SEAOC Resilience Committee Update and Report to the Membership

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Abstract

The engineering community has made great progress on improving building performance. Performance based design is now widely accepted in national standards. New tools (FEMA P58 and SP3) have been developed to evaluate the impacts of earthquakes on buildings and express results as decision variables like safety, repair cost, and downtime. Rating Systems enhance the communication of building performance to our clients and the public. Buildings can now be designed to regain functionality quickly after a disaster to meet the needs of the community. Structural engineers have the knowledge and expertise to become leaders in the community resilience movement, but we lack a common set of definitions and resilience framework.

There are numerous organizations related to resilience. Each one has their own system, framework, and definitions, making it difficult to triage all of the information available. Without consistent terminology, engineers cannot distinguish between thoughtful programs that improve a community's resilience and marketing campaigns that do not decrease recovery times after a natural disaster.

The SEAOC Resilience Committee is working to address these issues by developing terminology that defines community resilience. This paper provides an overview of what the Committee has developed over the past year which includes definitions for community resilience. It will help structural engineers better understand their role in community resilience and improve their ability to communicate with other design professionals, clients, and the public. Community resilience is changing at a rapid pace and the engineering community needs to adapt to keep up or risk being left behind.

Introduction

Recent hurricanes, wildfires, and earthquakes have shown how vulnerable our communities are to natural disasters. While casualties from these events have reduced due to implementation of modern life-safety building codes, economic losses from damage and downtime continue to rise, even reaching record levels.

In 2010 and 2011 New Zealand experienced a number of earthquakes that caused strong shaking in Christchurch. One of the biggest challenges they faced involved rebuilding their central business district. Figure 1 shows a satellite image of downtown Christchurch two weeks before the earthquake. Figure 2 shows the same image four years later. 50% of the more modern code designed buildings have been demolished after achieving their life safety design objective.

The hazards are not limited to earthquakes. In 2018, The Camp Fire destroyed 18,804 structures, including nearly 14,000 homes (Krishnakumar & Schleuss, 2018). Affected communities continue to struggle to recover and rebuild, with many residents choosing to relocate, construction stymied by the debris removal process, and reconstruction of the clean water supply expected to take two years because of fire contaminated pipes (Alexander, 2019).

The number of natural disasters that exceed $1 billion in damages is increasing over time. Between 1980 and 2013 the United States averaged roughly 6 of these events per year. In the last 5 years the number has jumped to more than 12 (Dennis, 2019). Continuing this trend is not sustainable into the future. It is better for communities to take proactive measures to mitigate their vulnerabilities and prepare for disasters before they happen. A study by NIBS found that $4 can be saved for every $1 spent on hazard mitigation (NIBS, 2017).

Political leaders have noticed these trends and have started on a path to improving the resilience of their communities. At the national level, Congress has reauthorized the National Earthquake Hazards Reduction Program (NEHRP) and explicitly directed the organization to convene a working group of experts to "recommend options for improving the built environment and critical infrastructure to reflect performance goals stated in terms of post-earthquake reoccupancy and functional recovery time" (S.1768, 2018).

At the state level Oregon has developed a resilience program to make communities more resilient to earthquakes and tsunamis (OSSPAC, 2013). California lawmakers are currently reviewing legislation (AB 393) that would direct the Seismic Safety Commission to explore the development of a functional recovery standard. Local jurisdictions like Los Angeles and San Francisco created resilience plans that identify and mitigate the most vulnerable parts of their community.

Structural engineers should take note of these developments outside of the profession. The core of every recovery plan requires buildings and critical infrastructure to allow community functions to take place. It is important that structural engineers provide policy makers with the technical information needed to make informed decisions and to educate their clients on how their buildings will perform after a natural disaster. Rating systems (USRC, SEAONC, REDi) have been developed to help with the decision making process.

Figure 1 - Downtown Christchurch approximately two weeks before the earthquake (source: Google Earth).

