver for increasing whole community resilience.

Figure 21

Freedom Tower at the new World Trade Center

Figure 22

The remaining section of the World Trade Center is surrounded by a mountain of rubble following the September 11 terrorist attacks.

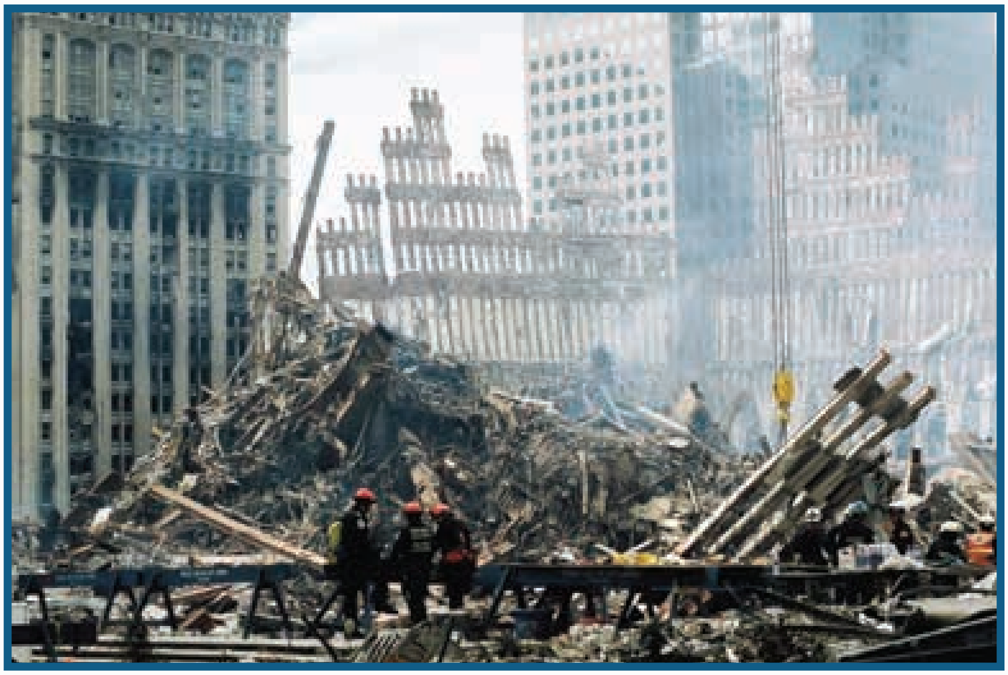


Photo by Bri Rodriguez/FEMA News Photo

How Implementation and Regular Updating of Building and Planning Codes Increases Resiliency

A comprehensive building regulatory system enables the achievement of many social and economic objectives by defining minimum levels of expected performance in terms of health, safety, welfare, accessibility, sustainability, and resiliency. A building regulatory system also facilitates economic development and stability by establishing effective, efficient, and reliable regulatory practices that incentivize economic investment. It does so by providing the market with a clear set of design and construction requirements and quality standards, which in turn minimizes barriers to trade and facilitates investor confidence.[1] Conversely, a deficient building regulatory system can result in a vulnerable built environment that creates risk for structures and their occupants when exposed to natural and technological hazards, that does not afford access for people of all abilities, that does not meet consumer and market usability needs, and that does not facilitate sustainability and resiliency objectives.

A modern and effective building regulatory system incentivizes economic investment by providing the market with a clear set of design and construction requirements and quality standards, which in turn minimize barriers to trade and facilitate investor confidence.

Figure 23

Building regulatory system ecology

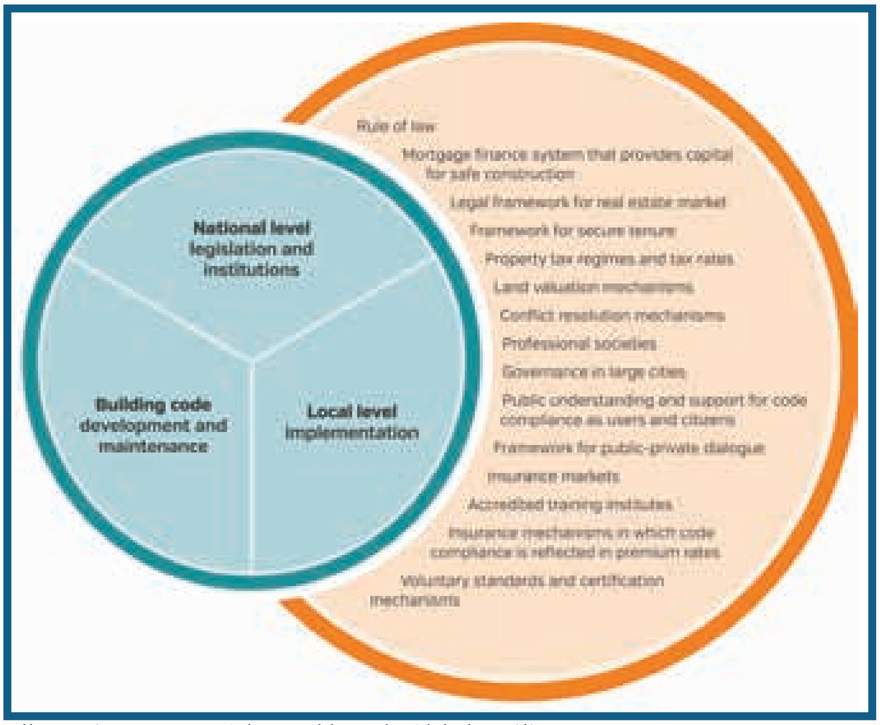


Illustration courtesy of the World Bank, Global Facility for Disaster Reduction and Recovery

