5. Building Sector

5.1. Introduction

This chapter focuses on establishing a basis for setting performance goals for buildings within a community to support a resilient community. Building stock within a community is widely varied, in terms of use, occupancy, ownership, age, and condition. The variability in occupancy and use leads to different performance goals. The variability in age and condition leads to different performance, even within the same class of building. The variability in ownership, between public and private, can lead to challenges in implementing minimum performance goals, particularly with existing construction. This chapter discusses the various classes and uses of buildings, their ideal performance goals to support community resilience, what past and current codes and standards provide, and what gaps are present and improvements needed to support community resilience.

5.1.1. Social Needs and Systems Performance Goals

Buildings fulfill a multitude of social needs, from the most basic – providing shelter – to housing necessary services, like medical care and food. There are also many types of buildings that house goods or businesses that can be forgone for a while following a major disaster. Therefore the performance goals for buildings depend specifically on what they house or the function they serve. Some buildings must be fully functional immediately or very soon after the disaster, while others need only provide basic stability so they do not collapse and kill their occupants. Because of the wide variety of social needs various buildings fulfill and the fact that the post disaster performance needs are tied to the building's occupancy and use, there are many different potential performance goals. Section 5.2 discusses different classes of buildings and some recommended performance goals based on the overarching framework set forth in Chapter 3.

5.1.2. Reliability v. Resilience

Many provisions within building codes and standards deal with resilience, rather than just pure safety. The scope of the *International Building Code*, a commonly adopted model building code, is to "safeguard public health, safety and general welfare through structural strength, means of egress facilities, stability, sanitation, adequate light and ventilation, energy conservation safety to life and property from fire and other hazards attributed to the building environment and to provide safety to fire fighters and emergency responders during emergency operations." There are many requirements for protection of routes out of the building and into the building for emergency responders. The fire suppression requirements are not simply based on allowing egress, but to quickly extinguish a fire to limit damage and allow for quick return to function.

However, the engineering standards currently used throughout the country for building design are focused primarily on preserving occupant safety in major natural hazard events. For some hazards, such as wind, snow and rain, the intention is that the building sustain little or no damage under the design event by requiring that each element have a specific safety reliability index. For other hazard events, such as earthquakes, the design intention is for typical buildings to provide life safety, which allows structural damage but not collapse. For these hazards the reliability is based on a target probability of collapse as opposed to element-specific safety reliability. Thus, while a building will protect its occupants, it may not function and will need to be demolished after a seismic event.

While safety reliability is important, it is not synonymous with resilience. If a building has sustained damage such that following the disaster it cannot perform its pre-disaster function even if there was no collapse, it may negatively affect a community's resilience. An example of this is a fire station where the doors cannot open and the fire trucks cannot exit to fight fires. Furthermore, some buildings may need to be brought back online sooner than others. Providing a uniform level of safety does not necessarily allow this to happen, which is why additional requirements exist throughout building codes for resilience.

5.1.3. Interdependencies

Community resilience depends on the performance of various different buildings. The performance of most buildings is directly linked to the utilities that feed power and water to them, their wastewater systems, and the local transportation infrastructure. Additionally, some buildings directly affect power infrastructure, water and wastewater systems, and other utilities. The effect of any specific building on an infrastructure distribution system should require that the building be as resilient as or more resilient than the infrastructure system of which it is a part. Refer to other chapters of this framework for the various infrastructure system resilience recommendations.

5.2. Buildings Classes and Uses

5.2.1. Government

In most communities, the primary emergency operations center, airports, penitentiaries, and first responder facilities are government-owned buildings. These buildings support and shelter the people and equipment that provide essential services and must remain operational during and after a major disaster event. Communities expect and plan for these facilities to be operational during and after hazard events. Therefore buildings for emergency operation centers, police and fire stations, penitentiaries and other correctional institutions, water and wastewater treatment facilities, and emergency shelters need to remain operational – Category A as defined in Chapter 3.

