NIST Special Publication 1269

NIST-FEMA Post-Earthquake Functional Recovery Workshop Report

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National Institute of Standards and Technology
U.S. Department of Commerce

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July 2021

U.S. Department of Commerce
Gina M. Raimondo, Secretary

National Institute of Standards and Technology
James K. Olthoff, Performing the Non-Exclusive Functions and Duties of the Under Secretary of Commerce for Standards and Technology & Director, National Institute of Standards and Technology

National Institute of Standards and Technology Special Publication 1269
Natl. Inst. Stand. Technol. Spec. Publ. 1269, 52 pages (July 2021)
CODEN: NSPUE2

This publication is available free of charge from: https://doi.org/10.6028/NIST.SP.1269

Abstract

To strengthen America's resilience, the Federal Government recognizes a need to reduce interruptions to services and jobs, and to lessen disruption to social and economic community functions after earthquake events. Current building codes and standards largely focus on saving lives. However, maintaining services and functionality will require new mechanisms that more effectively limit damage to buildings and lifelines infrastructure systems.

In response to a U.S. Congressional mandate, the National Institute of Standards and Technology and the Federal Emergency Management Administration[1] convened a Committee of Experts to recommend and assess "options" for improving post-earthquake re-occupancy and functional recovery time across the built environment. To inform the Committee of Experts and assist in their development of a report to Congress, stakeholder workshops were held in five cities across the country to gather information from subject matter experts and professionals in the earthquake community.

This document details the processes for gathering input from stakeholders at workshops. It summarizes participants' reactions to functional recovery concepts and options, particularly with respect to information that can help determine appropriate recovery times, as well as criteria for assessing various implementation options. In particular, workshop participants provided insights regarding which community functions were viewed as critical to post-earthquake recovery, and when components of the built environment that support those functions would need to recover in order to maintain community stability. Generally, participants categorized components of the built environment important in the short term (hours and days) more consistently than the components slated for return in longer timeframes (weeks and months). Participants noted the importance of local values and community contexts to these assignments. Attendees were also asked to consider what factors a policy maker could use to effectively assess and compare options to improve functional recovery. Cost, benefit, feasibility, effectiveness, and equity were the five categories of evaluative criteria identified most clearly and frequently across attendees.

Overall, participants supported the idea of developing a national framework for functional recovery, while emphasizing the importance of flexibility and adaptability of the framework such that it can be utilized as a tool for planning at the local level. Additional key themes stakeholders identified as important for inclusion in the report to Congress are detailed in Section 5. Input from a diversity of stakeholder perspectives gathered at the workshops were essential to help develop the concept of functional recovery and inform the report to Congress. In the future, additional feedback will be needed to develop specific resilience goals, set public policy, and prioritize the investment of resources to produce functional recovery performance.

Key words

Building; Built Environment; Community Resilience; Critical Infrastructure; Earthquake; Functional Recovery; Functionality; Lifeline Infrastructure Systems; Lifeline Services; Natural Hazard; Performance; Recovery-Based Objective; Reoccupancy; Safety.

[1] In association with the Applied Technology Council and the IDA Science and Technology Policy Institute

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Functional Recovery Workshop Report

1. Improving Post-Earthquake Performance

To strengthen America's resilience to earthquakes, the Federal Government recognizes that, in addition to an existing focus on saving lives, it is important to explore a shift toward preserving the functionality of buildings and lifeline infrastructure systems after earthquakes. This would reduce service interruptions and disruption of community functions and enable community members to return to their homes and resume their jobs. Additionally, because regaining function in an acceptable timeframe after an earthquake would necessitate mitigating damage, these efforts would simultaneously reduce costs associated with post-earthquake recovery.

This targeted performance state that extends the performance goal beyond life safety is called "functional recovery," and is the focus of this document and the workshops described herein.

As part of the December 2018 reauthorization of the National Earthquake Hazards Reduction Act of 1977 (Public Law 115-307), the National Institute of Standards and Technology (NIST) and the Federal Emergency Management Agency (FEMA) were asked to convene a Committee of Experts to identify options for moving the Nation towards functional recovery:

> *(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.*
>
> *(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 to create the report to Congress, hereafter referred to as the "NIST-FEMA report". Because functional recovery is inherently intertwined with risk tolerance, community preferences, and societal values, NIST and FEMA determined it would be critical for the Committee of Experts to consider feedback from additional stakeholders. The workshops were developed to serve as a mechanism for subject matter experts to provide additional input on key concepts being considered in the ongoing development of the NIST-FEMA report. NIST, in collaboration with FEMA, hosted five stakeholder workshops to collect broad national input on various

aspects of functional recovery. Since the report was still in draft form when the workshops were held, the intent of the workshops was not to obtain direct feedback from stakeholders on the report manuscript, but rather to compile subject matter expert insights on various impacts and risks, tradeoffs, and considerations particular to local geographies. This document details key findings from the workshops that were presented to the Committee of Experts.

Workshop findings were considered by the Committee of Experts and informed their development of the report to Congress. The final NIST-FEMA report, titled: *"FEMA P-2090/NIST SP-1254: Recommended options for improving the built environment for post-earthquake reoccupancy and functional recovery time"*, was submitted to Congress in January *2021*[6].

1.1. Functional Recovery Workshops

The five workshops were held in St. Louis, Salt Lake City, Seattle, San Francisco, and Los Angeles. The organizations represented at each workshop are provided in Appendix A, and an example workshop agenda is shown in Appendix B.

Additional information about the workshops is as follows:

- The workshops were designed to convene a broad range of stakeholders and subject matter experts, including local officials, private consultants, structural engineers, social scientists, utility and lifeline system representatives, among others. The range of expertise represented on the day of each workshop varied due to attendance.
- Workshop participants were not asked questions directly related to their subject matter expertise, but rather were encouraged to contribute to the conversation from a broader perspective based on their experience, knowledge, position, and/or those they represent, as applicable.
- The workshops were not intended to serve as community listening sessions, nor to receive detailed feedback on line-by-line draft text from the NIST-FEMA report.
- The workshops followed the Chatham House Rule [2]: participants' comments are not attributed in any external-facing documents generated following the workshop, including this document. This rule was used to encourage attendees to speak freely during each workshop.

1.2. Defining Functional Recovery

Functional recovery, as defined in the NIST-FEMA report, is intended to be a performance state less than full pre-earthquake functionality, but sufficient for reoccupancy of buildings or temporary provision of lifeline services. Figure 1 illustrates a spectrum of building performance states, in which lower post-hazard performance objectives are on the left and higher performance outcomes are on the right. Recovery-based goals (reoccupancy, functional recovery, and full functionality) are arranged with respect to each other as well as the current safety-based goals, safety, and collapse.

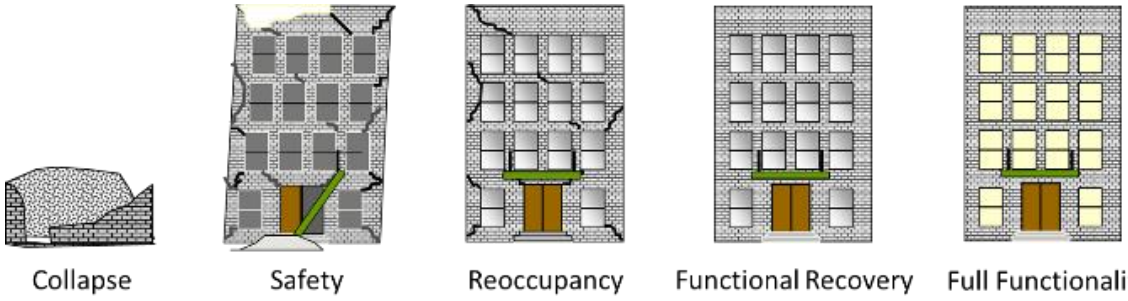

Fig. 1. Illustration of a Theoretical Range of Building Performance States (taken from NIST-FEMA, 2021).

In the context of NIST-FEMA report and the workshops, functional recovery performance level was defined 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.*

To further explain the concept of functional recovery, the following additional information was presented to workshop attendees:

- There is recognition that damage cannot be prevented in significant earthquake events, and some loss of service is likely to occur.
- Functional recovery objectives must be coordinated among elements of the built environment but will be applied independently in the design of each element. Therefore, functional recovery measures are aimed to be applicable at the individual building or lifeline infrastructure system level.
- It is envisioned that separate, but parallel, functional recovery performance objectives will be applied to the design of individual buildings and lifeline infrastructure systems.
- Time required for recovery of the function varies by use, occupancy, and criticality of function. Not all services are needed immediately, nor are all services needed at the same time.
- The desired functional recovery target for a given component of the built environment—a building or a lifeline system—may be less than full pre-earthquake functionality.
- Functional recovery, as a stepping stone toward full functionality, supports the goal of improving community resilience.