Figure 2 - Downtown Christchurch nearly four years after the earthquake (source: Google Earth).

This paper summarizes current perspectives on community resilience to help inform the structural engineering profession. The information presented here is based on documents reviewed and discussions that have occurred within various professional organizations that the authors are members of. The goal of this paper is to spur discussion among the structural engineering profession and to start on a path toward industry consensus and developing new standards for community resilience.

While the discussion herein focuses on *community resilience* to natural disasters, it is worthwhile to point out that other professions assume different and more holistic perspectives on the ability of societies to withstand and adapt to change, including topics such as sustainability, climate change, and social issues.

The concepts of community resilience presented here originate primarily from the perspective of building design because of the authors' professional experiences. Recovering infrastructure is critical to community resilience yet discussing it in detail is beyond the scope of this paper. While many examples reference earthquakes, the resilience discussion is relevant and adaptable to all hazards.

Community Resilience Concepts

Figure 3 identifies the four distinct phases of emergency management of a natural disaster: mitigation, preparedness, response, and recovery. The SEAOC Wildfire Bulletin (Lumbard, 2019) provides an overview of these different stages:

- Mitigation as any sustained action taken to reduce or eliminate long-term risk to people and property from natural or human-caused hazards and their effects.
- Preparedness involves activities undertaken in advance of an emergency to develop and enhance operational capacity to respond to and recovery from an emergency.
- Response includes activities conducted to save lives and prevent harm to people and property during an emergency.
- Recovery restores the community functions impacted by the disaster. The goal is to restore the community to its pre-event state or better within a reasonable time.

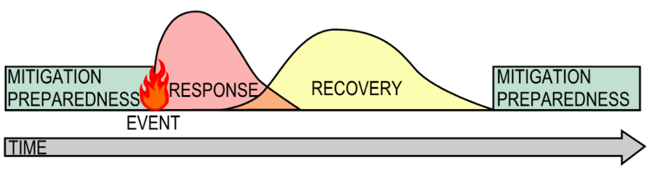

Figure 3 - Stages of emergency management (Lumbard, 2019).

When a disruptive event occurs there is a loss in community function. This is often idealized as the resilience triangle diagram shown in Figure 4. The initial loss of function is related to the magnitude of the event and how well the community has prepared for the event. This loss of functionality is restored over time and a new equilibrium will occur. The minimum goal is to return the community to its pre-event state. In many cases damaged buildings are repaired or re-built to the same standards used in their original construction making them vulnerable to the next disaster.

In an ideal scenario, the community will be prepared for the disaster. They can take the lemons they were dealt and turn them into lemonade. Damaged buildings can be repaired or replaced with newer ones built to better standards. While no one wishes a disaster will occur, they can be used as an opportunity to improve the community. This is known as building back better.

If the recovery process takes too long, it may not be possible to return to pre-event levels. Businesses will close if there are no customers to purchase goods and services. People will migrate to other areas if there is no place to live, schools are closed for prolonged periods of time, or if basic services are not restored within a reasonable time. This is a failure of community resilience.

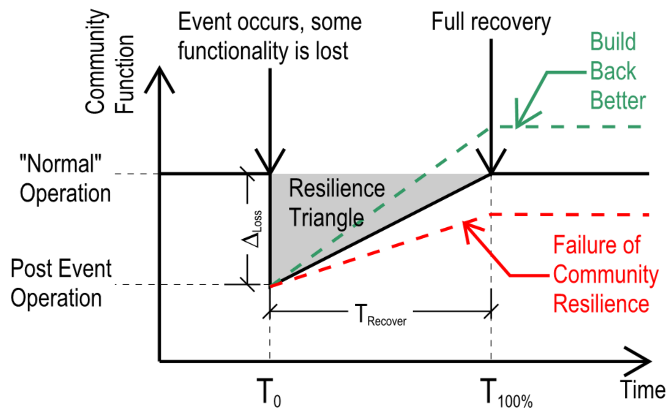

Figure 4 – Schematic of the Resilience Triangle, comparing community function over time following an event.