Currently, most of these essential buildings would fall under Risk Category IV in the *International Building Code*, which requires the highest design forces and has provisions for nonstructural systems remaining operable post-disaster. Some are classified as Risk Category III, which requires higher design forces than a typical building, but fewer specific nonstructural system requirements than a Risk Category IV building. However, as will be discussed in Section 5.5, gaps exist between the current model building codes and standards' requirements and providing truly functional buildings following a major disaster.

Other government buildings may not be immediately needed following a disaster, yet a community may determine they are critical to recovery, such as a City Hall or county administrative building, schools, mass transit stations and garages, courts, and community centers. A possible goal for these buildings would be to have them functional in about a month, depending on their role in the community, following the disaster. In some cases these buildings are designed as Risk Category III, while others are designed as Risk Category II (typical buildings). Neither Risk Category II or III have specific provisions which would provide a high level of confidence that the building could be returned to operation within a month. In the Chapter 3 performance vernacular, a performance level for these types of buildings might be Category B – Safe and usable during repair. This may be the performance Risk Category III delivers, but not what Risk Category II intends.

5.2.2. Healthcare

Emergency medical facilities are critical to response and recovery efforts following a major disaster. Therefore hospitals, other such healthcare facilities, and their supporting infrastructure must be operational (Category A) following the disaster. Currently, hospitals are designed to Risk Category IV requirements, with some local communities or federal agencies placing additional requirements on them. For example, the state of California requires that all hospitals, regardless of location or ownership (municipal or private), have their designs reviewed and construction overseen by a state agency.

Nursing homes and residential treatment facilities that house patients who cannot care for themselves independently may also need to be immediately functional after the disaster and are designed the same as acute care hospitals.

Other healthcare facilities, like doctors' offices and outpatient clinics, need not be immediately available, but a community may determine they are needed shortly after the initial shock of the disaster. Therefore medical office buildings may be designed to be safe and usable during repair (Category B). In most cases they are currently designed as Risk Category II buildings, meaning they have no major structural requirements beyond preservation of safety without consideration for post-disaster function.

5.2.3. Schools and Daycare Centers

Many communities have concluded that K-12 Schools should be designed to a higher performance than typical buildings because they have large assemblies of children. This belief is reflected in the IBC designated schools Risk Category III. In many localities, school gymnasiums or entire school buildings are also designated to serve as emergency staging areas or emergency shelters. Additionally, the research that went into the SPUR Resilience City Initiative found there is a perception that if children can return to school, then things are getting back to normal and their parents can return to work. Thus, expeditious resumption of function is important for schools across a community.

There is a dichotomy of performance requirements for a school. On the one hand providing enhanced safety and returning to operation quickly would place a school in Category B – safe and usable during repair. However, the expectation that it could be used as an emergency shelter, would in turn place it in Category A – operational. The current Risk Category III provisions, to which most K-12 schools are designed, may provide Category B, but definitely will not provide Category A performance. Therefore, it is recommended that any school that will be designated as an emergency shelter be designed for Category A requirements, which would mean being designed or upgraded to a higher level than is commonly used today, possibly Risk Category IV requirements per the IBC or greater.

Higher education facilities are generally regulated as business or assembly occupancies with some exceptions for specific uses, such as laboratories and other research uses. Research universities often have the added concern of protecting their research facilities and long-term experiments.

5.2.4. Religious and Spiritual Centers

Religious and spiritual centers have special role in many communities. They are places that can offer a safe haven for people following the emotional distress a major natural disaster can inflict. Logistically, they often become critical nodes on the post-disaster recovery network. Many religious organizations have charity networks that provide supplies to people following a disaster. In past disasters, a number of religious institutions have opened their doors to serve as shelters. In most cases, however, these buildings are designed to the same standard as any other building, meaning they have no explicit design for function preservation. Compounding the issue, these buildings are often some of the oldest in a community and built out of archaic materials that perform poorly in major disasters.

Because these facilities can have such an important role following a major disaster, a desired performance level would be Category B – Safe and usable during repair per Chapter 3. However, a number of factors could influence a community to accept a lesser performance goal. First, many of these institutions are nonprofit entities, with little funding for infrastructure improvement. Second, many of the historic buildings would have to be modified in such a manner that their historic fabric would be unacceptably disrupted to meet this higher performance category. Therefore, a community should understand the resilience of its various churches and spiritual centers and factor that into its recovery plan.