Components of a comprehensive building regulatory system include legal and administrative (i.e., enabling legislation), planning, building and fire code development and maintenance, and implementation and compliance mechanisms.[2] The building regulatory system is supported by regulatory infrastructure, which

1. World Bank (2017). *Building Regulatory Capacity Assessment: Level 1 - Initial Screening.* Washington, DC: World Bank. https://openknowledge.worldbank.org/handle/10986/27655 License: CC BY 3.0 IGO.
2. Meacham, B.J., Ed. (2010), *Performance-Based Building Regulatory Systems – Principles and Experiences*, IRCC (available for download at http://ircc.info/Doc_page.html, last accessed 9 June 2018).

includes requirements for education and training, licensing of practitioners, insurance, and more. The building regulatory system and supporting infrastructure function together holistically to ensure that a particular building on a particular site is able to achieve expected regulatory and market objectives for acceptable performance. These tenets are not only the basis of the building regulatory system in the United States, but they are shared by governments and non-governmental organizations around the world.[3]

The ICC governmental consensus process meets the principles defined by the National Standards Strategy of 2000, and the OMB Circular A-119, Federal Participation in the Development and Use of Voluntary Consensus Standards and in Conformity Assessment Activities (1998). It complies with Public Law 104-113 National Technology Transfer and Advancement Act of 1995.

US Building Regulatory System Overview

Responsibility for regulating buildings across the nation is determined by the constitution and administrative law of each state and territory. Within a state or territory, responsibility for developing, implementing, maintaining, and ensuring compliance with planning, building, and fire codes can range from the state level down to the local level. While each jurisdiction could develop its own building and fire codes, this would be inefficient and could lead to significant variation between locations. Instead, most jurisdictions that implement building, fire, plumbing, mechanical, and other codes adopt model codes. This provides a high degree of uniformity between jurisdictions and provides them with access to a pool of experts who keep the model codes up to date with the latest technologies, practices, and lessons learned.

ICC Mission
To provide the highest quality codes, standards, products and services for all concerned with the safety and performance of the built environment.

Most states and local jurisdictions adopt the model building codes developed and maintained through committees of the International Code Council (ICC). The ICC's family of codes (I-Codes) consists of 15 codes including but not limited to:

3. Meacham, B.J., Ed. (2010), *Performance-Based Building Regulatory Systems - Principles and Experiences,* IRCC (available for download at http://ircc.info/Doc_page.html, last accessed 9 June 2018).

- The *International Residential Code®* (IRC®), which applies to new one- and two-family dwellings and townhouses of not more than three stories in height;
- The *International Building Code®* (IBC®), which applies to most other types of new buildings;
- The *International Existing Building Code®* (IEBC®), which applies to the alteration, repair, addition, or change in occupancy of existing structures;
- The *International Fire Code®* (IFC®), which safeguards life and property from fires and explosion hazards;
- The *International Wildland-Urban Interface Code®* (IWUIC®);
- The *International Plumbing Code®* (IPC®), which provides innovative plumbing regulations addressing both prescriptive and performance-based objectives;
- The *International Mechanical Code®* (IMC®), which provides minimum regulations for mechanical systems using both prescriptive and performance-related provisions; and
- The *International Fuel Gas Code®* (IFGC®), which provides innovative regulations for the design and installation of fuel gas systems.

The I-Codes are developed through a governmental consensus process.[4] In this process, the codes are developed and maintained by committees, which include members representing public safety officials, industry, design professionals, building users, and more. The process is characterized by openness, transparency, balance of interest, due process, consensus, and availability of an appeals process. Anyone

Figure 24
Covers of I-Codes

Covers of I-Codes

The International Code Council develops construction and public safety codes through a governmental consensus process adhering to the these principles: openness, transparency, balance of interest, due process, appeals process, and consensus.

4. For more, please see https://www.iccsafe.org/codes-tech-support/codes/code-development/.

can submit a code change proposal, make a public comment, or participate in code hearings at no cost.

The first editions of the I-Codes were published in 2000. These reflected the consolidation of regional model codes that were previously developed by three different organizations. Since many state and local jurisdictions adopt the I-Codes, the consolidation in 2000 has resulted in a high degree of uniformity in building and fire codes across the country. Furthermore, the ICC publishes new editions of the I-Codes every three years. This affords states and local jurisdictions the ability to take advantage of the changes to the codes to facilitate advancements in technology, methods of construction, hazard mitigation techniques, and more.

