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RECOMMENDED OPTIONS FOR IMPROVING THE FUNCTIONAL RECOVERY OF THE BUILT ENVIRONMENT

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Abstract

During a strong earthquake, commercial and residential buildings designed to meet current building codes and standards may sustain damage that significantly hinders the restoration of building functionality. Similarly, lifeline infrastructure systems can be damaged and loose ability to provide critical services. The impacted buildings and lifeline infrastructure systems and their associated consequences such as dislocation of people, disruption of key services, and lack of access to jobs and schools, pose a significant impediment for communities during recovery. In the wake of recent disasters across the globe, there is mounting evidence that the public finds these kinds of disruptions unacceptable. Buildings and lifeline infrastructure systems can be designed for higher performance so that they are able to serve their function or regain functionality with acceptable interruption after an earthquake. This will require shifts in design philosophy from safety-based objectives to recovery-based objectives across multiple aspects of current practice. The 2018 Congressional reauthorization of the National Earthquake Hazards Reduction Program (NEHRP), P.L. 115-307, requires two Federal agencies, the National Institute of Standards and Technology (NIST) and the Federal Emergency Management Agency (FEMA), to work with experts across the U.S. to address this issue of improving post-earthquake functional recovery. FEMA and NIST convened a committee of experts to develop the report to the U.S. Congress to identify and assess options for functional recovery and post-earthquake re-occupancy. As part of this effort, stakeholder workshops were held in February 2020 in five U.S. cities to gather public feedback to inform the final report to Congress. This paper summarizes the main findings of this effort, including a list of the key recommendations identified for improving the functional recovery of buildings and infrastructure. The report to the U.S. Congress serves as a starting point for improving timeframes for re-occupancy and functional recovery of the built environment and critical infrastructure after earthquakes through the development and adoption of functional recovery concepts, codes and standards, policies, and practice.

Keywords: Functional recovery, post-earthquake re-occupancy, NEHRP.

1. Introduction

Earthquakes can affect communities through loss of life, injury, property damage, displacement of residents and businesses, and long-lasting economic and social impacts. The United States Geological Survey (USGS) estimates nearly half of Americans are at risk from potentially damaging earthquakes[1]. Despite decades of improvements in the seismic safety of the built environment, the economic and social systems of communities throughout the U.S. remain at risk of large scale, long-term disruption. The U.S. has not experienced a major damaging earthquake since 1994. However, the Federal Emergency Management Agency (FEMA) estimates the annualized cost of damage to U.S. building stock from earthquakes to be $6.1B per year [2]. A 2008 USGS exercise using a 7.8M earthquake in Southern California as a case study estimated 2,000 deaths, 50,000 injuries, and $200 billion in direct costs, in addition to staggering, destabilizing impacts to long-term community function. Depending on the size of the disaster, communities can also face significant and costly long-term consequences, including interruption of basic services (shelter, food, water, sanitation), loss of jobs and businesses, voluntary and forced relocation of residents, psychological trauma, and loss of important physical, cultural, and social assets [3].

The Federal Government has recognized the need to improve the state of practice in design and retrofit of multiple components of the built environment such that buildings and lifeline infrastructure systems can restore their function with minimum disruption in the services that they provide. Buildings and lifeline infrastructure support and enable society's continued economic, psychological, and social health, all of which may be severely interrupted or completely disrupted depending upon the magnitude of shaking and level of damage experienced. By strengthening the ability of the built environment to withstand earthquake effects, we can return community members to their homes, business, and normal activities more quickly. To move toward this desired performance state, the National Institute of Standards and Technology (NIST) and the Federal Emergency Management Agency (FEMA), as part of the December 2018 reauthorization of the National Earthquake Hazards Reduction Act, were charged to convene a committee of experts "*to assess and recommend options for improving the built environment and critical infrastructure to reflect performance goals stated in terms of post-earthquake re-occupancy and functional recovery time.*", P.L. 115-307, This paper summarizes the effort to fulfill this congressional mandate and presents some key findings on the recommended options for improving the recovery time.