5.2.5. Residential including neighborhood commercial districts

Current thinking suggests that residential buildings and neighborhoods should be designed to provide shelter for a significant portion of the population following a disaster. Houses, apartment buildings, and condominiums need not be fully functional, like a hospital or emergency operation center, but they do need to safely house their occupants to accelerate the ability of the workforce to return to work. By not being fully functional, we mean that a house or apartment may be without power or water, yet can still provide sufficient shelter for its inhabitants. The significant loss of housing stock led to the migration of a majority of the work force following Hurricane Katrina’s impact on New Orleans. Such a “shelter in place" performance level is a key component of the SPUR Resilient City initiative and prompted the City of San Francisco to mandate a retrofit ordinance for vulnerable multi-family housing.

In addition, an effective response to most disasters requires supplemental first responders and other personnel for a period of time. If the majority of the residential buildings are not functional, then the demand for emergency shelter competes with the demand for housing temporary responder and recovery workers.

Currently multi-unit residential structures are designed to Risk Category II provisions, except in certain cases where the number of occupants is quite large, over 5,000 people, then they are designed to Risk Category III. Risk Category II may not provide the requisite level of performance in a major disaster.

Most one and two-family dwellings are constructed based on pre-engineered standards using the prescriptive requirements of the *International Residential Code*. There has been some debate as to whether the IRC provides comparable performance to the *International Building Code*. In some cases, such as the Loma Prieta and Northridge earthquakes, one and two-family dwellings performed as well as, or in some instances better than, engineered buildings. Whether there is a discrepancy in performance between the IBC and the IRC should be investigated further, because of the importance of residential housing.

5.2.6. Business and Services

While it would be ideal to have all community businesses open shortly after the disaster, it may not be economically practicable. Most buildings that house offices, retail, and manufacturing are currently designed to Risk Category II. As we will discuss further in this chapter, the performance of Risk Category II buildings is really based on safety, but not function preservation or resumption. That is not to say, all commercial buildings are designed to the code minimum, because many are designed for higher performance, but for the purpose of this framework it is assumed that most are.

Certain types of commercial buildings are likely critical to the post-disaster recovery effort. The community needs to designate which buildings perform to a higher performance level so they can be available in an appropriate period of time following the disaster. Each community should select design and recovery performance goals for its businesses and services, depending on their role in the community during the recovery period. Some businesses and services that commonly are essential to recovery include:

- ***Grocery stores –*** It is important that people be able to get food and water following a major disaster. Additionally, major grocery stores typically have robust distribution networks outside of the affected area that can be tapped to bring supplies into the area. While the common preparedness recommendation is for people to have 72 hours of food and water on hand, the potential for disruption beyond the first three days is great in major natural disasters. For example, the Oregon Resilience Plan recommends two weeks of food and water.
- ***Banks or financial insinuations –*** Banks or at least structures housing automated teller machines are important because they provide people with access to money.
- ***Hardware / Home improvement stores –*** These stores are critical to the post-disaster recovery effort in their ability to provide building materials to aid in the reconstruction, and even emergency shoring of damaged buildings.
- ***Gas Stations and Petroleum Refineries –*** Many communities have been planned in a manner which necessitates that residents have automobiles to carryout basic functions, like shopping and commuting to work.
- ***Buildings that house industrial and hazardous materials or processes***.

5.3. Performance Goals

The resilience goal matrices in Chapter 3 are based on specific clusters of building and infrastructure being brought back on-line at specific intervals following the disaster. Chapter 3 contains a specific example of how a San Francisco public policy think tank, SPUR, adapted a resilience matrix for a major earthquake affecting San Francisco. The concepts used in that example and in Chapter 3 provide a basis for other communities to determine their needs post-disaster. The previous section discussed specific performance goals for various types of buildings using the Chapter 3 terminology, which are summarized in Table 5-1.