I-Codes provide minimum safeguards for people at home, at school, and in the workplace. The I-Codes are a complete set of comprehensive, coordinated building safety and fire prevention codes that benefit public safety.

Figure 25

A steel shelter bolted to a concrete garage floor was all that remained of a wood-frame home destroyed in the Joplin, Missouri, tornado of May 22, 2011. NIST researchers studied this, and other in-home shelters, as part of the agency's investigation of the storm's impacts.

FEMA Mitigation Assessment Team

Why Up-to-Date Codes Are Essential for Community Resilience

As introduced in the previous section, there are numerous examples of the economic benefit of adopting and enforcing up-to-date building codes, including:

- If the adopted building codes were enforced at the time of Hurricane Andrew in 1992, 25% of the insured losses could have been prevented.[5]
- When Hurricane Charley hit in 2004, statewide adoption and enforcement of the Florida Building Code (based on the IBC) resulted in actual losses being reduced by as much as 72% as compared with Andrew, the benefit-to-cost ratio being in \$6 in reduced loss to \$1 of added cost, with a payback period of approximately 8 years.[6, 7, 8]

5. Kunreuther, H. 1996. Mitigating disaster losses through insurance, *Journal of Risk and Uncertainty* 12:171–187.
6. IBHS, 2004. *Hurricane Charley: Nature's Force vs. Structural Strength*, http://disastersafety.org/wp-content/uploads/hurricane-charley-report.pdf (last accessed 7 June 2018).
7. Simmons, K.M., Czajkowski, J. and Done, J.M. (2017) "Economic Effectiveness of Implementing a Statewide Building Code: The Case of Florida," (July 25, 2017). Available at SSRN: https://ssrn.com/abstract=2963244 or http://dx.doi.org/10.2139/ssrn.2963244, last accessed 4 June 2018).
8. Multihazard Mitigation Council (2017). *Natural Hazard Mitigation Saves: 2017 Interim Report*. National Institute of Building Sciences, Washington DC.

- Approximately $500 million in annualized losses could be avoided in eight southeastern states due to do the adoption of modern building codes.[9]

- Effective and well-enforced building codes in Missouri reduced hail damage to homes by 10% to 20% on average.[10]

- Following the Northridge earthquake in 1994, the California Seismic Safety Commission concluded that there would have been far less damage had building codes been rigorously enforced and building code inspectors sufficiently trained.[11]

- A strong empirical correlation was found between weak local government code enforcement and the number of buildings damaged in particular localities affected by the Northridge earthquake.[12]

- With respect to natural hazard events, for every $1 invested in mitigation from a specific set of hazard mitigation grants, the nation receives $6 in benefits as avoided future losses—a 6 to 1 benefit-to-cost ratio.[13]

The cited reports focus on natural hazard events only. In addition, code changes aimed at reducing the impact of human-related events, such as fires and explosion, have demonstrable economic benefits. Furthermore, there are significant benefits other than economic, arguably in more important areas, such as life safety. This applies across all types of hazard events.

Figure 26

Damage from the Northridge earthquake

9. FEMA, Phase 3 National Methodology and Phase 2 Regional Study, *Losses Avoided as a Result of Adopting and Enforcing Hazard-Resistant Building Codes*. (See http://www.floods.org/Files/Conf2015_ppts/A4_Laatsch.pdf for an overview, last accessed 1 August 2018).
10. Czajkowski, J. and Simmons, K. (2014). Convective Storm Vulnerability: Quantifying the Role of Effective and Well-Enforced Building Codes in Minimizing Missouri Hail Property Damage, *Land Economics*, University of Wisconsin Press, Volume 90, Number 3, pp. 482–508.
11. California Seismic Safety Commission (1995). *Northridge Earthquake: Turning Loss to Gain*, Seismic Safety Commission Report to Governor Pete Wilson.
12. Burby, R.J., French, S.P. and Nelson, A.C. (1998). "Plans, Code Enforcement, and Damage Reduction: Evidence from the Northridge Earthquake," *Earthquake Spectra*, Vo. 14, No.1, pp. 59–74, https://doi.org/10.1193/1.1585988.
13. Multihazard Mitigation Council (2017). *Natural Hazard Mitigation Saves: 2017 Interim Report*. National Institute of Building Sciences, Washington DC.

Figure 27

Little remains of a commercial building destroyed by an EF3 tornado that struck the city of Mena, Arkansas, the evening of April 9, 2009.

Photo by Win Henderson/FEMA

Each year tornados wreak havoc on communities across the eastern half of the United States. In recent years, significant tornado events have caused widespread damage and numerous deaths. When tornado outbreaks occur, storm shelters—in homes, as part of designated safe shelter buildings, or as specifically design structures—can mean the difference between life and death.