2. Problem Statement

In the United States, building codes are the primary mechanism by which State and local jurisdictions manage earthquake risk for buildings. Most often, these building codes are adopted with the target of saving lives and reducing injuries, rather than preserving the structure's ability to be operational, or even recoverable, after an earthquake event. The primary, longstanding goal of building codes for most buildings is to protect lives by reducing the likelihood of structural collapse in rare extreme events (i.e., Risk-targeted Maximum Considered Earthquakes), and to provide some level of property protection in more frequent events. Current codes generally do not consider design of buildings to explicitly provide functionality after a hazard event. Buildings that are designed per these codes may sustain extensive damage in a significant event requiring lengthy and costly repair or rebuilding, which in turn can lead to lack of providing the intended function or service. This loss of function negatively impacts sociocultural and economic functions of the community and can lead to temporary or permanent dislocation or required relocation of community members after an event [3]. Older existing buildings may have been built with no (or earlier and less effective) seismic design considerations, and may pose an even greater hazard than newer buildings.

In most cases, the current design of lifeline infrastructure systems (such as water, wastewater, power, gas and liquid fuels, transportation, and telecommunications) does not take into consideration the functionality of the system after an earthquake event. Unlike building design, the state of practice for design of different lifeline systems to provide critical services is more complex due to their interdependencies and need to address the broad spatially distributed networks of specialized components. It is expected that various lifelines systems may not be able to provide their intended services after an earthquake. Because buildings and their occupants depend on lifeline infrastructure systems, the lack of their critical service would undoubtedly impact the operation and ability of buildings to function and provide their intended services.

The U.S. public, particularly in large urban areas, will find the disruption of sociocultural and economic services not only distressing, but unacceptable for the timeframes that it would currently take to restore infrastructure or building functionality—which may be in the range of months to years depending upon the earthquake event. There is a need to improve the ability of buildings and infrastructure systems to continue functioning at full or acceptably reduced capacity post-event. Ensuring a more limited disruption of sociocultural and economic services will require significant effort to move beyond the current design paradigm. A new functional recovery performance objective would improve the performance of buildings and lifeline infrastructure systems, so that they are less likely to be negatively impacted and more likely to maintain a sufficient level of functionality or regain it in a timeframe acceptable to community members. By providing the basic intended function or service of various components of the built environment within an acceptable time following an earthquake, communities can mitigate and recover more quickly from earthquakes and reduce vulnerability and long-term negative consequences. Greater emphasis on functional recovery has the potential to reduce the cost and social, psychological, and health consequences for communities at risk of seismic events, and will in turn improve resilience across the nation.

3. Congressional Mandate

The federal government has recognized the above-mentioned problems and the need for improving the state of practice in design and retrofit of buildings and lifeline infrastructure systems. The 2018 reauthorization of the National Earthquake Hazards Reduction Program (NEHRP) (P.L. 115-307), included a new requirement for the National Institute of Standards and Technology (NIST) and the Federal Emergency Management Agency (FEMA) to convene a "committee of experts" and develop a "report of recommended options" to Congress for moving the built environment and critical infrastructure:

> *(a) ASSESSMENT AND RECOMMENDATIONS.—Not later than December 1, 2019, the Director of the National Institute of Standards and Technology and the Administrator of the Federal Emergency Management Agency shall jointly convene a committee of experts from Federal agencies, nongovernmental organizations, private sector entities, disaster management professional associations, engineering professional associations, and professional construction and homebuilding industry associations, to assess and recommend options for improving the built environment and critical infrastructure to reflect performance goals stated in terms of post-earthquake re-occupancy and functional recovery time.*
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> *(b) REPORT TO CONGRESS.—Not later than June 30, 2020, the committee convened under paragraph (1) shall submit to the Committee on Commerce, Science, and Transportation, the Committee on Energy and Natural Resources, and the Committee on Homeland Security and Governmental Affairs of the Senate and the Committee on Science, Space, and Technology, the Committee on Natural Resources, and the Committee on Homeland Security of the House of Representatives a report on recommended options for improving the built environment and critical infrastructure to reflect performance goals stated in terms of post-earthquake re-occupancy and functional recovery time.*

In response to this mandate, NIST and FEMA convened a committee of experts with two components: the Project Technical Panel (PTP), which is responsible for developing the report, and the Project Review Panel (PRP), which is responsible for providing subject matter expertise peer review throughout the writing process. The report to Congress, hereafter known as NIST-FEMA report [4], addresses a breadth of mechanisms for driving change, including codes and standards, education, and planning and preparedness. In addition, five stakeholder workshops were held in St. Louis, MO; Salt Lake City, UT; Seattle, WA; San Francisco, CA; and Los Angeles, CA to gather broad national input to the NIST-FEMA report.