Table 5-1: Building Section Resilience Matrix

Disturbance		
(1)	Hazard	Any
	Hazard Level	Expected
	Affected Area	Community
	Disruption Level	Moderate

Restoration times		
(2)	30%	Restored
	60%	Restored
	90%	Restored
(3)	X	Current

Functional Category: Cluster	(4) Support Needed	(5) Target Goal	Overall Recovery Time for Hazard and Level Listed								
			Phase 1 -- Response			Phase 2 -- Workforce			Phase 3 -- Community		
			Days 0	Days 1	Days 1-3	Wks 1-4	Wks 4-8	Wks 8-12	Mos 4	Mos 4-36	Mos 36+
Critical Facilities		**A**									
Emergency Operation Centers			90%								
First Responder Facilities			90%								
Acute Care Hospitals			90%								
Emergency Housing		**B**									
Temporary Emergency Shelters				90%							
Single and Multi-family Housing				90%							
Housing/Neighborhoods		**B**									
Critical Retail				30%	60%	90%					
Churches and Spiritual Centers				30%	60%	90%					
Schools					30%	60%	90%				
Community Recovery		**C**									
Businesses						30%		60%		90%	

Footnotes:

1 Specify hazard being considered
Specify level -- Routine, Expected, Extreme
Specify the size of the area affected - localized, community, regional
Specify severity of disruption - minor, moderate, severe

2 30% 60% 90% Restoration times relate to number of elements of each cluster

3 X Estimated restoration time for current conditions based on design standards and current inventory
Relates to each cluster or category and represents the level of restoration of service to that cluster or category
Listing for each category should represent the full range for the related clusters
Category recovery times will be shown on the Summary Matrix
"X" represents the recovery time anticipated to achieve a 90% recovery level for the current conditions

4 Indicate levels of support anticipated by plan

R	Regional
S	State
MS	Multi-state
C	Civil Corporate Citizenship

5 Indicate minimum performance category for all new construction.
See Section 3.2.6

5.4. Regulatory Environment

No explicit building code is mandated by the federal government for use throughout the country. Building codes are left under the purview of the state or local jurisdiction. Federal buildings and certain buildings that receive federal funding to be built or operate are an exception to this rule. In the United States, two organizations publish model building codes that can be adopted by federal agencies or state and local governments. One building code is published by the International Code Council, which was formed as a merger of three organizations that published regional model building codes. The other building code is published by the National Fire Protection Association. The ICC's *International Building Code* is the most widely adopted model building code in the United States. Most federal agencies also use that code as the basis for their building standards. These model codes contain many reference standards that are typically published by non-for-profit standards development organizations, professional societies, and industry groups. The model building codes and the standards referenced are typically modified by federal, state, and local agencies for their specific purposes.

While the model building codes specify minimum requirements that are meant to be applicable throughout the country, states and local municipalities draft their own building codes based on modifications to the model codes to achieve specific goals for local or regional hazards. For example, in areas of Florida, building codes were changed to require more hurricane-resilient construction following Hurricane Andrew – requiring certain types of roofing materials, stronger windows and doors, and greater inspection and enforcement.

In general, most states and municipalities adopt building codes as stringent or more stringent than the model building codes. However, there are locations where no building code may be adopted or portions of the model code may be excluded.

Enforcing standards is as important, if not more important, than having a building code and building standards. Typically enforcement is the purview of the local jurisdiction. The level of enforcement can have a very significant impact on resilience. Even if the most up-to-date building code and standards are in effect, buildings designed and constructed in a substandard manner negatively impact community resilience. Therefore, having a properly trained building department to review designs for code conformance and inspect construction for conformance with the approved plans, is an essential component of community resilience.

5.5. Standards and Codes

The expected performance of each building depends upon the codes and standards in-force at the time of construction, as well as the level of maintenance. Building codes and standards are dynamic and ever-changing. Many changes have come in response to disasters, while others have come from a perceived weakness to natural disasters brought about by research on the subject. That means that codes from a generation ago, or even a decade ago, may not have produced a building stock with the resilience needed for a community.