2. Overview of Workshops

2.1. Goal and Objectives

The primary goal of the workshops was to provide additional input and information to the Committee of Experts and assist them in their development of the NIST-FEMA report.

To achieve this, workshop discussions were organized around two main objectives. The first was to receive input on the functional recovery framework, and centered on exploring the maximum amount of time acceptable to achieve a basic level of function for various components of the built environment. The second was to explore how potential options for improving the built environment (i.e., the task from Congress) might be evaluated and objectively assessed.

These two objectives were identified in collaboration with the Committee of Experts and developed to solicit additional viewpoints on relevant subjects that may vary across communities. The purpose was to gain insight on how these ideas and concepts could be presented in a national level report, while still maintaining relevance across communities with different needs and values. Information from workshop discussions was explicitly considered by the Committee of Experts in their development of the NIST-FEMA report.

The input gleaned from the workshops is valuable not only for the development of the NIST-FEMA report, but also relevant to other efforts to advance the concept of functional recovery and support the resilience of communities. It is envisioned that the findings from these workshops can inform future efforts to implement the recommendations contained in the NIST-FEMA report. This document summarizes important data collected at these workshops on acceptable recovery time for various components and functions within each community. This data can inform future development of a functional recovery framework.

2.2. Agenda

A sample workshop agenda is included in Appendix B.

Workshops began with an overview of the progress of the Committee of Experts in developing the NIST-FEMA report. The Committee's definition of functional recovery was provided, enabling participants to have a shared basis for the day's discussion. In addition, workshop organizers provided context for how workshop discussions would inform the Committee of Experts and support their development of the NIST-FEMA report.

The remainder of the morning, i.e., Breakout Session 1, focused on discussing important community functions and then establishing appropriate timelines for recovery of those functions and services to produce functional recovery.

Breakout Sessions 2 and 3 were held in the afternoon. These sessions focused on the topics of risk tolerance, community preferences, and societal values to develop criteria for evaluating and comparing options for improving functional recovery of the built environment, and prioritizing implementation of these options.

The three breakout sessions, and results from each, are described in detail in Sections 3 and 4 of this document.

2.3. Workshop Invitation

Multiple workshops were hosted in varied locations to ensure that a range of dates and geographic opportunities were available, and to attract a diverse set of stakeholders from across the country.

Invitations were extended to stakeholders representing the following characteristics:

- *Locations:* Emergency management, city building and planning officials, public safety, and utility managers were identified in workshop locations across the U.S. to represent regional differences in seismic risk and earthquake mitigation activities. Additional participants from other areas of seismic risk were also invited, including San Juan, Puerto Rico; Charleston, South Carolina; and areas in Missouri, Tennessee, and Illinois in proximity to the New Madrid seismic zone.
- *Expertise:* The location criteria provided a strong foundation of expertise on seismic hazards and the built environment. A number of individuals with expertise in lifeline infrastructure, social sciences, policy, and community planning were also invited to each workshop to provide diverse perspectives on the human aspects of functional recovery.
- *Sector:* Workshop invitation lists also reflected a range of sectors to ensure that viewpoints from the private sector, Federal, State and local governments, academia, and various not-for-profit organizations would be heard.

NIST, FEMA, and the Committee of Experts also provided additional names for the invitation list. A minimum of 50 invitations were sent for each workshop location with a goal of 10–30 attendees at each workshop.

2.4. Attendee Summary

Approximately 70 people participated across the five workshops.[2] A complete list of participating organizations is provided in Appendix A. The workshop in San Francisco was the largest, with 21 attendees, while Los Angeles was the smallest, with 10 attendees (Fig. 2). Each workshop had representation from across all sectors (Fig. 2). San Francisco also had the largest proportion of structural engineers present (50 percent), while the workshop in St. Louis had the widest breadth of expertise, at 80 percent of attendees having expertise other than structural engineering (Fig. 3).[3]

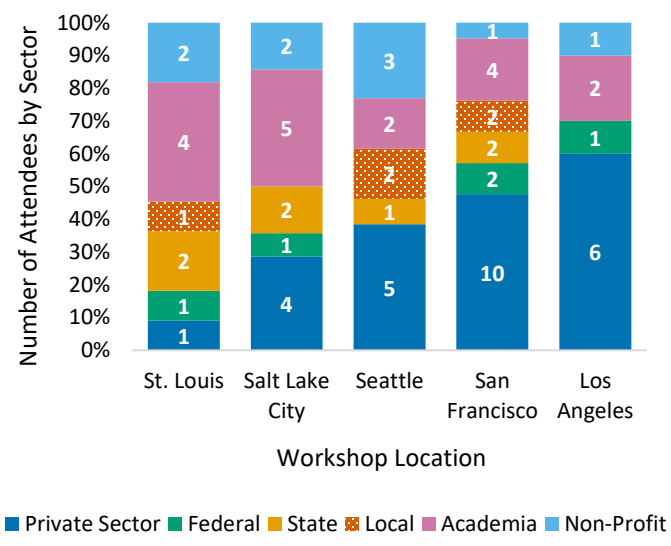

Fig. 2. Workshop Attendees across the Five Locations by Stakeholder Sector.

[2] The attendance is based on the workshop sign-in sheet. Additional participants may not have signed in.

[3] The numbers in Fig. 3. do not sum to the number of participants as indicated in Fig. 2; participants were characterized by one and sometimes more, area(s) of expertise per person based on evaluation of their past experience and current position.

2.5. Additional Notes on Attendee Perspectives

Information gathered at the five workshops provided valuable insights into the attendees' viewpoints on functional recovery and what criteria should be used to evaluate different functional recovery options, but some limitations should be noted.

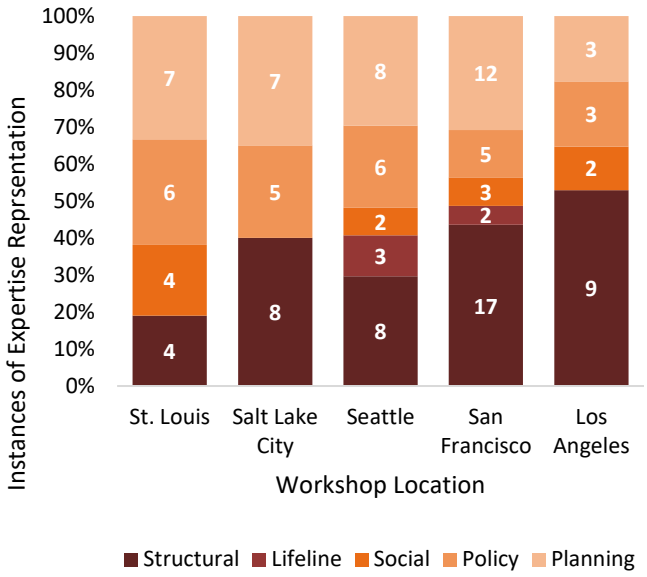

Fig. 3. Workshop Attendees across the Five Locations by Area of Expertise.

Since a fraction of overall invitees attended and the subject matter expertise was not necessarily balanced at each workshop, attendee perspectives should not be assumed to constitute a representative sample of the population of community resilience and functional recovery professionals. Similarly, workshop locations should not be looked at as representative of views of any particular sample populations; therefore, geographic comparisons across workshop locations, or comparisons across sectors and/or expertise of attendees should be avoided, or executed cautiously within the appropriate context of the discussion.

Since most workshop attendees possess disciplinary expertise related to community resilience and/or functional recovery, workshop findings are not representative of views of the general public. Workshop attendees were identified specifically for their subject matter expertise, as was required in the Congressional mandate. Expert knowledge and information were key for the development of workshop takeaway messages. Further work to gather and incorporate public input is still required for future development of functional recovery concepts and policies.

3. Breakout Session 1: Developing a Functional Recovery Framework

One key aspect of post-hazard recovery is time [1]. How long a community is willing or able to remain in a place post-hazard depends on many variables; however, having access to key components of the built environment may mitigate lasting impacts and enable residents to resume normal activities sooner. This exercise explored which community functions were viewed as integral to recovery, and when components of the built environment that support those functions would need to achieve functional recovery status to best sustain a community.

Ultimately, the first recommendation in the NIST-FEMA report is that a Framework for Post-Earthquake Reoccupancy and Functional Recovery Objectives should be developed [6]. This framework should help define what community functions and services need to be in place to promote recovery after a seismic event, as well as acceptable timeframes for recovery; develop design criteria for what performance attributes, capacity, or level of function a component of infrastructure must achieve to reach reoccupancy or functional recovery status; and determine the appropriate earthquake hazard levels on which to base recovery objectives.

3.1. Objective

The focus of Breakout Session 1 was to provide input on development of the framework for functional recovery as described by the acceptable amount of time a function can be out of service before there is a lasting impact on a community. The session was structured around a set of proposed recovery categories included in an early draft of the NIST-FEMA report, and aimed to validate or dispute the notion of hours, days, weeks, and months as appropriate timeframes for recovery, as well as develop distinct concepts and descriptions for each timeframe (e.g., describe fundamental differences in examples placed in the hours category versus those placed in days).