4. Functional Recovery

The NIST-FEMA report defines functional recovery as follows:

> *Functional recovery is a post-earthquake performance state in which a building or lifeline infrastructure system is maintained, or restored, to safely and adequately support the basic intended functions associated with the pre-earthquake use or occupancy of a building, or the pre-earthquake service level of a lifeline infrastructure system.*

Using concepts from performance-based earthquake engineering framework, design for functional recovery would involve the creation of a new functional recovery performance objective, defined as follows:

> *A functional recovery performance objective is functional recovery achieved within an acceptable time following a specified earthquake, where the acceptable time might differ for various building uses and occupancies, or lifeline infrastructure services.*

The notion of functional recovery supports community resilience goals by focusing on the design, construction, and retrofit of individual buildings and lifeline infrastructure systems. A functional recovery performance objective is one component of community resilience and can help a community to achieve resilience by enabling buildings and lifeline systems to recover their basic functions in a timely manner. The definition of *basic* intended functions may be somewhat less than full functionality, but more than what would be considered sufficient for simple re-occupancy of buildings, or temporary provision for critical lifelines services. The determination of basic, necessary, or critical services may require community context and information on the dependencies among various aspects of a community's built environment.

Although the ability of buildings and lifeline infrastructure systems to provide services depend on interactions among different systems, a functional recovery objective will be most efficient at the individual building or lifeline infrastructure system level. In current design philosophy and practice, buildings and lifeline infrastructure systems are designed separately using different codes and standards and are regulated by different jurisdictions and sectors. A new recovery-based design paradigm envisions separate but parallel functional recovery objectives applied to the design of individual buildings and lifeline infrastructure systems. These objectives must be coordinated between buildings and lifeline systems, for example, a building design will be informed by the expected performance of lifeline infrastructure systems, but not controlled by it. The separate functional recovery objectives for buildings and lifeline systems will prevent delay in progress due to complications in either sector and will be easier to implement as assets are constructed at different times by different stakeholders, using the then-applicable codes and standards. In this way coordinated and simultaneous development of functional recovery performance objectives is expected to expedite the progress toward the goal of reducing the time it takes for communities to recovery.

5. Design Based on Recovery Time (Beyond Safety)

As mentioned earlier, the primary objective of building codes for most buildings is achieving life safety. The International Building Code (IBC) currently categorizes building use or occupancy using a building's Risk Category as defined in the Table 1604.5 of the IBC [5]. The Risk Categories are developed based on the level of protection or risk to public safety. The Risk Categories do not represent the desired recovery time for different building uses, except at the highest risk category for essential facilities. To develop functional recovery performance objectives, the Risk Category concept can be extended to consider the desired recovery time for various building uses. This new categorization could be called the Recovery Category. In this new design paradigm, buildings and lifeline infrastructure systems would be designed to meet specific recovery time goals at a specified hazard level. The recovery categories can be determined based on the needed basic services from a building or lifeline infrastructure system, and the timeline these services are needed during response and recovery. The time required for recovery of function varies by the use, occupancy, and criticality of function that a building or lifeline infrastructure system provides. Not all services are needed immediately after an earthquake, nor are all services necessarily needed at the same time. Possible Recovery Categories for buildings and lifeline infrastructure systems are described in Table 1, which is used strictly as a means to illustrate the Recovery Category concept; the target recovery times and descriptions provided in Table 1 will be influenced and likely modified by future research.