Building codes and standards are primarily aimed at regulating new construction and are based on the best understanding of hazards at the time they are published. The challenge is that with every major hazard, there are commonly portions of the building code that are found insufficient and are enhanced. Some provisions, when changed, become retroactive or are enforced during renovations. Examples of these are egress protection, access for disabled people, and fire suppression system requirements. However, the most significant changes to the code, most commonly in structural provisions, would require such major modification to existing buildings that retroactive compliance is deemed impractical to mandate. This is a major issue in resilience planning because an egress or fire system can meet the state of the art, but the stability of the entire building due to a hazard event could be questionable. Communities primarily consist of existing buildings, most of which were not designed to conform to current code standards. Therefore, most buildings do not fully comply with the state-of-the-art standards for resilience. The mix of building types, construction, and age can create significant challenges when developing plans for a resilient community, because the structural stability of buildings may not be sufficient for the expected hazard.

5.5.1. New Construction

Current design criteria for new construction are critical, as they form the basis for future resilience planning. It is important to draft standards for new construction that provide for the resilience goals a community desires. This is the easier place to make changes, because the consequences in increased requirements for new design are orders of magnitude less costly than trying to require retrofit of existing construction to meet those standards.

Building codes and standards have primarily focused on life safety of occupants during major natural hazard events, specifically in their structural design criteria. Early building codes addressed routine environmental design loads for frequent hazards such as wind and snow. The hazard design load and self-weight and occupancy live loads were used to design a structure. This approach produced structures that withstood routine, moderate hazards. However, the 1906 San Francisco Earthquake demonstrated that some hazards induced large forces that were difficult to resist without any structural damage. This led to a philosophy of designing buildings for major hazards, such as earthquakes, that remain stable with some structural damage but do not collapse.

As scientific understandings of natural hazards evolved, return periods for the given hazards were selected to define the loadings, as opposed to determining specific loadings based on judgment and experience. The design intention, however, was still that the individual structural elements have a margin of safety against failure when subjected to that specific load. Code provisions were developed with the intent of most buildings having the same level of structural safety. However, in actuality, this level of safety was greatly influenced by the selected construction material and local building regulations and practices.

As codes evolved, two things became apparent – certain buildings need to perform to a higher level of safety and other buildings, because of their use, should retain their pre-even function. For example, model building codes specified that schools and buildings with very large occupancies be designed for higher forces, in an attempt to provide a greater level of safety than typical buildings. Additionally buildings, such as unoccupied agricultural storage facilities, could be designed for lower forces, permitting them to have a lesser level of safety for natural hazards than a typical building. Hospitals, first responder facilities, and emergency operations centers are classified as buildings that should have some ability to return to their pre-disaster function following the design hazard level. This delineation of buildings into different categories has evolved into the four Risk Categories found in current national model building codes specifically the International Building Code.

Following the 1994 Northridge Earthquake, where there was little loss of life but extreme economic losses, there was a move toward performance-based design and evaluation of buildings. It was felt that engineers should be provided tools to allow for designing buildings beyond the prescriptive provisions in the building codes, and instead target an intended performance to a specified hazard. That approach led to definition of discrete building performance states of Operational, Immediate Occupancy, Life Safety, and Collapse Prevention. With this came the recognition that the nonstructural systems in a building, such as the architectural element and the mechanical, electrical and plumbing systems, contribute significantly to building performance, especially in critical facilities that communities expect to be functional.

One major design criterion missing from the *International Building Codes* is explicit performance goals for post-disaster recovery. Many municipalities' emergency plans are based on certain buildings being available within a set period of time from the onset of the disaster. While this goal is not at odds with the current Risk Category or performance-based design approach, it does present challenges because some buildings' current design parameters may not align with community needs. The major difference between this need and typical performance-based design approaches is the use of downtime as the key performance metric.

Wind hazards. Today, for wind load designs, ASCE 7-10 prescribes design wind speeds based on different return periods. The return periods are tied to the Risk Category of the facility. For Risk Category I a facility, typically unoccupied agricultural buildings, the return period is 300 years. For Risk Category II facilities, typical buildings and other structures, the return period is 700 years. For Risk Category III facilities, schools and high occupancy structures, and Risk Category IV facilities, hospitals and emergency responder facilities, the return period is 1,300 years. The wind speeds derived from these return periods are based on extratropical winds and hurricane winds. Tornadic wind speeds are not currently addressed.