Community resilience is the ability of a community to prepare and plan for, absorb, recover from, and more successfully adapt to adverse events. While there are many different views of what makes a community resilient, there are a number of common themes.

1. Community resilience is a multi-hazard problem. California is often characterized as an earthquake state, but recently there have been a number of devastating wildfires that have cost billions of dollars in damages. Flood can also have devastating consequences. The ARkStorm scenario study found a large storm could overwhelm the levees around Sacramento and flood large portions of the central valley causing up to $400 billion in damaged property and the evacuation of 1.5 million people (USGS, 2011). All hazards need to be assessed when evaluating a community. The resilience triangle shown in Figure 4 can be used for any hazard.

2. Resilience is an attribute of organizations, not individual buildings or products. The term can be applied to organizations of all sizes, examples include a family, business, university, city, or state. Buildings provide an important role for these organizations and allows them to perform important functions, but the building by itself does not create a functional organization. It requires people (employees and customers), commerce (supply chains and financial transactions), and management (business or government). A badly run organization may not recover no matter how well their physical building is designed.

3. Community resilience is primarily concerned about time to recover functions, not safety. Current building codes emphasize life-safety and do not explicitly consider recovering building function. The goal of community resilience is to restore essential functionality within a reasonable time frame after a disruptive event. The amount of time that can be tolerated for each building depends on the function and will vary for each community. A building that meets a recovery goal is also going to satisfy life-safety, but a building meeting life-safety may not be able to recover within a reasonable amount of time.

4. Community resilience is a multidisciplinary problem. Structural engineers, architects, mechanical engineers, and contractors design and build buildings and infrastructure that enable community functions to take place. Businesses occupy buildings to provide goods and services. People serve as both employees and customers. Government organizations manage basic services and maintain public resources. A community resilience program requires political leaders, technical expertise, and buy-in from community stakeholders (businesses and the public).

Building Recovery

Communities rely on buildings to allow important functions to take place. They consist of numerous buildings that were constructed at different times, designed to different standards, and have their own unique vulnerabilities. Understanding how the individual building recovers from a disruptive event is critical to improving the performance of the entire community.

There are three recovery states for an individual building after an event (Bonowitz, 2010; Almufti, 2013):

- Re-occupancy occurs when the building is safe and can act as a shelter, but not all functions and/or utilities have been restored.
- Functional recovery is a post-earthquake state in which capacity is maintained or restored to support the basic intended functions of the pre-earthquake use (adapted from CA Assembly Bill 393, 2019). Some damage may still be present, but it is only cosmetic and does not prevent building functionality.
- Full recovery means the building has been returned to its pre-event status.

When discussing community resilience, the performance objective for a given building should include two variables: a desired recovery state from the list above and the maximum time until that state can be achieved. Safety is assumed to be satisfied when recovery-based designs are implemented and current building code requirements are met.

For community resilience, performance objectives for buildings should target functional recovery. While re-occupancy provides a level of benefit, it does not guarantee a building can perform its function. A safely occupied building may take a long time before functions can be restored. The one exception to this is for residential buildings. Even if the kitchen and mechanical systems are not functioning, it can still allow the occupants to shelter-in-place. This will allow people to stay in their homes and reduce the amount of emergency services. At a minimum, shelter-in-place implies a building that is safe to occupy with some limited functionality.

After a disruptive event, buildings have two recovery paths outlined in Figure 5. First, an inspection by a trained professional is performed to determine if the building can be safely occupied. The first path occurs when the building is not damaged and no repairs are necessary, though the building may still not be functional due to externalities.

Externalities are factors outside of the building that influence a buildings ability to function. It includes unsafe placards on adjacent buildings and disruption to utilities and transportation infrastructure. The building may not be damaged, but it may not have power or employees/customers may not be able to access it. While some of these can be mitigated in the building design (i.e. backup generators) and thoughtful recovery planning, it is not possible to control all of these variables within the building footprint.