3.2. Process

The session was framed by discussing the ultimate goal of functional recovery: to support societal needs following an earthquake such that the community avoids population displacement and retains its economic and societal growth trajectory. As the goal of functional recovery is to enable recovery of the function or service that different components of the built environment provide, the discussion began with functions or services that a community needs, rather than performance of the components of the built environment. This approach encouraged participants to think about recovery of various critical services and functions first, rather than prioritizing particular building types.

- Stakeholders were first asked to brainstorm the community functions necessary to maintain the population following an earthquake, thinking in terms of activities and processes rather than buildings and other infrastructure. To focus these efforts on recovery, participants were specifically urged not to think about the initial emergency response phase post-disaster in too much detail.
- Once the stakeholders were satisfied with their list of community functions, the group was asked to brainstorm components of the built environment (hereafter referred to as “components”) that enabled those functions. As participants

brainstormed, each component was listed on an individual sticky note, and once the group finished brainstorming, the sticky notes were distributed among participants.

A wall in the breakout room was labeled with the recovery categories described in the draft NIST-FEMA report, including: hours, days, weeks, and months.[4]

- Participants were then asked to place each of their assigned components into the appropriate time for recovery category and were reminded that the time category should represent the longest allowable time a community could go without that component of the built environment, and the community function performed within. To ensure internal consistency, each group was asked to define hours, days, weeks, and months (see Appendix C).
- Once all participants placed their components in a recovery category, the groups discussed where components were placed and were allowed to revise the initial placements. Participants then discussed why certain components were placed in certain recovery categories and what situations would cause some of the components to shift (i.e., how local contexts or use of temporary work-arounds may alter the results). Participants were also asked to describe the overall characteristics of each recovery category (see Appendix D).

The exercise was not designed to develop a comprehensive list of examples for each recovery category; rather, the goals were to better distinguish between the contents listed in each timeframe category, and to develop descriptions for each category.

3.3. Analysis Method: Functions, Components and Recovery Times

The 10 breakout groups across the five locations brainstormed a total of 120 community functions and 322 components of the built environment. The groups also indicated the acceptable recovery time for providing basic functions of each component of the built environment. Appendix E summarizes the community functions discussed throughout the workshops, and Appendix F summarizes the components of the built environment and their associated acceptable timeframe for recovery.

In analyzing the information gathered during this workshop breakout, a list of "generalized community functions" was developed by grouping similar community functions brainstormed at the beginning of Breakout Session 1. Each component of the built environment that was listed on a sticky note was then mapped to the generalized community function it served. Table 1 shows examples of brainstormed community functions, the corresponding generalized community function, and components of the built environment that were grouped under the generalized community function. The components of the built environment and generalized community functions were then compared across breakout groups, resulting in a unique list of 62 components that enabled 13 generalized community functions (see Table 3).

[4] One breakout group preferred to include a 'minutes' category as well, while a second breakout group included 'years' in their discussions.

Table 1. Examples of Brainstormed Community Functions and Components of the Built Environment Mapped to "Generalized" Community Functions.[5]

Brainstormed Community Function	Generalized Community Function	Unique List of Components
Emergency response	**Public Health and Safety**	communications poles
Fire		critical facilities
Fire-fighting		critical health centers
Fire protection		fire stations
Garbage removal		hospital systems
Law and order		jails
Law and order/public safety		police
Lifelines		police stations
Public health		police station, 911 call center
Public safety		police, fire
Safety		prisons
Security, safety		sewer system
Trash removal/basic sanitation		landfill/space for debris
Waste removal, services		waste/wastewater treatment infrastructure
Roads, transportation	**Transportation Services**	airport
Transit/transportation		bridges
Transportation		emergency transportation routes
Transportation (goods, people)	**Transportation Services**	main roads
Transportation systems		public transportation
		transportation nodes (bridges, ports, runways)

Table 2 illustrates the relationship between generalized community function and acceptable recovery time for that function. The color represents the number of times a component of the built environment enabling that function was included in each recovery time category. Attendees were not given components or functions to evaluate, so the number of times an item is mentioned is not a ratio (i.e., mentioned 3/25 times) but rather a reference that indicates how often a component was mentioned. Thus, the number of counts (represented by the darkness of each cell) for each generalized community function is influenced by the number of similar components of the built environment brainstormed across breakout groups.

[5] A full list of all brainstormed community functions and components of the built environment can be found in Appendix E and Appendix F, respectively.

Table 2. Distribution of the Acceptable Recovery Times for Generalized Community Functions across All Workshop Breakout Groups.

Generalized Community Function	Hours	Days	Weeks	Months
Public Health and Safety	25	6	2	1
Telecommunications/Information	12	6	1	0
Healthcare	12	5	2	0
Transportation Services	11	12	9	3
Shelter/Housing	11	10	9	2
Energy/Electricity	8	16	1	0
Food and Water Resources	5	10	1	1
Local Economy/Jobs	1	10	15	8
Governance	1	2	3	0
Entertainment/Recreation	0	5	7	9
Social Support	0	5	1	0
Education	0	4	7	1
Cultural Identity	0	0	3	2

Darker color corresponds to the most often selected time category for a component that supports the generalized community function listed.

Table 3 details examples of the components corresponding to each generalized function (presented in Table 2) and illustrates the relationship between components of the built environment and maximum recovery time. Breakout groups generated their own lists of components, so not all components were discussed by each group.

Some breakout groups placed components on the border of specific recovery categories, and these components were counted in both. Thus, 322 components resulted in 349 total counts. A few breakout groups also defined additional recovery categories (minutes and years), and the components placed in these categories were grouped with hours and months, respectively.

Table 3. Detailed Representation of the Components Identified in Breakout Groups Mapped to the Corresponding Generalized Community Function and Recovery Times.

Generalized Community Function	Unique List of Components	Hours	Days	Weeks	Months
Public Health and Safety	police stations	25	6	2	1
	fire stations	25	6	2	1
	jails/prisons	11	2	0	1
	waste/wastewater treatment infrastructure	2	9	3	0

Generalized Community Function	Unique List of Components	Hours	Days	Weeks	Months
	sewer system				
	critical facilities				
	landfill/space for debris				
	military bases				
	construction equipment and materials				
Telecommunications/ Information	communication/ cyber infrastructure				
	emergency communication				
	Internet				
Healthcare	hospitals				
	medical clinics				
	dialysis centers				
	pharmacies				
Transportation Services	transportation nodes (bridges, ports, runways)				
	major roads				
	emergency transportation routes				
	airport				
	public transportation				
	railroads				
	minor roads				
	bike lanes				
Shelter/Housing	temporary housing/shelter				
	elder care/nursing home				
	multi-family housing				
	single-family housing				
Energy/Electricity	electricity (generation, transmission, distribution)				
	energy/fuel (generation and distribution)				
	dams				
	emergency power				
Food and Water Resources	residential water				
	reservoirs				
	emergency water				
	grocery stores				
	emergency food				
Local Economy/Jobs	banking/finance				
	distribution centers				

Generalized Community Function	Unique List of Components	Hours	Days	Weeks	Months
	commercial/industry				
	commercial (retail)				
	commercial (major employer)				
	commercial (small businesses)				
	hotels				
	office buildings				
	restaurants				
Governance	government buildings				
	court houses				
Entertainment/ Recreation	recreation center				
	libraries				
	stadiums/arenas				
	movie studios/theaters				
	museums				
	country clubs				
	night clubs				
Social Support	daycare				
	social services centers				
	veterinary clinics				
Education	schools				
	universities				
Cultural Identity	religious centers				
	historic buildings/landmarks				

Darker color corresponds to the most often occurring time category selected for a given component.

3.4. Analysis of Results

From the Breakout Session 1 analysis, the following conclusions (in bold) and overall observations that led to each conclusion (shown as bullets) are synthesized.

a. A consistent functional recovery framework would help local communities in their planning

Across all workshops, participants supported the development of a consistent functional recovery framework and viewed a functional recovery framework as a useful tool for planning at the local level.

- Participants also acknowledged it would be difficult to develop a national-level framework with the degree of flexibility needed to make it adaptable to local

contexts, such as weather, socioeconomic makeup, and available resources. For example, the recovery times for components supporting the local economy/jobs varied across breakout groups, as the desired recovery times depended on how heavily the local economy relied on different industries and small businesses.

- Despite these differences in local contexts, participants described the recovery time categories fairly consistently. As seen by the descriptions provided in Appendix D, the Hours and Days recovery time categories focused on supporting life safety, emergency response, and basic services. The Weeks and Months recovery time categories focused on supporting a return to community normality and improving quality of life, respectively.

b. Early stages of recovery (hours and days) were more consistent across communities than later stages (weeks and months)

The components placed in the Hours and Days recovery time categories tended to be more consistent across breakout groups than the components in the Weeks and Months recovery categories, which appeared to be more dependent on local values and community contexts.