The majority of the wind design requirements are for the structural frame and the cladding. There are some requirements for attachment strength of nonstructural components. Requirements for serviceability and functionality are not explicitly codified, but are indirectly addressed through elastic design methods at specified wind speeds for desired performance levels. The International Building Code requires consideration of a drift limit under a reduced wind load (the factor used intends to approximate the 100-year return period wind). There are no explicit structural design requirements to preserve the building envelope so post-disaster function is not impacted, but there are some prescriptive requirements on the requirements of doors and windows. Nor are there requirements that exterior equipment must be functional following the design windstorm.

Snow hazards. Snow design uses a 50-year mean recurrence interval for ground snow loads. It is increased with an importance factor for higher Risk Category structures.

Rain hazards. Rain design uses a 100-year rain storm as the design hazard, with loads increased by 60% to account for uncertainty in predicting rainfall in a major event. However, the majority of rain design provisions relate to providing proper drainage and stiffness to the roof to prevent ponding. There are no code requirements in a design rain event that the building envelope must maintain its ability to keep water out. In many instances this is accomplished without explicit code requirements because of the liability seen with water intrusion and its adverse effects, such as mold.

Flood hazards. Flood design provisions for all structures are typically based on a 100-year mean recurrence interval for flood elevation, though 500-year flood elevations are recommended for design of critical facilities. Recommended practice is to locate structures out of the flood zone, or to elevate the structure above the design flood elevation. For structures subject to flood forces, the current provisions provide methods to resist flood forces, but may not necessarily preserve functionality of the building.

Seismic hazards. The performance of buildings during earthquake events is most developed of the hazards in the building codes and standards. Since the beginning of earthquake design, it has been recognized that designing for the hazard elastically, as is done with other hazards, would not be practical or economical. Therefore the approach adopted prescribed forces and design requirements that would allow the building to be damaged, but not collapse. Following the 1971 San Fernando earthquake it was recognized that essential facilities like hospitals needed to be designed to a higher standard, to significantly improve their likelihood of remaining functional following the design earthquake. A design earthquake with approximately a 500-year return period was chosen and used until the early 2000s, when it was decided that a longer earthquake return period was needed to capture the seismic hazard in other parts of the country. Since then the maximum considered earthquake shaking hazard has been around a 2,500 year return period.

Recently, there was a shift from a uniform 2,500 year hazard to a risk targeted hazard level. By setting a uniform risk of 1% probability of collapse (or a 99% probability of not collapsing) in 50 years, the return period required to achieve that goal varies based on the seismicity at a specific location. For most parts of the country the return period is not significantly different than 2,500 years.

The emphasis placed on the design of nonstructural systems is a very important distinction between seismic design provisions and design provisions for other hazards. All nonstructural systems have bracing requirements. In addition to the bracing requirements, nonstructural systems in essential facilities or those systems that relate to the life-safety system of the facility are required to maintain function or return to function following the design earthquake shaking hazard. The design earthquake shaking level is currently defined as 67% of the Risk Targeted Maximum Considered Earthquake shaking level.

Fire hazards. Fire hazards typically are addressed prescriptively through fire protection requirements for structural members or other construction standards that are typically under the purview of the building architect, not the structural engineer. Performance-based provisions for providing fire protection are becoming more common, but are mostly for large or high profile buildings.

Man-made hazards. Currently codes and standards do not have explicit structural design requirements and design standards for man-made hazards such as explosions or impact events, although some nominal provisions attempt to provide robustness to arrest the spread of damage so a disproportionate collapse does not occur. There are many requirements in the IBC that require facility layout and hazard mitigation measures that attempt to prevent explosions of building contents.

5.5.2. Existing Buildings

Existing buildings pose an even greater challenge than new buildings. For new buildings, codes can be amended or re-written and, while construction costs may increase, the new buildings would therefore be designed for the state-of-the-practice. Retrofit of existing buildings to the state-of-the-practice level of resilience, in contrast, can require significant financial commitment and necessitate major disruption to the building’s function. That tends to dissuade building owners from retrofit.