Table 1: Recovery Categories [4]

Recovery Category (RC)	Target Recovery Time	Description
RC-4	Hours	Emergency Response - Basic services and systems needed for immediate response, rescue, and event stabilization to ensure emergency response activities can be undertaken
RC-3	Days	Short-Term - Basic services and systems needed at the initial stages of recovery
RC-2	Weeks	Intermediate-Term - Basic services and systems needed to restore neighborhoods and the workforce, and to care for historically underserved populations
RC-1	Months	Long-Term - Basic services and systems needed for restoring vitality to economy, sociocultural institutions, and physical infrastructure

In current performance-based design practice, buildings are designed to meet specific performance level(s) at specified hazard level(s). In current practice, most buildings across the U.S. required to meet seismic provisions are designed to provide life-safety protection at a “design-level” hazard event. The design-level earthquake is an earthquake with a statistical likelihood of occurring once in every 300 to 700 years (also called a return period), at a particular location throughout the country. The seismic hazard level tentatively considered for functional recovery considerations in this paper, i.e., Table 1, is also taken to be the design-level event. Alternatively, scenario-based events may be more appropriate for the basis of design for locations with well-defined fault mechanisms. Future research is needed to inform selection of an appropriate hazard level for the design of functional recovery.

6. Recommended Options for Improving Built Environment and Critical Infrastructure

The NIST-FEMA report presents nine recommendations across four areas of emphasis including developing a national recovery framework, improving the built environment, improving planning, and raising awareness and understanding of potential earthquake impacts on the built environment and lifeline infrastructure systems. This section summarizes these nine recommendations. Further information regarding different options for implementation of each recommendation may be found in the NIST-FEMA report. Please note that the nine recommendations discussed here are preliminary recommendations and are subject to modification in the final draft of the NIST-FEMA report.

6.1 Develop a National Functional Recovery Framework

One of the fundamental steps identified in the NIST-FEMA report to support the development and implementation of functional recovery performance objectives is developing a functional recovery framework for buildings and lifeline infrastructure systems. This framework would address the multidisciplinary aspects of functional recovery. The framework needs to incorporate policy, social science, and engineering aspects of the issue. The framework would identify acceptable recovery times for different building uses and lifeline infrastructure services and would also address the required provisions to achieve the desired performance goals. A minimum standard is recommended for consistency across the nation, while still allowing local jurisdictions to exceed the minimum recommendations according to their priorities and distinctive challenges. The national framework should determine the functions that are critical to recovery as well as their desired timeline. The framework should also consider mechanisms to support coordination between the desired recovery times of buildings and lifeline infrastructure systems, as well as the costs and benefits associated with selecting particular hazard levels or recovery times. Future research will be needed to provide the information required for developing the national framework.

6.2 Design New Buildings to Meet Recovery-based Performance

Buildings designed according to current codes and standards may experience significant damage during a design-level earthquake that can hinder the intended function of the building. A cornerstone to all of the options for achieving functional recovery goals is to design new buildings to meet recovery-based design objectives. In this new design paradigm, in addition to designing for life-safety objectives, new buildings will also be designed to satisfy a specific recovery time after a design-level event. One of the first steps in this process is to benchmark the recovery time that current buildings codes and standards deliver. It is possible that some current building uses may already meet the desired recovery time. If the benchmarking results identify a need for reducing the desired recovery time, two alternative approaches may be pursued. In the first approach, the design requirement for a higher Risk Category building can be applied to a broader class of new structures. In an alternative approach, new buildings could be designed using new codes and standards with design criteria developed to achieve re-occupancy and recovery of function in an acceptable timeframe. Regardless of the chosen approach, the implementation of this recommendation may be achieved through either mandatory or voluntary mechanisms, and at the national, state, or local levels. Both mandatory and voluntary mechanisms are associated with implementation pros and cons that will require careful evaluation.