- Components needed to support life safety, emergency response operations, and basic services may be more universal across communities than the components supporting a return to community normality and improved quality of life. For example, fire stations and hospitals were consistently placed in the Hours recovery category, and police stations were categorized in Hours in 26 out of 27 instances.[6] Components related to energy/electricity, food/water resources, and telecommunications/information were placed in the Hours and Days recovery time categories in 73 out of 81 instances.
- Participants expressed more variability in judgment on buildings and infrastructure related to functions other than life safety and life essentials. For example, components related to local economy/jobs and entertainment/recreation community functions were placed in the Days, Weeks, and Months recovery categories. Furthermore, components related to transportation supported both life safety (e.g., transportation nodes) and non-life safety services (e.g., minor roads), which explains why there is less consistency across the transportation community function. This again highlights how any national functional recovery framework would need to account for local contexts.

c. Challenges in determining acceptable recovery times

Throughout the first session, participants asked questions regarding the assumptions they were being asked to make when deciding which recovery times were acceptable.

- Many participants noted that their expectations for how long a building might take to regain its function would depend on the hazard level (i.e., if the magnitude of the event was relatively large [9 Mw] or small [5 Mw]). It will therefore be important to specify the hazard level as it relates to any recommendations.

[6] The other group categorized them in Weeks, recognizing that they could still function without physical police stations.

- Participants also asked whether they should be realistic or idealistic when deciding how long a community could go without a certain component of the built environment.
- During the exercise, workshop participants also identified interdependencies between components of the built environment that became a factor in determining appropriate time categories. For example, in some areas, roads would have to be functional before grocery stores to ensure that people and goods could get to and from the store.

3.5. Discussion

Beyond the direct results from the analysis above, broader themes emerged from the discussions throughout the framework development process.

a. A functional recovery framework should relate community functions and building functions

As shown in Table 3, the maximum recovery time for many components differed between breakout groups (e.g., commercial sector vs. recreation center). While some of the variation was due to differences in local contexts, the desired recovery time of certain components also depended on how the participants viewed alternatives or work-arounds to buildings for achieving pre-earthquake functionality.

- Participants identified that some functions could be shifted to different buildings as a work-around without long-term consequences to the communities. For example, schools and universities were placed in the Weeks recovery category, but participants assumed education would resume in alternative locations (e.g., trailers) before schools and universities were reopened. All breakout groups that explicitly discussed office buildings placed office buildings in the Weeks and Months recovery time categories and placed communication/cyber infrastructure in the Hours and Days categories; if communication/cyber infrastructure was functioning, participants cited the ability to telework and thus did not need office buildings. People saw these work-arounds as viable options, but whether a work-around was appropriate depended upon other factors. For example, people were willing to say school was not needed immediately, particularly if schools were being used as shelters. However, if schools were not functioning as shelters, children would need to go to school so parents could go to work. This reiterates the possibility for work-arounds, but also the utility in ensuring that different functions can be accomplished without affecting other required services or functions.
- Some communities will tolerate temporary solutions longer than others, highlighting the benefit of designing a framework that focuses on community functions (e.g., education) rather than only on components of the built environment (e.g., school buildings).
- An exception to the suggestion that the functional recovery framework should be rooted in community function rather than pre-disaster building functionality was that participants identified a potential disparity between criticality of function and ease of replacement. For example, participants noted that historic monuments may

not serve a critical function for the community, but their historic value may be irreplaceable.

- Some workshop participants questioned whether "pre-earthquake functionality" is an appropriate target, or if they were being asked to do better than that. Participants questioned whether pre-disaster functionality is a sufficient target for all communities and considered whether investments in functional recovery may perpetuate inequities. For example, one participant in Salt Lake City noted that "*we are not in the best of worlds today. The thought of bouncing back to where we are, we need to bounce forward instead*." They went on to suggest that this effort should take "*the opportunity to get people to think about incentivizing people to move forward."*

b. Functional recovery should be put in a broader context of disaster preparedness and response

Throughout the workshops, participants consistently inquired as to how this functional recovery effort fit into the broader context of disaster preparedness and response.

- While recognizing the congressional request was focused on earthquakes, workshop participants preferred that the NIST-FEMA report convey how functional recovery could apply across multiple hazards and therefore be applicable to communities facing other hazards as well.
- Participants wanted to know how the functional recovery framework would relate to similar efforts, such as the NIST Community Resilience Planning Guide.
- Workshop participants questioned the relationship between functional recovery and emergency operations efforts. In particular, they questioned whether the functional recovery framework should encompass emergency response efforts or if it should be thought of as distinct. For example, variations in the maximum recovery time for recreation centers highlight the conflation of emergency response with functional recovery. Some groups note that recreation centers could serve as temporary shelters, causing them to put recreation centers in the Days recovery time category. Other groups saw recreation centers as purely luxury spaces and placed them in the Months recovery timeframe. Another example was water systems: participants questioned if they would have bottled water and whether other emergency means of water supply should be assumed when specifying a recovery timeframe for municipal water systems. This issue can be resolved or clarified by outlining the relationship between functional recovery and emergency operations in any future reports or recommendations.

4. Breakout Sessions 2 and 3: Comparison of Functional Recovery Options

The congressional mandate specified that the report to Congress shall recommend options for improving the built environment and critical infrastructure systems. When the workshop was being developed, the Committee of Experts was considering a vast number of different options that could potentially be included in the NIST-FEMA report as recommendations. To assist the Committee of Experts in assessing the options, Breakout Sessions 2 and 3 delved into potential criteria, both technical and non-technical, that workshop participants viewed as important to assess or compare across options.

4.1. Objective

The goal of Breakout Sessions 2 and 3 was to identify consistent evaluation criteria with which to assess options for improving the functional recovery of the built environment. The approach of determining consistent criteria was intended to inform the thinking of the Committee of Experts in their comparison and assessment of options for inclusion in the NIST-FEMA report. The results of these sessions could also help to inform further development of metrics which policy and other decision makers can use to better evaluate individual options as well as to compare amongst a suite of options.

4.2. Process

In Breakout Session 2, facilitators asked participants to consider what information a policy maker would need to effectively compare different functional recovery options. Workshop stakeholders identified a list of criteria that policy makers may need to consider in evaluating options for moving towards functional recovery.

- These criteria were compiled until workshop participants felt they had produced a reasonably comprehensive list.

Once the list had been developed, workshop participants voted for the two criteria they thought were most important when assessing the options.

The top five criteria from Breakout Session 2 were then determined based on the number of votes for each criterion and were assigned a color.

For Breakout Session 3, the five criteria identified in Breakout Session 2 were used as a basis for evaluating several hypothetical options based on an early draft of the NIST-FEMA report.

- Participants were given sticky notes in five colors, and each color was associated with one of the five criteria from Breakout Session 2.
- Workshop facilitators then described the option being evaluated and asked participants to place their sticky notes on a board, indicating how important each criterion was when evaluating that particular option (Fig. 4).[7] The four options participants evaluated were:

[7] This example is from the Los Angeles workshop Breakout Group B.

1) Design all new buildings using new codes/standards with specific functional recovery performance objectives,

2) Incentivize pre-disaster retrofits of existing buildings through Federal or State tax breaks,

3) Educate building owners and tenants on the seismic risk to their building and community, and

4) (If time allowed) Maintain the status quo of designing for life safety (i.e., business as usual).[8]

After each round of voting, participants discussed trends within their votes and explained their thought processes. Time was typically provided at the end of this exercise to discuss participants' thoughts on their results: whether they looked as anticipated, what was common and different across options, and what criteria they thought were missing now that the exercise was completed.