If the inspection identifies damage, repairs will be required. Impeding factors are activities that need to occur before repairs can begin. Arup's REDi Downtime Assessment Methodology (Almufti, 2013) identifies a number of common impeding factors and estimates the time for each activity. Examples include: engineering mobilization and design, financing the repair work, permitting, contractor mobilization and bidding, and procurement of long-lead time components like elevators and air handler units. After addressing the impeding factors repairs can occur to achieve the desired recovery state. Note that externalities can still prevent a building from functioning even if all of the repairs have been completed.

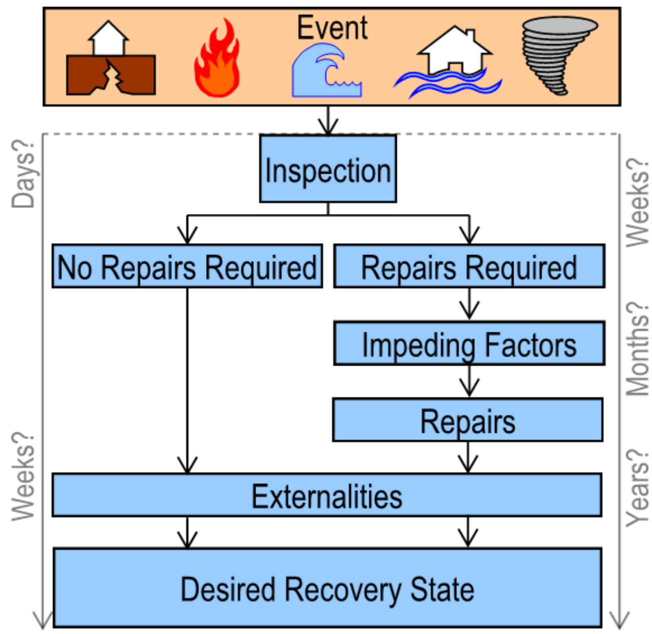

Figure 5 – Process of building recovery following an event.

For further discussion of developing a recovery plan for an existing building see FORWARD Paper (Lang, 2018)

Community Resilience Planning

There are two scales considered for resilience planning: the community and the individual building. Resilience is measured at the community level. Community functions need to be restored within a time period to prevent out migration and permanent business closures. Buildings and infrastructure collectively are needed for these functions to take place. Connecting the performance of the built environment, which is designed one structure at a time independently of other structures, to the collective recovery of a community can be challenging.

A resilience field shown in Figure 6 is helpful for understanding this relationship. On one axis the range goes from technical to holistic, on the other axis has a scale from the individual facility to the entire community. Engineers work in the top left corner of this diagram. They work on individual buildings using technical standards and codes. Community resilience and public policy tends to operate in the bottom right corner. A community resilience program connects these two areas by identifying recovery goals and how the performance of the built environment can achieve those goals.

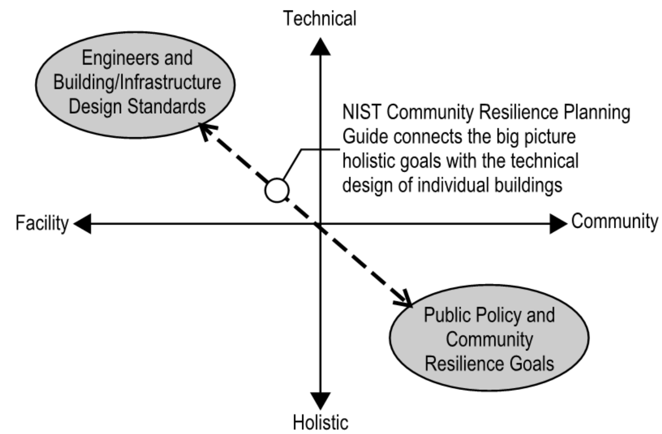

Figure 6 – Resilience field (adapted from Meister Consulting Group and modified by David Bonowitz).