6.3 Retrofit Existing Buildings to Meet Recovery-Based Objectives

Enhancing the performance of existing buildings is a critical aspect of improving community resilience since existing buildings comprise the majority of the building stock and pose the greatest threat to the community. Existing buildings are more challenging to address than new buildings, as improving the performance of this building group is constrained by various factors including the technical feasibility of achieving higher performance goals, as well as the costs associated with retrofit. There is also a concern that aiming towards higher functional recovery targets (i.e., relatively short target recovery times), for retrofitting existing buildings may adversely impact safety-targeted retrofit actions. This would be an unintended negative consequence of aiming for greater resilience. One way to manage challenges related to existing buildings is to adopt lower re-occupancy or functional recovery goals than for new buildings. Such an approach will mitigate the greatest risks associated with marginally deficient buildings. In addition, retrofit programs can be paired with pre-event planning such as developing re-occupancy plans and relocation of critical uses to enhance the effectiveness of the retrofit programs. Regardless of the target recovery-based performance goal for existing building retrofits, local jurisdictions need to identify buildings that require re-occupancy and functional recovery design, as well as actionable triggers for retrofit and appropriate requirements. Similar to the design of new buildings, implementation of existing building retrofits can be done through mandatory or voluntary approaches, using national, state, or local design criteria. Both mandatory and voluntary mechanisms are associated with implementation pros and cons that will require careful evaluation.

6.4 Design, Upgrade, and Maintain Lifeline Infrastructure Systems to Meet Recovery-based Performance Objectives

Lifeline infrastructure systems have numerous operational requirements as well as regulatory environments. Most regulations for lifeline systems focus primarily on public health, as well as safe and reliable operations. These regulations are not currently intended to enable the provision of services in a specific timeframe after most hazard events, including earthquakes. Although there are multiple manuals and guidelines for design of the components of lifeline systems, design criteria are inconsistent among systems, and most of them do not incorporate seismic design. Lifelines infrastructure systems are vital components of the built environment and community recovery highly depends on the recovery of the services they provide. Therefore, there is a critical need for a shift in the design paradigm of lifeline infrastructure systems from protecting lives and property to focus on recovery of function after a hazard event within an acceptable timeframe.

To ensure consistent design and operations throughout the systems and among various owners and operators, national-level seismic design guidelines, standards, and codes are needed. These guidelines, standards, and codes would be based on functional recovery performance objectives. To develop the functional recovery design paradigm for lifeline systems, clear guidance and multiple implementation and support tools are needed. The development of codes, standards, guidelines, and tools will require additional research. Implementing the Earthquake Resistant Lifelines: NEHRP Research, Development and Implementation Roadmap [6] can serve as a stepping stone for this work.

Due to the interconnected, complex, and interdependent nature of lifeline infrastructure systems, coordinated efforts across various stakeholders are needed to develop and implement coherent and consistent performance goals for lifeline infrastructure systems. Continued support for the development of state or regional lifeline councils could significantly help engagement from different lifeline infrastructure owners and operators and is essential to implementing the framework at local levels. Besides the above-mentioned design and implementation activities, seismic resilience plans for each lifeline infrastructure system need to be developed. These plans should focus on improving (1) pre-earthquake integrated asset management plan to address aging/vulnerable components to enhance system-level resilience and (2) post-earthquake disaster recovery plans for rapidly repairing and recovering the systems. The re-establishment of the national program, as part of NEHRP, to advance the engineering of lifeline infrastructure systems could significantly assist with the leadership, management, and coordination of cross-country efforts.

6.5 Develop and Implement Plans Needed to Facilitate Functional Recovery

While codes and standards are necessary to achieve functional recovery goals, they are not sufficient in themselves. In addition, robust planning activities that enable the success of a functional recovery objective are needed. Planning is an essential step towards meeting functional recovery goals. Effective plans engage relevant and representative stakeholders in dialogue around mutually-agreed upon goals and objectives, strategies and tactics. Engaging diverse stakeholders, by educating them, getting buy-in, and feedback from them about functional recovery actions, will increase the chances of successful implementation of the functional recovery framework. Planning for functional recovery can be incorporated into all types of ongoing and future community plans.

One of the first steps related to planning efforts is to adjust the language and tools in the existing mitigation plans such as FEMA's local mitigation plan [7], that spells out requirements for communities to be eligible for FEMA post-earthquake aid for public and non-profit facilities. Similarly, functional recovery can be integrated into the community resilience activities undertaken by chief resilience officers, emergency managers, community development professionals, and other similar representatives. Moreover, state and local government can play an important role in achieving functional recovery goals by considering improvements to the development and implementation of regulatory incentives for mitigation plans, supporting planning for swift re-housing efforts after an earthquake, and the development of protective measures that can help communities to recover quickly and maintain their populations.