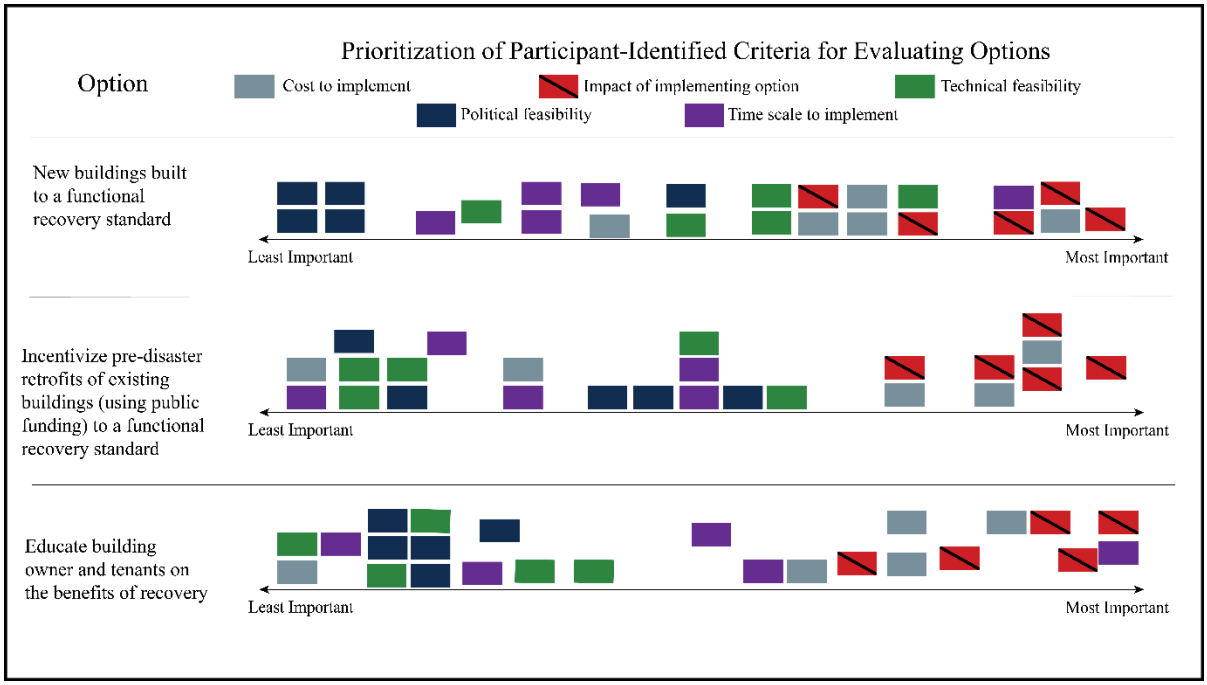

Fig. 4. Example of Top Five Criteria (shown by five different colored boxes at the top of the figure) for Assessing three Functional Recovery Options and Participants' Votes [The placement of colored boxes shows how important each criterion was to evaluating that particular option].

[8] Multiple groups did not have time to address option 4, or chose to have more robust discussions around options 1-3. Because not all groups evaluated option 4, it was not included in this analysis.

4.3. Analysis Method: Criteria used to Assess Options

Workshop participants across nine breakout groups considered 46 criteria for evaluating functional recovery options.[9] After the top five criteria were identified by participant voting in Breakout Session 2, those criteria were used to assess four hypothetical functional recovery options. For the purpose of comparing the placement of each criterion across the breakout groups, the prioritization scale (least important to most important lines drawn in Breakout Session 3) was partitioned into five sections of equal length, applying a value of 1 through 5 to each section. Sticky notes placed toward the "least important" end of the scale criteria were given corresponding low values and criteria closer to the "most important" end received corresponding higher values. The average importance score was determined for each criterion by averaging the values assigned to each note representing that criterion. This process was repeated for each of the criteria in each of the breakout sessions and for all the options (see example in Appendix G).

To evaluate thematic trends across the different breakout groups, criteria were merged into like-categories of "generalized criteria" and the scores were averaged. The colored circles in Fig. 5 represent eight generalized criteria that were "Top 5"-ranked in at least two breakout groups. Criteria that were unique to a breakout group were not included in Fig. 5. The size of each circle is based on the number of breakout groups that ranked the criterion in their Top 5, with "Cost" included most often (9 groups), while "Consequences" and "Public Buy-In" were used by only two groups. The number of breakout groups that used a criterion to evaluate the options presented in the exercise is also indicated by the number in parentheses after each criterion name in the legend in Fig. 5. The position of each circle along the horizontal line corresponds to the average importance of the criterion across all breakout groups, with least important on the left and most important on the right.

[9] One workshop breakout group was excluded from this analysis because of a differing approach in the third breakout session. One breakout group ranked six criteria instead of five.

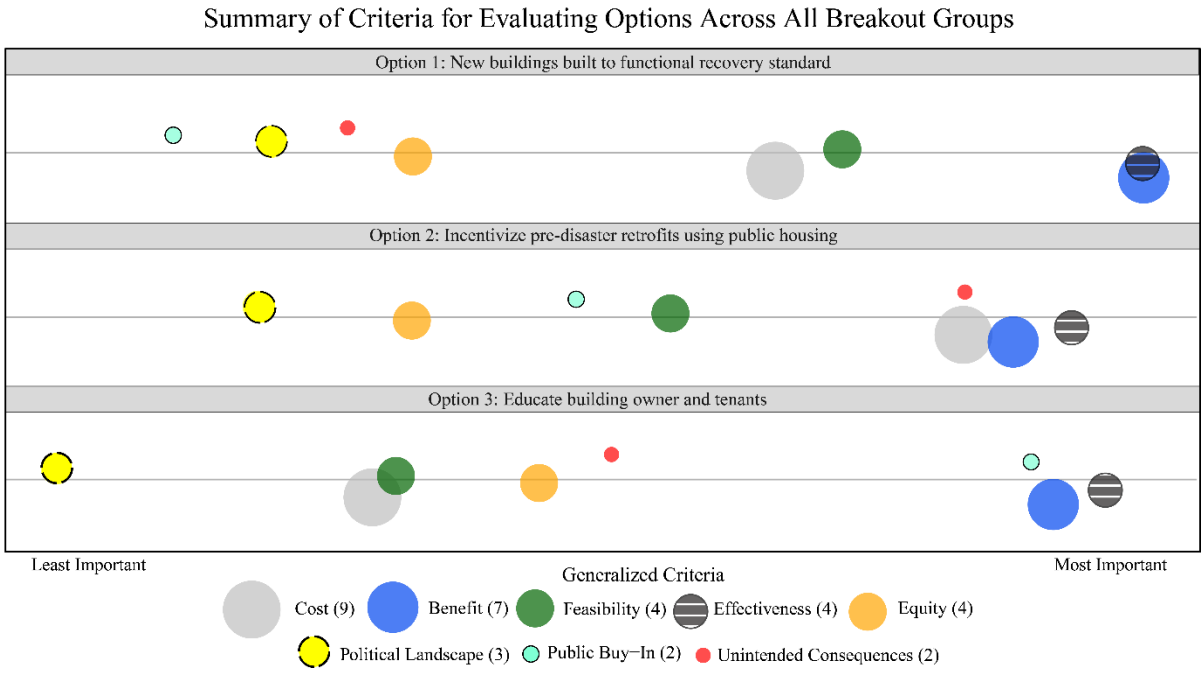

Fig. 5. Relative Importance (least to most) of Generalized Criteria for Assessing Three Functional Recovery Options across All Breakout Groups [the size of each circle is based on the number of breakout groups that ranked the criterion in their Top 5].

4.4. Analysis of Results

Each workshop breakout group defined the criteria they listed differently, which has implications for the analysis. While most of the breakout groups identified "Cost" and "Benefit" as key criteria, each group defined these terms in different ways. For example, questions such as "What type of cost/benefit?", "Who receives the cost/ benefit?", and "Who is the audience perceiving the cost/benefit?" all might have different answers for different breakout groups. However, there are some generalizable observations that can be made from the information collected in Breakout Sessions 2 and 3. One observed trend was that "Benefit" and "Effectiveness" were consistently considered criteria of high importance across all three options considered. Additionally, while "Cost" was a common criterion listed in Breakout Sessions 2 and 3 of the workshops, its relative importance varied depending on the option being discussed. Finally, "Feasibility" and "Equity" were not always included in the list of Top 5 criteria, but when included, they had the highest variability in individual responses within a breakout group.

4.5. Discussion

From the analysis of Breakout Sessions 2 and 3, the following has been synthesized: conclusions (in bold), as well as the Breakout Sessions 2 and 3 overall observations that led to each conclusion (shown as bullets).

a. The options should be specific and actionable

Participants found that consistent interpretation of the option is critical for reliable assessment. A key source of variability in the Session 3 exercise occurred from differences in how the option was interpreted by the workshop participants.

- Participants expressed their preferences for the options to be specific and actionable. Participants noted the more specific and action-oriented the option is, the more consistent the analysis, because it reduces the potential for misinterpretation, and it allows for a more concrete assessment of important criteria, such as "Cost" and "Benefits".

b. The options should be assessed according to a stated list of criteria

Participants viewed having clear justifications for options to be very important.