The NIST Community Resilience Planning Guide (CRPG) is a valuable resource to understanding how the built environment enables community functions to take place and how to develop a resilience program. Note that there are many other documents available to develop resilience programs like the City Resilience Index developed by ARUP or the RELi rating system adopted by the United States Green Building Council. These other documents tend to be more holistic in nature and cover other topics beyond recovering from a disaster.

The NIST CRPG is chosen to help illustrate important components of a community resilience program. It outlines a six step process for communities to develop a plan to improve their resilience against natural disasters, as shown in Figure 7.

The <u>first step is to form a collaborative team of leaders and technical experts</u> to engage stakeholders. As mentioned earlier, resilience is multidisciplinary problem and cannot be solved by any one profession. It also requires buy-in from the public and businesses.

Figure 7 – NIST Community Resilience Planning Guide Outline (NIST, 2015).

The next step is to characterize the community. This involves identifying important functions and how they are dependent on each other. The plan should understand the built environment (both buildings and infrastructure) and how it enables community functions to take place. This will often involve a survey to identify how many buildings are exposed to the hazard and what functions they perform for the community.

The third step is to identify the desired performance objectives, define hazards, and determine the anticipated performance of the current built environment. Step three often culminates in a table similar to Figure 8 (adapted from NIST CRPG). Buildings are sorted into groups, called cohorts, based on their role and relative importance in the community. For each group the community establishes desired performance objectives ("30%, 60%, 90%"). Note that this is independent of the hazard and merely reflects what disruption can be tolerated. Once a hazard is identified, the community can establish anticipate performance of the current built environment ("X").

	PHASE 1			PHASE 2			PHASE 3		
	DAYS			WEEKS			MONTHS		
	0	1	2-5	1-4	4-8	8-12	4	4-24	24+
CRITICAL FACILITIES									
GROUP 1A	90%						X		
GROUP 1B	90%						X		
GROUP 1C	60%	90%						X	
INTERMEDIATE FACILITIES									
GROUP 2A	30%	60%	90%					X	
GROUP 2B		30%	60%	90%					X
GROUP 2C				30%	60%	90%			X
REMAINING BUILDINGS									
GROUP 3A				30%	60%		90%		X
GROUP 3B					30%	60%	90%		X
GROUP 3C						30%	60%	90%	X

30% 60% 90% DESIRED RESTORATION TIMES FOR PERCENTAGE OF ELEMENTS WITHIN EACH GROUP

X ANTICIPATED PERFORMANCE FOR 90% RESTORATION IN EXISTING CONDITION

FIGURE BASED ON NIST COMMUNITY RESILIENCE PLANNING GUIDE

Figure 8 - Example schematic of time to restoration of Critical, Intermediate, and Other Facilities for community planning.

Step four is to develop a plan to bridge the gap between the current performance ("X") and the desired performance ("30%, 60%, 90%"). The plan will be unique to each community and can cover a large range of topics and disciplines. The most common response to the problem is to retrofit existing buildings and design new buildings to better standards. This can be done voluntarily by offering owners incentives or can be mandatory through ordinances.

It is important to note that the plan can go beyond modifying the physical buildings. The plan can include educating the public. This could create market demand for better performing buildings and psychologically prepare them for the recovery process. Another component is to develop recovery plans. Individual building owners should prepare a plan to recover after an event. Cities can also plan for recovery by removing barriers to repairing buildings by inspecting buildings quickly, expediting permit reviews, or by developing a building occupancy resumption program. See FORWARD Paper (Lang, 2018) for additional information on recovery plans for individual buildings.

The final two steps are to approve and implement/monitor the community resilience plan. The goal of the plan developed in step 4 is to improve the performance of existing built environment to match the desired outcomes of the community.

Note that Figure 8 suggests that community resilience is dependent only on the performance of individual structures, but there are other aspects that need to be considered. Examples include, but are not limited to, educating the public, establishing recovery plans, and developing programs to stream line recovery. Each community will cater the resilience program to meet their specific needs.