While storm shelters were not required by the building code enforced in Joplin at the time of the 2011 tornado outbreaks, the National Institute of Standards and Technology (NIST) investigation noted that where shelters existed, they did their job: "based on a few instances observed in this tornado, in-home shelters did perform well and provided life safety protection to the home owners."[14]

Similar outcomes were observed in the tornado outbreaks that cut across eastern Mississippi, north and central Alabama, northwestern Georgia, and eastern Tennessee in 2011; Kansas and Oklahoma in 2012 and 2013; and the many other devastating tornados before and since. It cannot be repeated enough that residential and community storm shelters save lives, and where adopted, provisions for storm shelters and safe rooms in current building codes and standards, such as ICC/NSSA 500, can be the difference between life or death in areas prone to hurricanes and tornados.

As a result of lessons learned from the widespread damage of the 2011 tornado season, the IBC was modified to include a requirement for storm shelters in essential facilities and schools in certain tornado zones (starting in the 2015 edition of the IBC). While there is not a requirement for storm shelters in the IRC, a requirement was added that if a storm shelter is to be built, it must comply with ICC 500, *ICC/NSSA Standard for the Design and Construction of Storm Shelters.*

Having construction that meets current building code requirements saves lives and reduces cost in a wide range of buildings, not just residential. Whole community resilience means that businesses and critical supporting infrastructure need to be

14. Kuligowski, E.D., Lombardo, F.T., Phan, L.T., Levitan, M.L., and Jorgensen, D.P. (2014). *NIST NCSTAR 3, Technical Investigation of the May 22, 2011, Tornado in Joplin, Missouri - Final Report,* National Institute of Standards and Technology (NIST), Gaithersburg, MD (https://nvlpubs.nist.gov/nistpubs/NCSTAR/NIST.NCSTAR.3.pdf, accessed June 2018).

resilient to disasters as well: If grocery stores are destroyed, access to food is difficult; if retail stores are destroyed, it can have an impact on getting materials needed to rebuild. Designing civic buildings, such as schools, town offices, and other buildings, as safe shelters helps those unable to upgrade the safety of their homes. All of this is enabled with implementation of the most current building codes.

Figure 28

This business in Greenville, Kentucky, has been heavily damaged due to a severe storm and tornado.

Photo by George Armstrong/FEMA

Likewise, building code provisions aimed at reducing wildland fire threats can be a differentiator between building survivability and destruction. Implementation of ignition-resistant construction, noncombustible roof coverings, screens to prevent burning embers from penetrating into eaves and under foundations, controlling for direct connection to combustible decking, fencing and related exterior components, and creating and maintaining defensible spaces around the building are some of the important components within the *International Wildland-Urban Interface Code.*

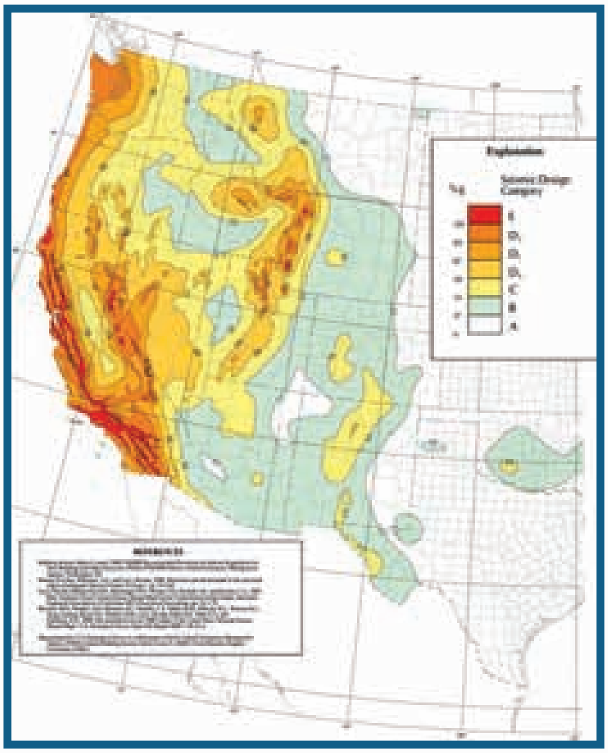
Importantly, the process of updating the building codes on a 3-year cycle allows for the updating of hazard maps. This is particularly important as climate and weather patterns change, resulting in higher wind speeds during storms, more intense short duration rainfall events, extended drought conditions, and increased snow and ice potential. Similarly, as the U.S. Geological Survey (USGS) updates hazard maps for riverine flooding, earthquakes, tsunamis, and more, these become adopted into the I-Codes, along with related mitigation technology and methods, to significantly increase the hazard resiliency of buildings.

ICC 600 specifies prescriptive methods to provide wind-resistant designs and construction details for residential buildings of masonry, concrete, wood-framed, or cold-formed, steel-framed construction sited in high-wind regions where design wind speeds are 120 to 180 miles per hour.