The cost and disruption associated with retrofit has made mandating retrofit measures a politically unpopular decision. In California, only the class of building deemed most prone to collapse in an earthquake – Unreinforced Masonry Buildings – has had widespread, albeit not universal, acceptance as something that should be mandated to be retrofit.

When existing buildings are evaluated for their expected performance relative to resilience goals and required retrofit actions, the standards for new construction are typically applied for the structural design, which often leads to very conservative results. However, the recent advancement in performance-based engineering has led to development of specific standards for existing buildings with regards to evaluation and retrofit.

One of the biggest impediments to retrofit of existing buildings lies in the conservatism embedded in current engineering codes and standards. Under-predicting a building’s performance in a given hazard because the standards are too conservative can lead to significant retrofit requirements. Those requirements can make the retrofit economically unappealing to building owners. Therefore, a major impediment to mitigating existing building natural disaster hazards that needs to be addressed, is refining engineering standards to allow simple, focused identification and retrofit of the most dangerous or most significant existing building hazards.

5.6. Resilience Assessment Methodology

5.6.1. Assessment Methodology (current conditions, including dependence on sources outside the community)

Current engineering standards provide tools to assess the structural safety of buildings. ASCE 41, the existing building seismic standard, provides a methodology to assess the performance of buildings for both safety and the ability to be reoccupied following an earthquake. Similar standards do not exist for other hazards. Building codes provide provisions that can be used to understand whether a building has sufficient fire resistance, egress, and other occupant safety related issues. These methodologies are useful for individual buildings safety, but fall short of being able to understand the amount of damage versus time to return to function.

The FEMA-created HAZUS project provides a platform for communities to assess their vulnerabilities to earthquakes, hurricanes, and other hazards. HAZUS is a useful tool for assessing the effects of a disaster on a community. HAZUS is useful only if the existing building stock is adequately reflected in the model, which can require significant data gathering to accomplish.

5.6.2. Strategies for new/future Construction

New construction standards are a good vehicle to begin making changes to better enable community resilience. One major place where change can be made is to align new risk categories with the resilience goals set forth in Chapter 3. By clearly defining the performance of buildings following a major disaster in terms of function preservation and return to function, communities could better tailor their building codes and standards to their specific resilience goals.

There needs to be better alignment between various engineering and architectural requirements within the building codes and standards to promote resilience. There are instances currently where architectural requirements for existing and life safety are more stringent than the nonstructural anchorage requirements that keep objects from falling and obstructing egress points.

5.6.3. Strategies for Existing Construction

In addition to the issues raised with new construction, there is the major issue of the varied quality and resilience of existing buildings. Building codes and standards have evolved, but very little retroactive compliance is required, meaning that when a code or standard changes a building does not have to be retrofit to conform to the latest edition's requirements. This is a major issue because the cost of retrofit exceeds, by orders of magnitude, the cost to add resilience to a new building that is under design. The presence of a strong willingness to neglect building retrofit because of the cost, inconvenience to the building occupants, and disruption of operations creates a significant challenge for resilience planning. As discussed in Section 5.2, many types of buildings have been designed to codes that did not provide for the performance that the Chapter 3 framework would recommend. Most of these buildings are not public buildings, so any attempt to mandate retrofit for resilience planning would mean placing a financial burden on a private property owner. This is one major issue that the SPUR Resilient City initiative identified for San Francisco.

A strategy that has been shown to work is to identify the most significant hazards posed by various types of buildings and to mandate retrofit or demolition of those buildings. There have also been programs specifically aimed at critical facilities like hospitals and fire stations, where those buildings must be retrofit or replaced.

Another strategy that is gaining momentum in Los Angeles is requiring that all building owners have their building's safety rated. The belief is that such a rating system could create a market-based mechanism where more resilient buildings become more desirable and people are willing to pay a premium to be in those buildings. This approach is modeled after the very successful LEED rating systems created by the US Green Building Council, which created and continues to inspire advances in designing and building environmentally sustainable buildings.