- Participants were fairly consistent in identifying criteria that should be used to assess options, such as Cost, Benefit, Feasibility, and Effectiveness.
- Participants recommended that the NIST-FEMA report include an assessment of each option; for example, rated as low, medium, or high for each criterion. This would allow communities and other decision makers to prioritize options themselves according to their own needs and preferred tradeoffs.
- Participants articulated the need for criteria to be clearly defined. For example, across the workshops, "cost" was defined as a variety of metrics (e.g., cost to individual, life cycle cost, whomever is bearing the cost, upfront capital investments). Small differences in definitional interpretation led to large differences in ranking of the criteria with respect to importance for an option.
- Participants recommended that the criteria used to evaluate options should incorporate political, social, and implementation issues in addition to technology and economic considerations. Traditional engineering economic evaluation criteria such as cost and benefits were consistently voted as important; however, participants also consistently highlighted the need to consider complex issues such as governance, meeting needs of underserved populations, and variation in degree of buy-in across communities.
- Participants noted that in addition to specified criteria for assessing options, the evaluation needed to include a consistent stakeholder perspective through which the evaluation is conducted. For example, are the options being assessed through the lens of the individual? The community? The Federal Government? Even with a consistent basis of evaluation criteria, the assessment of the option may depend on the perspective being applied.

c. Options are inter-related and may not be fully effective if implemented in isolation

- Participants stated that the options should not be assessed independently from one another because options may not be effective on their own. For example, in the options discussed in Session 3, participants noted that education on its own may not

be highly effective, but education paired with new design requirements for new buildings could be more effective.

- Participants suggested that options be presented to Congress as a proposed portfolio that addresses a variety of needs, as not every option can or should meet the desired criteria. For example, by defining a strategic pathway that presents complementary actions that build upon one another and that highlights interdependencies between options.

5. Important Themes from Across the Workshops

The following section summarizes a number of additional important themes that developed across the workshops. Many participants expressed ideas and opinions that were germane to the report and how it might be framed, as well as for future research and application efforts for functional recovery. Therefore, specific points made by participants are summarized here in order to help illustrate or describe each theme. This information was considered by the Committee of Experts as they drafted the NIST-FEMA report.

5.1. Specificity on the Goal of the Report: Minimum National Requirements or Best Practices for Leading Communities

Participants expressed that the options selected for the NIST-FEMA report would vary depending on whether the purpose of that report is intended to establish best practices for leading communities or provide an acceptable baseline for all communities. It was discussed that some locations may want or be willing to invest more heavily in higher levels of protection, while other locations may not due to various restrictions.

- A participant in San Francisco stated that while San Francisco needed a gold standard, another city may need some sort of minimum standard.
- A common theme across the workshops was how functional recovery was going to address the existing public misconceptions about earthquake safety—that they already believe their buildings would be recoverable, even if only designed to achieve life safety.
- One participant noted that life safety is currently not achieved everywhere, and wondered if functional recovery goals perhaps distract from the mitigation goals of bringing up the baseline to life safety.

5.2. Achieving Functional Recovery May Require Options Beyond Building Codes

Building codes are on a different scale than community functions: an overarching message across workshops was that it was not enough to have individual buildings up to code.

- Even if individual buildings are up to a newer code, the rest of the community needs to be resilient in order to have effective recovery. An example given in the Seattle workshop was of the fires in Paradise affecting property values, where a house that remained standing no longer had value because the surrounding community had been destroyed. Participants in Seattle recommended identifying key commercial hubs and critical components in neighborhoods that should be targeted.
- Effecting change through building codes will take a long time to affect majority of buildings. In Salt Lake City, a participant noted that changes to building codes will take decades to affect the majority of buildings. Multiple participants expressed support for more considerations of lifeline infrastructure.
- Participants recommended the options take into account systems beyond structural considerations, such as community planning and social aspects. For example, a participant in Seattle stated that "*Social things are super important for a sense of*

place." They went on to describe that it is not just about businesses; it is about what makes people want to live in a certain place.

5.3. Incorporating Social Functions and Community Values Is Necessary

Participants across the workshops stated that social functions are essential community functions.

- In Salt Lake City, participants listed social institutions, non-profits, social capital, social welfare, and cultural welfare as community functions. In San Francisco, participants discussed the importance of the structure provided by support systems, the community of friends, religious communities, and family. A Los Angeles participant discussed the importance of social functions by using homeless shelters as an example. They pointed out that homeless shelters provide different social functions in different parts of the country, and that they should be designed based on their function in a community.
- In San Francisco, a participant stated that "*the built environment needs to serve the social environment,*" and that "*this needs to be explicit*."
- An important consideration is not just where, but who will be most affected. Participants in Salt Lake City noted that those who were most vulnerable would have the longest displacement time. Another participant in Salt Lake City noted that, historically, disasters result in poor people getting poorer, and that "*ideally we wouldn't see that disparity on ability to recover based on your demographics or class.*" Another participant added that it was "*important not to overlook this in planning.*" As another example, Seattle participants noted that representing shared values of people in the community was important, which could include social equity.

5.4. The Report Should Acknowledge Limitations

Workshop participants recognized the challenge in developing, prioritizing, and analyzing options, and the limitations of this process.

- Participants emphasized that the NIST-FEMA report should explicitly describe the method utilized for report development and option selection, and acknowledge limitations of these processes. Participants felt it was important to acknowledge that the input from the stakeholder workshops was from the perspective of subject matter experts, and not average community members. In the Seattle workshop, one participant suggested that "*communities can take this report back and see how these options reflect community values.*" Another participant suggested that the Committee of Experts create "a core set of attributes," and communities can take those attributes as suggestions and discuss how their community identity and sense of place can help adapt it to be more effective.

6. Summary and Future Work

Transforming communities to better achieve earthquake resilience is a long-term goal that will take time and resources. As a mechanism to improve performance of buildings or lifeline infrastructure systems, functional recovery will help support key community functions, as well as define acceptable timeframes for their recovery following a seismic event.

In response to a Congressional mandate, NIST and FEMA provided a report to Congress, "*FEMA P-2090/NIST SP-1254: Recommended Options for Improving the Built Environment for Post-Earthquake Reoccupancy and Functional Recovery Time*" [6], that recommends options for improving the built environment and critical infrastructure systems. As part of this effort, NIST and FEMA conducted stakeholder workshops to inform the Committee of Experts. Workshops were organized in five cities across the country to gather input from a broad group of additional subject matter experts and to get a sense of how community preferences, societal values, and risk tolerance might vary and influence the topic of functional recovery. The content used to create this document was considered by the Committee of Experts in developing the NIST-FEMA report. As such, these materials, findings, and summary points pre-date the final development of the NIST-FEMA report [6]. Readers are encouraged to refer to the final NIST-FEMA report (FEMA P-2090/NIST SP-1254) for a more complete explanation of functional recovery and its application across the built environment.

The workshops described in this document represent a starting point for important topics that need further exploration as the pathway to resilience is plotted and the concepts of reoccupancy and functional recovery are developed. Based on analysis of stakeholder derived data across the workshops, participants identified a need for a national functional recovery framework to help guide individual communities as they devise plans that can be actionable at the local level. Further, participants voiced a preference that this guidance be flexible and adaptable such that it can be easily tailored to incorporate local community needs and values.

Workshop participants considered factors that could be used to assess and compare options for improving the built environment in terms of functional recovery. Criteria were defined in different ways among various breakout groups; however, cost, benefit, feasibility, effectiveness, and equity were the five categories of evaluative criteria identified most clearly and frequently across workshop breakout groups.

Further efforts to incorporate community goals into high-level plans (e.g., comprehensive plans, hazard mitigation plans, economic development plans) are needed to support effective and coordinated implementation and local buy-in. Additional feedback from a diversity of perspectives is needed to help develop specific resilience goals, set public policy, and prioritize the investment of limited resources.

Building on this work, future workshops could more systematically identify acceptable reoccupancy and functional recovery times for different building functions and lifeline system services. Future research efforts should sample representative populations to help provide the information needed to inform the development of a national functional recovery framework, which involves addressing technical criteria and design requirements; hazard levels for design; and retrofit and maintenance of buildings and lifeline infrastructure systems.

Improving the built environment by achieving reoccupancy and functional recovery performance status will require dedicated effort and commitment of resources toward making incremental progress over time. Ultimately, the improved resilience resulting from further studies and implementation of well-planned options will yield communities that are better prepared, and in a much better position to recover from future earthquakes.

Appendix A. Workshop Attendees

This list includes all organizations represented at the workshops. Names of participants were also included if participants agreed to have their name published.