6.6 Perform Rapid Building Inspections and Evaluations to Facilitate Functional Recovery

Assessment of buildings' performance after an earthquake is essential to evaluate whether the they are safe to occupy and also to determine their post-hazard functionality level. Timely inspection and evaluation of buildings after an earthquake plays an important role in expediting the recovery process. There are multiple opportunities for improving the state of practice concerning inspection and evaluation of buildings ranging from development of technical guidelines to programs and policies that can support re-occupancy and functional recovery efforts [8], such as a pre-arranged plan to provision building inspectors.

From a technical standpoint, inspection guidelines need further development to effectively incorporate recovery-based assessment tools as current inspection guidelines primarily focus on the safety of buildings. Recent advances in remote sensing technologies make it possible to use seismic instrumentation to expedite the assessment and recovery of buildings and lifeline infrastructure systems. Improvements and development of these technologies are needed and may be essential for certain types of buildings. In addition, development of alternative standards for temporary habitability of buildings in post-earthquake scenarios may mitigate current stringent requirements for evacuation of buildings during the repair process. Another factor that can prevent unnecessary evacuation of residents is developing protocols for establishing safety cordons around damaged buildings that consider their associated risk with damaged buildings in conjunction with the disruption in the recovery process.

From the policy perspective, there is a need to enact policies and procedures that facilitate post-earthquake safety inspection of buildings by state and local government. For example, development and implementation of programs for funding and sharing local jurisdiction and county staff for earthquake inspection and recovery programs after an earthquake can significantly expedite the inspections and tagging process.

6.7 Explore Financial Resources to Facilitate Functional Recovery

Speedy access to financial capital after an earthquake event plays a key role in expediting recovery. There are currently different post-disaster funding mechanisms including federal programs, insurance, and loans; one common factor among these mechanisms is the slow process of administration that can significantly delay the recovery process. Improving the speed of access to resources plays an important role in expediting the recovery of buildings and lifeline infrastructure systems meeting functional recovery objectives; this can occur by modifying existing or developing new financial programs. Further coordination of existing federal programs to enable quicker access to and distribution of funds to local jurisdictions in post-event situations is also needed. One example related to access to federal financial support would be developing a Federal Case Management System and single application form, where one application can be submitted by the building owner for all applicable federal programs for disaster assistance. Consideration can be given to improving the availability of affordable housing loans after earthquakes as well as improving grant programs to expedite access to financial resources. Federal agencies may also encourage the use of parametric insurance for homes and businesses.

In addition, consideration can be given to improving the access to quick funds after an earthquake event through natural hazards insurance programs, and particularly by additional work to supporting the development of a fiscally viable and affordable earthquake insurance program. Other programs to facilitate access to post-disaster funds by private individuals, such as disaster accounts, or pre-arranged repair loans, could significantly help building owners more quickly begin the journey through repair and restoration of their buildings.

6.8 Educate Building Owners, Tenants, and Customers/Users about Building Performance Expectations and Enable Action that Will Lead to Functional Recovery

Public acceptance and input are important components of any functional recovery design and implementation. Effective public outreach requires developing and implementing appropriate educational materials, incorporating risk communication methods, and establishing ongoing engagement mechanisms. The public should be educated on the current safety-based target of the building code and its consequences on the community and its built environment in an event of an earthquake. This educational effort may help support the need for an enhanced performance target. In addition, educating building owners, tenants, and customers on the benefits of the functional recovery design may positively influence their willingness to enact functional recovery concepts. Additional work is needed to help inform the users and owners of buildings and lifeline infrastructure systems about the significant shifts required to achieve functional recovery objectives and how they are fundamentally distinct from current practice. Key components of the educational effort should include enhancing public understanding of their level of risk from seismic activity and what their buildings or lifeline infrastructure systems may or may not be able to provide given their current state. Stakeholders should also be educated on mitigation and preparedness strategies that can improve the recovery of function after an earthquake. Federal agencies could play a significant role in this effort not only by educating the public, but also by creating and promoting a nationwide seismic continuity program for all building uses to owners and tenants to address their respective unique situations. Consideration should be given to improving the continuity programs to identify effective mitigation and preparedness strategies for resuming functions post-earthquake in a timely manner.