With respect to code changes, during each 3-year ICC code change cycle about 3,000 or more code change proposals are processed for the family of I-Codes, mostly

Figure 29

Seismic hazard map of the West Coast



USGS

Figure 30

Aerial view of homes destroyed in Rancho Bernardo neighborhood due to the Southern California wildfires

Photo by Andrea Booher/FEMA

within the building code, residential code, fire code, existing building code, plumbing code, and mechanical code. These include enhancements associated with mitigation of damage due to wind, rain, flooding, earthquake, and wildland fire. This amount of code changes per cycle is near the historical norm. Considering that there have been six code change cycles since the first edition of the I-Codes in 2000, and using 3,000 code changes per cycle, *this reflects some 18,000 changes since 2000.*

Consider the range of natural hazards that have occurred since 2000:

- the M6.8 Nisqually earthquake near Seattle, WA, in 2001;
- Hurricane Charley in 2004;
- Hurricane Katrina in 2005;
- the California wildfires in 2007;
- the "Super Tuesday" tornados in Tennessee, Arkansas, Kentucky, Alabama, and Illinois in 2008;
- the 2011 tornado season, which impacted most southern and southern-Midwest states;
- Superstorm Sandy in 2012;
- the April 2014 tornado outbreaks in Nebraska, Louisiana, Oklahoma, Illinois, Florida, North Carolina; and
- the devastating hurricanes, wildland fires, flooding, and mudslides of 2017—just to name a few.

In addition, the nation has experienced the terrorist attacks on the World Trade Center and Pentagon in 2001, The Station nightclub fire in 2003, and a wide range of fires and explosions in the residential, commercial, and industrial sectors.

In response to these related events, numerous changes have been made to the I-Codes. Table 1 provides a very small sampling to indicate the breadth and impact of updates to the I-Codes.

As reflected in Table 1, lessons are learned from each event—updates to hazard maps and mitigation technology—and these are integrated into the subsequent editions of the I-Codes following each event. This is extremely important as a means of continuously increasing the resilience of buildings and communities.

Furthermore, lessons are learned from disasters that have struck elsewhere in the world, which come from hazards that may not have been experienced in the United States for some time but will strike again at

Table 1

A Small Sampling of Selected Contemporary Resiliency-Related Changes to the International Codes

Subject	Brief Description
Tsunami-resistant design	Many coastal communities in the western US (Alaska, California, Hawaii, Oregon, and Washington) need tsunami-resistant design for essential facilities and critical infrastructure. A new appendix establishes protections for at risk coastal communities, including updated design loads[a] for these facilities.
Wind map and design enhancements	Tables detailing wind structural design requirements by region were updated to align with the latest wind design standards and to include special wind regions of mountainous terrain and gorges.
Protection of openings in windborne debris regions	Requirements for glazed openings (e.g., windows) to be protected from windborne debris were enhanced.
Seismic map updates	Seismic maps and corresponding design criteria have been updated to better capture seismic risk.
Structural observations	High-rise buildings and Risk Category IV buildings (e.g., hospitals and police/fire stations) require structural observation to ensure that complex, critical design elements are reviewed and done to exact specifications.
Fire watch for buildings under construction	Several significant fires have ignited at construction sites. In response to this challenge, fire code officials are authorized to require a fire watch during nonworking hours for buildings more than 40 feet in height.
Storm shelters	Storm shelters are required to be constructed in critical emergency operations facilities and in educational facilities in high-risk tornado areas.
Photovoltaic panel systems	Design requirements for roof structures supporting PV panels have been added to ensure panels remain connected during wind events and roof support structures can handle the panels' weight. Clearance is also required for fire fighter access and panel disconnects must be readily accessible.
Special inspection for seismic resistance	Special inspection of certain steel frame connections is mandated, given the importance of these connections to structural integrity during a seismic event.

Table 1

A Small Sampling of Selected Contemporary Resiliency-Related Changes to the International Codes