Organizations	First Name	Last Name
St. Louis		
CCS Group Inc.	Michael	Griffin
Central U.S. Earthquake Consortium	Brian	Blake
City of St. Louis Emergency Management Agency		
International Code Council (ICC)	Michael	Pfeiffer
Missouri University of Science and Technology	Genda	Chen
NIST		
South Carolina Earthquake Education and Preparedness	Norm	Levine
State Emergency Management Agency (MO)		
Stony Brook University	Sara	Hamideh
Texas A&M University	Negar	Mohammadgholibeyki
University of Colorado, Boulder	Dustin	Cook
Salt Lake City		
BHW Engineers		
Burns & McDonnell		
Utah Chapter of the Earthquake Engineering Research Institute	Brent	Maxfield
FEMA	Amal	Centers, Jr.
J.R. Harris & Company	James	Harris
Natural Hazard Mitigation Association	Edward	Thomas
Reaveley Engineers	Jessica	Chappell
University of Auckland (NZ)		
University of Utah	Divya	Chandrasekhar
University of Utah		
University of Utah	Kristine	Pankow
University of Utah	Chris	Pantelides
Utah Division of Emergency Management (UDEM)	Robert	Carey

Organizations	First Name	Last Name
Utah Geological Survey	Steve	Bowman
Seattle		
City of Portland	Jonna	Papaefthimiou
Clackamas County Disaster Management	Jay	Wilson
Collins Woermann	Steven	Moddemeyer
Earthquake Engineering Research Institute (EERI)	Nicole	Errett
Geologic Hazards Group		
International Code Commission		
KPFF Consulting Engineers	Andrew	Taylor
Magnusson Klemencic Associates	John	Hooper
Natural Hazard Center	Nnenia	Campbell
NW Natural		
PCS Structural Solution	Donald	Scott
University of Washington	Jeffrey	Berman
University of Washington		
San Francisco		
Arup	Ibbi	Almufti
ASCE SEI		
CoreLogic	Mahmoud	Khater
Degenkolb		
Earthquake Engineering Research Institute (EERI)	Heidi	Tremayne
FEMA Regional Earthquake Program Manager	Anne	Rosinski
Forell/Elsesseer Engineers	Russell	Berkowitz
Jumpstart Insurance Solutions, Inc.	Katherine	Stillwell
Nabih Youssef Structural Engineers		
NIST	Therese	McAllister
OSHPD	Roy	Lobo
OSHPD	Chris	Tokas
Rutherford and Chekene		
University of San Francisco and Scyma Consulting	Zahraa	Saiyed
Walter P Moore		

Organizations	First Name	Last Name
Los Angeles		
Arup	Tasha	Harvey
Degenkolb	Garrett	Hagen
Degenkolb	Daniel	Zepeda
Englekirk		
Mehrain Naeim International		
Oregon State University	Andre	Barbosa
RAND Corporation		
Structural Focus		
University of Southern California	Adam	Rose
USGS	Nicolas	Luco

Appendix B. Workshop Agenda

NIST-FEMA Functional Recovery Workshop

January 27, 2020

ROBERT A. YOUNG FEDERAL BUILDING
First Floor Cafeteria Conference Rooms 1-2
1222 Spruce Street | St. Louis, MO 63130

Agenda

Time	Title	Speaker(s)	Location
8:30 – 9:00	REGISTRATION		Conference Rooms 1-2
9:00 – 9:05	Welcoming Remarks	Steve McCabe	
9:05 – 9:15	Workshop Opening and Framing	Leslie Abrahams	
9:15 – 10:05	30 min: Project Technical Panel 20 min: Q&A	Ryan Kersting Jon Heintz	
10:05-10:15	FIND BREAKOUT ROOMS		
10:15 – 11:15	**Session 1: Functional Recovery Framework**		Breakout Rooms
11:15 – 11:45	Report-Out and Group Discussion	Leslie Abrahams	
11:45 – 1:00	LUNCH		On Your Own
1:00 – 2:00	**Session 2: Implementation Considerations for Functional Recovery**		Breakout Rooms
2:00 – 3:00	**Session 3: Tradeoffs in Functional Recovery Implementation Options**		Breakout Rooms
3:00 – 3:10	RETURN TO PLENARY		
3:10 – 3:55	Report-Out and Group Discussion	Leslie Abrahams	
3:55 – 4:00	Workshop Conclusion		

Appendix C. Definition of Recovery Times

Table C-1 summarizes how each breakout group in each location defined the recovery time targets.

Table C-1. Definition of Recovery Times by Breakout Group.

	STL		SLC		SEA		SFO		LAX	
	A	**B**	**A**	**B**	**A**	**B**	**A**	**B**	**A**	**B**
Minutes	n/a	n/a	n/a	n/a	n/a	n/a	n/a	< 1 hour	n/a	n/a
Hours	*	*	*	< 72 hours	< 24 hours	< 72 hours	< 24 hours	< 24 hours	< 24 hours	< 24 hours
Days	*	*	*	3–10 days	1–6 days	3–14 days	1–6 days	1–6 days	1–6 days	1–6 days
Weeks	*	*	*	2–8 weeks	1–4 weeks	2–12 weeks	1–4 weeks	1–4 weeks	1–4 weeks	1–4 weeks
Months	*	*	*	> 8 weeks	> 4 weeks	> 12 weeks	> 4 weeks	> 4 weeks	> 4 weeks	> 4 weeks
Years	n/a	n/a	*	n/a	n/a	n/a	n/a	n/a	n/a	n/a

*The breakout group did not explicitly define the recovery time.

Appendix D. Descriptions of Recovery Categories

Table D-1 summarizes how each breakout group in each location described the characteristics of each recovery category. The information in this table is the raw output from the discussions and includes a combination of phrases, word associations, adjectives, and other means the breakout groups found meaningful to distinguish between the categories.

Table D-1. Descriptions of Recovery Categories by Breakout Group.

City	STL		SLC		SEA		SFO		LAX	
Breakout Session	**A**	**B**	**A**	**B**	**A**	**B**	**A**	**B**	**A**	**B**
Minutes	n/a	n/a	n/a	n/a	n/a	n/a	n/a	emergency response; emergency communications	n/a	n/a
Hours	safety; emergency response; life safety	critical services; routes of distribution	"got to have"; life safety; life essentials	emergency response	safety; emergency response; protect vulnerable populations	emergency response	security; basic needs; single point of failure (i.e., lack of redundancy)	communications; necessary support services for components in days category	basic needs, essentials; safety; community backbone functions	lifelines; health and safety; critical communications; and law and order
Days	basic functions; sheltering; restore daily routine	basic necessities; moving toward recovery	"need to have"; support resources for continuing function of life safety essentials	lifeline restoration	essential services	basic needs	things that can be stored; temporary alternative solution; bootstraps; avert crisis to vulnerable individuals	starting to rebuild community	rights; necessity; individual backbone functions	roads; shelters; electricity

City	STL		SLC		SEA		SFO		LAX	
Breakout Session	**A**	**B**	**A**	**B**	**A**	**B**	**A**	**B**	**A**	**B**
Weeks	accessibility; settling back in	return to normality	"like to have"; economic viability; social stability	basic normal	return to normality; progress; self-reliance; community connection	community connectivity	risk of loss of community; economic activity; things needed to avert crisis to average individual	more of the nice to haves; community normality	continuing economic functions; privileges	larger lifelines
Months	thrive; economic prosperity; local economy; normal sense of community	debris removal; construction and cosmetics; repairs	would be nice; resilience building; cultural identity	*	quality of life	rebuilding	luxuries	n/a	leisure; luxuries	important but not as critical for function of community
Years	n/a	n/a	*	n/a	n/a	n/a	n/a	n/a	n/a	n/a

*The breakout group did not explicitly define the recovery time.

Appendix E. List of Community Functions

Table E-1 shows all of the community functions that were discussed within breakout groups at the workshops. This is raw output and has not been modified.

Table E-1. List of Community Functions Identified at Workshops.

Community Functions
access to supplies
activity center (e.g., rec center, library)
avoiding displacement
banking
being safe
business continuity/going to work
buying groceries, grocery supply
cell communications
childcare
civic support, governance
clean water
commerce – leisure
communication (telecom, cyber)
communications
communications - first responders
communications - interpersonal/family
communications (cell, internet)
communications (e.g., cell phone, wifi, telecommuting)
community centers
community organizations
community, religious support
construction services
construction working
counseling
critical infrastructure
cultural welfare
culture, character
culture, entertainment
culture, identity
earn a living, local industry
economy, commerce, jobs
education
electricity
emergency response
emergency response services
emergency services

Community Functions
emergency services (e.g., fire)
energy
entertainment
feeling of safety
financing/cash flow
fire
fire-fighting
Food
friends, family
garbage removal
go to work
going to school
governance
governance, law enforcement
government functions/activities
greenspaces/parks; liveable
groceries, etc.
having shelter/having a house
healthcare
healthcare, well-being
home
hospitals
housing
identity
industry
information
information, communication
Internet
jobs – economy
jobs, earn money
law and order
law and order/public safety
leisure
leisure, entertainment, hobbies
leisure, hobbies
lifelines (power, water, sewer, gas, telecom/IT)
make money
medical care
mental health and wellness
mobility
non-profits, institutions

Community Functions
normalcy, neighborhood feel
paychecks, earn a living
police
power
public health (e.g., trash pickup)
public safety
radio/tv
recreation
recreational activities and nature
religious/community center
religious/spiritual organizations
resources (e.g., water)
resources (food)
restaurants
retail necessities (e.g., grocery)
retail, commercial
roads, transportation
safe environments (not toxic)
safety
safety, security
sanitation
school/child care
school/daycare
security, safety
security/public safety
sense of hope
sense of place
sense of safety, security; fire protection
services
sewer/water
shelter
shelter in place
shelter/housing
social capital
social gathering
social networks, support systems
social support; access to services, childcare
social welfare
stability
standard/regular healthcare
structural stability

Community Functions
supply chain operating
support systems
telecommunications
transit/transportation
transportation
transportation (goods, people)
transportation systems (roads/bridges, public and private transportation)
trash removal/waste management/basic sanitation
trash/sanitation services
utilities
utility services (electricity, gas/fuel, water)
vets, animal support
waste disposal
water
water, services
work remotely
work/make money, jobs

Appendix F. Assignment of Components of the Built Environment to Recovery Times

Table F-1 lists each component of the built environment identified across all breakout sessions by the time category in which they were placed by the participants (Hours, Days, Weeks, Months).[10] Note, not each component's time category placement was discussed and agreed upon by the group.