6.9 Enhance Outreach and Continuing Education Efforts for Building Industry Professionals and their Associations

The functional recovery efforts will be more successful if adopted by many individuals, organizations, and jurisdictions. Recruiting and maintaining a workforce knowledgeable about functional recovery and implementation methods will be crucial to ensure a common understanding across the building professions and government agencies. The workforce includes engineers, architects, contractors, code officials, etc. The professional associations of the building industry are key players in moving the nation toward functional recovery because they can reach out to significant numbers of building design and construction professionals. Multiple activities can be undertaken to enhance outreach and continuing education for building industry professionals. For example, functional recovery concepts along with a discussion of the societal benefits of functional recovery could be added to the codes of ethics for different building industry associations. Similarly, the continuing education requirements for professional licensing could incorporate the functional recovery concept.

Designing buildings to functional recovery performance objectives will be a notable shift from current standards of practice for the engineering and architectural fields. Training programs will be essential to introduce skilled professionals to new concepts and to educate them on new codes, regulations, and inspection protocols.

7. Workshops

Functional recovery inherently incorporates risk tolerance, community preferences, and societal values. As a result, it is critical to gather feedback from stakeholders on developing the functional recovery framework and prioritizing options for improving functional recovery time. As part of the congressionally mandated effort, five stakeholder workshops were held across the U.S. to gather input from a broad range of community leaders and subject matter experts throughout the community on concepts that will inform the functional recovery framework and the NIST-FEMA report. The workshops were conducted in St. Louis, Salt Lake City, Seattle, San Francisco, and Los Angeles. The workshop participants represented a broad range of stakeholders and subject matter experts, including local officials, private consultants, structural engineers, social scientists, utility and lifeline system representatives, and others. The workshop collected information on three main topics: 1) the time-frame for recovery of difference components of the built environment that support various social functions, 2) attributes for evaluating and assessing options for improving functional recovery time, and 3) trade-offs among different attributes to inform evaluation of options for improving functional recovery time.

[The workshops recently concluded. Assessing results of the workshops is currently in progress. The final manuscript and presentation will include key findings from the workshops].

8. Summary

Buildings and lifeline infrastructure systems designed per current codes and standards may sustain extensive damage during an earthquake event. The widespread damage is likely to hinder the service that buildings and lifeline infrastructure systems provide to support the sociocultural and economic functions of a community [3]. The required time for regaining function of various components of the built environment is either likely to be extensive, or not well understood and difficult to estimate. A post-earthquake state in which people may not have access to their jobs, schools, housing, and other services can produce sociocultural and economic consequences that can lead to temporary or permanent displacement of a community's population. The U.S. federal government has recognized the need to extend the target of risk mitigation for the built environment from life safety to include timely recovery of function. The functional recovery design concept is proposed as a means to achieve the target performance of timely recovery of function after an earthquake. This paper summarizes the effort undertaken by NIST and FEMA in response to a Congressional mandate to recommend *"options for improving the built environment and critical infrastructure to reflect performance goals stated in terms of post-earthquake re-occupancy and functional recovery time".* The paper provides an overview on nine recommendations across four areas of emphasis related to developing a national recovery framework, improving the built environment, improving planning and expediting response and recovery, and raising awareness and understanding of potential earthquake impacts on the built environment. Future research and consensus-based decision making are needed to prioritize these options; attributes such as costs, benefits, impact, feasibility, and timeline are likely candidates for evaluation criteria. Achieving functional recovery across a community requires a multi-faceted approach that includes parallel efforts on aspects of: design of new buildings; retrofit of existing buildings; lifeline infrastructure systems; planning, outreach, and education. Developing and implementing functional recovery objectives represents a significant shift in the design philosophy for buildings and lifeline systems that demands a multi-disciplinary perspective and engagement from a broad range of community stakeholders, but this can happen within mechanisms currently in place for codes and standards development, policy development, and community resilience planning. Achieving greater seismic resilience through functional recovery goals will benefit not only local communities; the entire nation will benefit. This work can be accomplished through the strong partnerships and interactions across traditionally disparate sectors that have already initiated efforts on functional recovery.

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