Subject	Brief Description
Fire testing for indoor finishes	More accurate burn tests are required for certain plastics used in interior finishes.
Furniture storage and display fire sprinkler	Automatic fire sprinkler requirements were added for manufacturing, storage, and display of furniture and mattresses in facilities larger than certain sizes.
Floor level exit signs	Where exit signs are required in hotel and motel facilities, floor level exit signs are also required in the means of egress serving the guest rooms.
Fire service and occupant evacuation elevators	Fire resistance requirements have been added for elevator system components to ensure fire service and occupant evacuation elevators are able to continue to function and serve their intended purposes in an emergency.
Foundation strengthening	Minimum requirements for building foundations (i.e., footings) were made to be more responsive to the structural design characteristics of the buildings they support.
Floor, ceiling, and roof strengthening	Lumber load carrying capacities have been reduced to align more accurately with the characteristics of currently utilized lumber materials.
Wood fastening requirements	Wood fastening requirements (e.g., nails, nail patterns) are revised and updated to reflect best practices.
Energy conservation	Numerous provisions have been added so that buildings can be conditioned using less energy, which means that they can also be habitable for longer periods of time after loss of power in both hot and cold exterior conditions.
Enhanced anchorage requirements for concrete and masonry walls	These requirements increase resiliency of existing buildings where large alterations are undertaken.
Enhanced bracing requirements for unreinforced masonry walls above the roofline (parapets)	These requirements increase resiliency of existing buildings where large alterations are undertaken.
Strengthened wind resistance requirements for retrofit structures	New guidance is provided for retrofitting existing structures, roof decks, and roof ends (gable ends) to strengthen their resistance to wind forces.
Protection of drinking water	New standards to protect drinking water in water tanks, which can be relied upon for potable water during an interruption in the external water supply, have been added. Requiring that all components in water treatment meet the correct standards ensures dangerous toxins are not leached and makes the production of potable water systems more resilient.
Rainwater, graywater, and reclaimed water	Rainwater, graywater, and reclaimed water can be used to flush water closets and urinals and be used for subsurface irrigation systems, ensuring continued internal plumbing function during a drop in external water pressure.
Emergency preparedness	Evacuation plans are now required for factory/industrial buildings and additional crowd managers are now required for events exceeding 500 people.
Protection of fire service and occupant evacuation elevators	Water from automatic sprinklers must be prevented from entering into fire service and occupant elevators.
Smoke detection for airport traffic control towers	Provisions for smoke detection in airport traffic control towers, critical infrastructure in disaster response, have been improved.
Fire fighter air replacement systems	New criteria have been included for the design, installation, and testing of fire fighter air replacement systems that are installed in buildings for use during firefighting operations.
High-rise fire sprinkler installation	Automatic fire sprinkler system provisions have been added to be retroactively installed in existing high-rise buildings.
Wildland-Urban Interface Code	Requirements concerning roof covering fire resistance and standby power for water pumps, controllers, and related electrical equipment have been recently added to the Wildland-Urban Interface Code, which addresses the protection of urban areas from wildland fire disasters.
Flood mitigation	Minimum building/structure elevations have been increased to better protect residential buildings in areas with flood risk.

a. In a general sense, design load is the maximum amount of force the components comprising a building are designed to withstand.

some point in the future. Earthquake and tsunami hazards are two examples.

Although the United States has not suffered a significant earthquake in many years, it will happen again, and the impacts could be significant. It is not possible to predict when, but as scientific and engineering understanding of the hazards and how they can be mitigated through building design grows, and as lessons from earthquakes that happen in other parts of the world and how buildings in those regions performed are learned, the I-Codes are appropriately updated. To facilitate this learning and knowledge transfer, the ICC has close relationships with counterparts in many countries, including earthquake- and tsunami-prone countries such as Haiti, Chile, Japan, and New Zealand. When significant earthquakes occurred in those countries in recent years—the 2010 Haiti Earthquake, the 2010 Maule Earthquake in Chile, the 2010–2011 Canterbury Earthquakes in New Zealand, and the 2011 Great East Japan (Tōhoku) Earthquake and tsunami—earthquake experts, who sit on ICC code development committees, were part of teams that provided help, investigated impacts of those events, and facilitated changes to the *International Building Code* where deemed appropriate.

In particular, following the 2011 Great East Japan (Tōhoku) Earthquake and tsunami, subsequent revisions to the *International Building Code* included the addition of a new Appendix M on refuge structures for vertical evacuation from tsunami-generated flood hazard. This appendix, which cites FEMA P646, *Guidelines for Design of Structures for Vertical Evacuation from Tsunamis*,[15] provides guidance on siting and structural resiliency of these safe havens.

These and countless more benefits are available in the most recent I-Codes because lessons have been learned

Figure 31

This building was damaged by the magnitude 6.0 earthquake that struck Napa and is in dangerous condition, resulting in a fenced-off street and closed businesses in the area.

Photo by Eilis Maynard/FEMA

Figure 32

This photo shows a dedicated tsunami refuge shelter in Sendai City, Japan, which was constructed following the 2011 Great East Japan (Tōhoku) Earthquake and tsunami.

Photo by Brian Meacham

15. FEMA P646, *Guidelines for Design of Structures for Vertical Evacuation from Tsunamis*, FEMA, 2008 (https://www.fema.gov/media-library-data/20130726-1641-20490-9063/femap646.pdf, accessed June 2018).

IBC Appendix G

The intent of this appendix is to protect human life, minimize the expenditure of public money for flood control projects, minimize the need for rescue and relief efforts associated with flooding, minimize prolonged business interruption, minimize damage to public facilities and utilities, help maintain a stable tax base by providing for the sound use and development of flood-prone areas, contribute to improved construction techniques in the flood plain, and ensure that potential owners and occupants are notified that a property is within a flood hazard area.

In its most recent five-year strategic plan, FEMA states that "disaster resilience starts with building codes, because they enhance public safety and property protection."

from past events, new mitigation technologies are embraced, and the goal of protecting public safety remains paramount. Achieving this goal is facilitated through the fostering of whole community resilience; however, the only way to gain these benefits is from the regular adoption of the most current I-Codes. If this is not done, these benefits are lost.