5.6.4. Addressing Gaps in Resilience Plans

This section is under development. Text to be provided in a future draft.

5.7. Tools Needed for Resilience

As discussed previously there are a number of resilience gaps in the current inventory of buildings that involve both the standards used for the design of new buildings as well as the need to retrofit some buildings. As part of the process, communities should prioritize the mitigation of the gaps that exist and develop programs that address closing those gaps.

5.7.1. Standards and Codes Gaps

Performance goals needed for post-disaster recovery are one major design criterion missing from model building codes. Many municipalities' emergency plans are based on certain buildings being available within a set period of time from the onset of the disaster. While this is not at odds with the current Risk Category or performance-based design approach, it presents challenges because some buildings' current design parameters may not align with community needs. The major difference between this need and typical performance-based design approaches is the use of downtime as the key performance metric.

Existing codes and standards provide minimum requirements and some options for higher performance levels. Until recovery and other resilience concepts are incorporated into the codes and standards, communities must make decisions to go beyond the model building code that will provide a built environment that can meet their resilience goals.

The most significant challenge for disaster resilience standards development is aligning the design philosophy of all the environmental hazards with intended performance goals. As discussed earlier, wind, ice, rain and snow are based on an element-specific reliability at different hazards level, while seismic is calibrated based on system reliability for another hazard level. The hazards designed with element-specific reliability may have greater system reliability than those hazards where system reliability is the only design goal. The inability to accurately predict what is safe enough versus what is truly dangerous has led to impediment to addressing the hazards posed by the most dangerous existing building.

In addition, few provisions exist for facility function preservation for most hazards. Seismic has the most significant requirements, in part because it has established nonstructural requirements. For other hazards structural and nonstructural requirements to preserve function in essential facilities are needed. This is a significant issue that must be addressed because, although a facility's structure may be undamaged, if critical systems not functioning prevents it from performing its intended function, the recovery is hindered.

Along with the lack of function preservation provisions, the lack of tools that engineers can use to estimate a building's reliability of being returned to function in a given time period is a factor. Disaster plans and the Chapter 3 resilience goals assume that specific buildings are brought back online with a set period of time for each hazard. Without the ability to assess this, engineers are typically left with the binary distinction of whether or not a building meets Risk Category IV or Immediate Occupancy criteria (similar to Category A), which are typically too conservative for Category B facilities.

Another overarching issue related to existing engineering standards is how to bridge the gap between deterministic performance-based goals, like those enumerated in Chapter 3, and the probabilistic basis of the hazards. In many cases this has led to overly conservative provisions because of the goal of having significant certainty in the hazard outcome. Conversely, determining an acceptable level of reliability is difficult to quantify. For a dense, urban area, there may be several hospitals within an affected area of a disaster. Therefore the reliability of each hospital need not be 100%, because the loss of one hospital may not significantly hinder community resilience. On the other hand, a rural community may have one hospital for the entire county and that hospital must have significantly higher reliability. Designing for a very high reliability of safety and return to function for all new buildings has not been a significant issue, but allowing lesser reliability of return to function for redundant facilities may alleviate some of the burden of evaluation and retrofit costs for existing buildings needed to achieve the resilience goals.

For specific hazards, there are some disparities in the magnitude of hazard events that is currently being designed for. Flood and storm surge loads are currently the most significantly out of harmony with other hazards. The fact that an essential facility is designed for a 1,700 to 3,000-year return period hurricane, but need only be designed for a 100-year storm surge or flood, is disproportionately unbalanced. Flood design hazards for essential facilities need to be increased, possibly significantly.

Currently tornadoes are not explicitly addressed in building codes for a number of reasons. There are beliefs that the probability of a tornado striking a specific building is so low that it need not be explicitly considered or that nothing can be done to resist tornadic events. The commentary to the wind design provisions in ASCE 7 discusses this issue in more detail. However, a significant number of communities are affected by tornadoes every year, and design guidance to improve performance and recovery of the built environment is required.

5.7.2. Practice and Research Needs

This section is under development. Text to be provided in a future draft.

5.8. Summary and Recommendations

This section is under development. Text to be provided in a future draft.