Table F-1. Components of The Built Environment Assigned to Desired Times for Recovery.

Minutes	Hours	Days
emergency communication	airports	airports
public communications systems	ATMs	apartments, condos (multi-family)
	bridges	apartments, multi-family homes
	cell phone distributions	assess commercial
	cell phone supporting infrastructure	assess critical facilities
	cell phone towers	banking
	cell towers	banking/finance
	central plants (generation site)	banks
	communication poles	big box stores
	communications (radio)	bridge inspection
	critical health centers	bridges
	cyber infrastructure	bridges, ports, "nodes"
	dams	cell towers
	dams, reservoirs	cell towers, internet
	data center	clear debris, restore environment
	dialysis centers	clinics, medical, dental (MOBs)
	elder care	clinics, pharmacies
	elder care/nursing home	communication - cell towers
	electricity distribution	communication internet

[10] One group also included Minutes, and one added a Years category.

Minutes	Hours	Days
	electricity distribution system	communication poles
	electricity generation and transmission	community centers
	emergency power	community hubs
	emergency response infrastructure	designating space for debris
	emergency shelters	dialysis
	emergency transportation routes	distribution centers
	evacuation centers	distribution of basic supplies
	fire	electric distribution
	fire stations	electric generation/power plants
	hospital systems	electricity
	hospitals	electricity generation and transmission
	internet services	emergency water
	jails	energy (fuel)
	main roads	financing availability - municipalities, emergency relief
	major bridges	food emergency
	nursing homes	fuel distribution
	pipelines	fuel/gasoline distribution system
	police	gas lines
	police station, 911 call center	gas station
	police stations	gas stations
	police stations, fire	governance
	police, fire	government buildings
	police, fire stations	groceries
	police/fire	grocery stores
	ports	grocery stores, food commerce
	ports, nodes, transport, runways	homeless shelters
	prisons	homes

Minutes	Hours	Days
	public safety/governance	hotels
	radio (emergency)	houses
	reservoirs	housing - high occupancy
	road network	Insurance
	roads	jails/prisons
	sewer	library
	shelter	main employer
	shelters	medical, dental, urgent care
	telecom	mental health facilities
	temporary shelter	military bases
	transportation	multi-family
	urgent care	municipal service buildings
	wastewater/sewer	parks, greenspaces
	water	pharmacies
	water for emergency	pharmacy
	water to mains/key structures	pipelines
	water, water treatment	pipelines (utility infrastructure)
		ports
		ports, bridges, transportation nodes
		power
		power plants
		public transportation
		railroads
		retail – pharmacy
		roads
		roads/bridges
		routine healthcare

Minutes	Hours	Days
		school/daycare
		schools/daycare
		server farms
		sewer/water
		Shelters
		shelters (housing)
		single family homes
		small businesses, "main street"
		social service centers
		storage/staging, landfills
		stores (food)
		subways
		temporary housing
		temporary shelter
		transmission/distribution lines
		underground pipelines
		vets (pets)
		warehouses
		wastewater
		wastewater distribution network
		water
		water for survival
		water treatment
		water/sewer
		water/wastewater

Weeks	Months	Years
activity centers	“main street”	“main street”
airport	affordable housing	affordable housing
assess commercial	amusement parks	
assess residential	arenas, entertainment	
banks	banks	
big box stores	bike lanes	
Bridges	coffee shops	
building officials, governance	commercial (small businesses)	
city hall	community centers	
city hall, local government	construction equipment and materials	
clinics	country clubs	
Commerce	court houses	
Commercial	distribution centers	
commercial (major employer)	factories/manufacturing	
commercial (shopping)	farmer's markets	
community centers	gyms	
core sector, employer	gyms, yoga studios	
court facilities	historic buildings	
courts	jails	
cyber infrastructure	leisure	
day care	museums	
daycare	night clubs	
distribution center	office buildings	
distribution of basic supplies	parks, open spaces	
doctor offices	places of worship	
energy, refineries, fuel	ports	
environmental clean up (toxics)	railways	

Weeks	Months	Years
environmental monitoring (toxics)	religious centers	
financing credit - funding for assessments, small businesses, home owners	residential housing	
grocery store	retail buildings	
hotels	retail stores	
housing	roads	
housing residential	schools	
insurance	shopping malls	
internet	sports arenas	
key distribution/commercial areas	stadiums, arenas, theaters	
libraries	theaters	
library	transportation	
local large employer	water household	
main employer		
main sector		
natural gas distribution		
office buildings		
office buildings (work)		
open spaces		
other roads		
passenger, freight rail		
pharmacy		
police/law maintenance and infrastructure		

Weeks	Months	Years
rail/freight		
residential		
residential buildings		
restaurants, bars		
roads		
roads (“networks”)		
roads (arterial) network		
schools		
schools/daycare		
single family housing		
small businesses		
small businesses, “main street”		
stadiums, arenas		
studios (movies)		
surgical centers/clinics		
temporary housing		
trash trucks and maintenance		
waste treatment plants and pumping		
water household		
water treatment plant		

Appendix G. Summary of Assessment Criteria for Option 1

Table G-1 shows an example of data gathered to create an average score for assessment criteria. The table presents the number of sticky notes placed on the scale of importance from least important ("Section 1") to most important ("Section 5"), where the scale was divided into five equally spaced segments. Section 1 was given a score of 1 and Section 5 was assigned a score of 5. Therefore, an average score of 1 indicates lowest average importance score, while 5 indicates highest average importance score. Criteria with the same or similar names were used in multiple breakout sessions, and thus appear more than once in the list below.

Table G-1. Criteria Voting for Option 1, New Buildings Built to a Functional Recovery Standard.

Criteria	Section 1	Section 2	Section 3	Section 4	Section 5	Average Score
Effectiveness			1	1	4	4.5
Cost/lifecycle			1	1	4	4.5
Degree of regulation		4	1		1	2.7
Equity/fairness	2	1	1	1	1	2.7
Governance	1	2	3			2.3
Effectiveness				1	7	4.9
Cost	3	1	2	2	1	2.7
Equity	1	2	4	1		2.6
Economic Growth	3	2	1	1		2
Mitigating Displacement	1	1	3	2		2.9
Cost		1	2	1	1	3.4
Benefit				1	4	4.8
Perspective			1	1	3	4.4
Uniformity of Application	2	1	1		1	2.4
Feasibility				1	4	4.8
Degree of Buy-in	4	1			1	1.8
Cost	2			3		2.8
Benefits		1		3	2	4
Serving Underserved Populations		2	2	1	1	3.2
Effectiveness				1	5	4.8
Cost				1	4	4.8

Criteria	Section 1	Section 2	Section 3	Section 4	Section 5	Average Score
Perceived risk	1		1	2	1	3.4
Benefit					5	5
Feasibility		1	2	1	1	3.4
Unintended Consequences	1		2	1	1	3.2
Cost/Benefit	1			2	8	4.5
Measurable outcome	1	1	3	4		3.1
Political Landscape	1	3	4	3		2.8
Complexity		2	2	3	3	3.7
Public Expectations	3	4	3		1	2.3
Cost	3	3	1			1.7
Benefit				4	3	4.4
Ability to model		3	2	2		2.9
Co-benefits	4	2		1		1.7
Effectiveness			3	1	3	4
Cost					4	5
Benefits					4	5
How Different	1	1		2		2.8
Unintended Consequences	2	1	1			1.8
Systems Level	1	2	1			2
Cost to implement			1	3	1	4
Benefit				2	3	4.6
Technical Feasibility		1	1	3		3.4
Political Feasibility	4		1			1.4
Timescale		3	1		2	3.2

Acknowledgments

The authors gratefully acknowledge the contributions of the many individuals who participated in and helped organize these stakeholder workshops. The authors also acknowledge support from the Committee of Experts, which provided input regarding potential workshop participants as well as feedback on workshop content. The Committee of Experts consisted of the Project Technical Panel, which wrote the NIST-FEMA report, and the Project Review Panel, which reviewed the NIST-FEMA report.

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