Furthermore, there are several other benefits to regular updating of building codes, as identified by the insurance industry,[16] homeowners, business owners, and others:

- Giving residents a sense of security about the safety and soundness of their buildings;
- Offering protection to first responders during and after fires and other disaster events;
- Promoting a level, predictable playing field for designers, builders, and suppliers;
- Allowing for economies of scale in production and building;
- Reflecting recent design and technology innovation, often incorporating newly identified best practices and cost efficiencies; and
- Reducing the amount of solid waste in landfills produced by homes and other buildings that are damaged or destroyed during disasters.

The I-Codes also include information and guidance that can be essential in even further mitigating the impacts of hazard events through nonmandatory guidance that is provided in appendices. A great example is Appendix G to the *International Building Code* on flood-resistant construction. Appendix G provides additional flood-plain management and administrative requirements embodied in the National

16. https://disastersafety.org/ibhs-public-policy/building-codes/

Flood Insurance Program (NFIP) that are not included in the code. However, adoption and implementation of the IBC and Appendix G will meet the minimum requirements of NFIP as set forth in Title 44 of the Code of Federal Regulations.

Figure 33

The original home in Stratford, Connecticut, was a victim of Hurricane Irene but is now in the process of being rebuilt to current standards for coastal construction and elevation.

Photo by Marilee Caliendo/FEMA

Finally, FEMA recognizes, and promotes, the concept that code adoption and application should be part of any mitigation plan. It demonstrates an investment in emergency management programs because safer structures: allow limited emergency management resources to be focused on a smaller set of risk areas; aid rescue efforts; and help keep emergency responders safe. In its most recent 5-year strategic plan, FEMA states "disaster resilience starts with building codes, because they enhance public safety and property protection."

In the end, well-developed and maintained building codes save lives, save money, and increase sustainability and resiliency. To achieve this, regular adoption of the most current codes is essential. When this is done, the benefits to society and the economy are significant. The International Code Council facilitates the development and publication of state-of-the-art model codes for adoption at the state and local level to achieve these benefits for all.

As lessons that have been learned from past events and new mitigation technologies are embraced in the updating of the ICC's codes and standards, the goal of protecting public safety remains paramount.

About the ICC and Its Role in Facilitating Whole Community Resilience

About the ICC

The International Code Council (ICC) is a member-focused association with over 64,000 members. It is dedicated to the development and publication of model codes and standards used in the design, build, and compliance process to construct safe, sustainable, affordable, and resilient structures. The ICC publishes the International Codes®, or I-Codes®, which provide minimum safeguards for people at home, at school, and in the workplace. The I-Codes are a complete set of comprehensive, coordinated building safety and fire prevention codes that are available for adoption by US states and territories, local jurisdictions, government agencies, and other countries to meet public safety, sustainability, and whole community resiliency needs.

Figure 34

ICC's I-Code books

ICC Covers

The I-Codes are strong, reliable, and effective because they are developed by thousands of professionals across all aspects of the built environment: building code officials, engineers, architects, builders, first responders, product manufacturers, scientists, the public, and more. Everyone has the opportunity to submit code change proposals and be part of the code development process. In the end, government officials—those appointed to protect the safety and welfare of the public—review comments and vote on final text for the codes.[1] In this way, the public interest is always in the forefront of the code development process.

All 50 states and the District of Columbia have adopted the I-Codes at the state or jurisdictional level. Federal agencies including the Architect of the Capitol, General Services Administration, National Park Service, Department of State, US Forest Service, and the Veterans Administration also enforce the I-Codes. The Department of Defense references the IBC for constructing military facilities, including those that house US troops around the world and at home. Amtrak uses the IgCC for new and extensively renovated sites and structures. Puerto Rico and the US Virgin Islands enforce one or more of the I-Codes.

Support for code officials and others does not stop with the publication of the codes—rather, that is just the starting point. The ICC and its family of companies offer unmatched technical, educational, and informational products and services in support of the I-Codes, with

1. The ICC develops construction and public safety codes through the governmental consensus process. This system of code development has provided the citizens of the United States the highest level of safety in the world for more than 80 years. The ICC governmental consensus process meets the principles defined by the National Standards Strategy of 2000; OMB Circular A-119, Federal Participation in the Development and Use of Voluntary Consensus Standards and in Conformity Assessment Activities (1998). It complies with Public Law 104-113 National Technology Transfer and Advancement Act of 1995.

The ICC is a founding member of the Alliance for National & Community Resilience (ANCR—pronounced "anchor"), a 501(c)(3) national coalition aimed at improving resilience and implementing good community practices in towns and cities across the United States and helping cities prevent infrastructure failures caused by natural and other disasters, thereby avoiding negative social, economic, and welfare repercussions caused by such damages. ANCR's primary objective is the development of a system of community bencmarks—the first system of its kind in the United States—that will allow local leaders to easily assess and improve their resilience across all functions of a community. ANCR intends to give communities a voluntary, transparent, usable, and easily understandable accredited self-assessment that helps to showcase their whole community resilience and to provide a simple gauge of how their resilience continues to strengthen.

more than 370 highly qualified staff members at offices throughout the United States.

The ICC is a strong advocate for whole community resilience and has engaged in several activities to help communities become more resilient to the wide range of events that will be faced over time. Resilient and energy efficient buildings were once thought to be elite ways to construct a new structure. That cannot be further from the truth. Practically, resilient and sustainable construction is the foundation upon which communities that want to grow, prosper, and be safe become resilient.

As discussed throughout this publication, creating a resilient nation requires diligent planning and innovative thinking. Incorporating new technologies in current building practices to achieve higher resiliency is exciting but can be expensive. Thankfully, effectively utilizing current codes and standards throughout all phases of the building's lifecycle increases the efficacy of new building technologies and offers a cost-effective path toward community stability during times of disaster. Resilience starts with strong, regularly updated, and properly implemented building codes.

Figure 35

International Code Council Governmental Affairs Office in Washington, DC

In the end, the ICC helps the nation be safer, healthier, more sustainable, and more resilient across a wide range of natural and human-related hazards and events by facilitating safer, healthier, more sustainable, and more resilient buildings. Thus, when adverse events occur, all gears in the local system can continue to function. By adopting, implementing, and enforcing the most current I-Codes, all communities can partner in advancing and achieving these objectives.

DISASTER RECOVERY REFORM ACT

- The Disaster Recovery Reform Act and the I-Codes

As this publication, *Building Community Resilience through Modern Model Building Codes*, was going under press, the US President signed into law the Disaster Recovery Reform Act (DRRA 2018). The essence of the DRRA and participation of the Federal Emergency Management Agency (FEMA) and the ICC are reflected in a document the ICC released just prior to the publication of this book and is printed on the next three pages.

The Disaster Recovery Reform Act and the I-Codes

On October 5, 2018, the President signed into law the Disaster Recovery Reform Act (DRRA) as a section within a broader package of legislation reauthorizing the Federal Aviation Administration's activities (H.R. 302). The International Code Council worked closely with its members, partners, the Federal Emergency Management Agency (FEMA), and the US Congress on this important legislation to support US communities before and after a disaster. This groundbreaking legislation will benefit communities across the United States and provide additional incentives for jurisdictions to adopt and enforce the latest International Codes (I-Codes). In short, the DRRA:

- Provides additional resources for the implementation of building codes post-disaster;
- Roughly quadruples funding for competitive pre-disaster mitigation (PDM) grants for state, local, tribal, and territorial governments;
- Allows PDM funding to be used for adoption and enforcement of I-Codes;
- Increases jurisdictions' chances of receiving PDM awards based on their adoption and enforcement of the latest edition of the I-Codes; and,

- Codifies FEMA's requirement that federally assisted facility repair and rebuilding efforts post-disaster be done to the ICC's latest building codes.

As it relates to the I-Codes and building safety, the main areas of the DRRA are:

Eligibility for Code Implementation and Enforcement (Sec. 1206)

For 180 days after a major disaster is declared, states may use public facility repair and replacement Stafford Act funds for base and overtime wages for extra hires to facilitate the implementation and enforcement of adopted building codes.

In a major disaster, the President may provide assistance to state and local governments for building codes and floodplain management ordinance administration and enforcement.

National Public Infrastructure Pre-disaster Hazard Mitigation (Sec. 1234)

The legislation permits the President to put 6% of annual disaster spending into a new national PDM grant account. By some estimates, this provision could increase annual PDM spending from approximately $250 million currently to between $800 million and $1 billion, based on the level of disaster spending each year.

Lack of resources is an often-cited reason that jurisdictions do not update their codes to more recent editions. The ICC spearheaded a successful effort to ensure that under the final DRRA, communities can use PDM grants to facilitate the adoption of the latest published editions of the I-Codes.

The legislation encourages jurisdictions to adopt and enforce the latest published editions of the I-Codes by making their PDM applications more competitive.

As applied to the I-Codes, the term "latest published editions" in this bill section is defined as the two most recently published editions—currently, this means the 2015 and 2018 I-Codes. This definition sunsets after five years. After October 2023 when this definition sunsets, FEMA will have the discretion to determine which code edition, or code editions, constitutes the "latest published editions."

The International Code Council has taken the lead to ensure that the resiliency benefits of modern building codes are at the forefront of the public debate. In early October 2018, the US Congress passed the Disaster Recovery Reform Act, which provides new resources for disaster mitigation and supports the adoption and implementation of modern building codes. The ICC worked closely with its members, partners, the Federal Emergency Management Agency, and Congress on this critical legislation.

The bill limits future PDM grants to jurisdictions that were partially or entirely subject to a major disaster declaration in the last seven years.

Additional Mitigation Activities (Sec. 1235)

Eligible costs for federally assisted public facility repair and replacement post-disaster are to be determined based on conformity with the ICC's latest building codes or their equivalents. Prior to the DRRA, the Stafford Act had tied the eligible cost determination to adopted codes, not the latest published code editions. As a matter of administrative policy, FEMA currently requires federally assisted public facility repairs and replacements to be done to the latest published editions of the ICC's building codes or their equivalents regardless of the codes the underlying jurisdiction has adopted.