Functional Recovery Standard

Using a tool like the NIST CRPG, the community can develop performance goals for buildings and infrastructure based on their functions and quantify how much disruption can be tolerated. Using this information, individual buildings and infrastructure systems can be designed to satisfy those objectives.

For the purposes of this paper, a functional recovery standard (FRS) is a set of technical requirements used to design buildings and infrastructure systems whose performance objective is based on restoring functionality after a disruptive event. This section is based on discussions that are taking place at organizations like NEHRP, EERI, SEAOC, and NCSEA who are interested in developing a functional recovery standard. Currently, there is no functional recovery standard available.

There are many challenges involved with developing an FRS and it is helpful to sort them into three different categories: technical, policy, and implementation.

The technical challenges are focused on the criteria used to design buildings to meet a recovery based performance objective. A FRS would guide the design team (engineer, architect, MEP consultants, and owner) on how achieve a range of performances. This will include things like drifts limits, nonstructural detailing to accommodate drift, demand-capacity ratio limitations, design of backup systems, identification of nonstructural components that require design, etc. New tools like FEMA P58 allow engineers to estimate repair cost and repair time for seismic events. This information can be used to help design teams achieve better performing buildings. Note that a FRS could not prevent all damage and make all buildings immediately functioning after a disruptive event. Some downtime and damage will occur in many buildings, but it will be limited based on the performance objective.

The policy challenges are focused identifying the performance objective (how much downtime is acceptable?). The technical side of the FRS will (theoretically) enable a certain building to be designed for a number of different recovery times, it is up to policy makers to decide which level of performance will meet the community's needs. Ultimately, the policy decisions are shaped by what is feasible given the limitations discussed in the implementation challenges listed below. Iteration is needed to develop a best solution.

Implementation challenges cover a wide range of logistical issues associated with a FRS such as: educating design teams, role/scope/authority of building departments and plan reviewers, improving quality control and inspections, authority of jurisdictions to regulate beyond life-safety, developing triggers for when change of occupancies occur, cost/benefit analysis to identify how to prioritize the limited resources on a community resilience program, voluntary versus mandatory implementation, new or existing building scope, etc.

While the list of challenges is long, the technical side of the FRS standard can be developed independently of the policy and implementation questions. The FRS may be similar to the existing building standard ASCE 41. It will contain numerous technical provisions for different structural and nonstructural components that will vary depending on a number of input variables like building function, hazard level, and performance level. ASCE 41 does not change if it is used for voluntary or mandatory applications. There are many implementation challenges associated using ASCE 41 for a mandatory retrofit program, but those are independent of the technical standard itself.

There is a spectrum of technical options that can be utilized for a FRS. At one end is performance based design, where the engineer provides calculations to show a design explicitly shows the downtime meets the maximum limit specified in the FRS. This option assures the design meets the objective, but has many implementation challenges like educating engineers and plan checkers. At the other end of the spectrum is a simple prescriptive approach like using an importance factor of 1.5 or risk category (RC) IV. This can be implemented fairly easily because it follows our current code procedures, but the results may not meet the community's desired objective. Studies have shown that RC IV procedures reduce repair costs, but may not improve the time to restore functionality (Haselton, 2019). The middle ground is to have a number of prescriptive provisions that depend on variables like building function, size, and/or structural system.

Functional Recovery Standard Challenges and Limitations

One of the biggest challenges for a FRS is defining its scope and limitations. The scope of the standard is limited to an individual structure with the ultimate goal of achieving a functioning building within a certain period of time. The problem is that there are many variables that influence recovery time that are beyond the scope of the design team and cannot be anticipated. Figure 9 poses a number of questions that arise from externalities in the community. Some of these can be influenced by the design team and owners (backup generators, recovery plans, financing for repairs, pre-arranged contracts with contractors/engineers), but many of them cannot.

It gets more complex when one realizes the impact of externalities on a building's recovery time will vary for each community. One can imagine four identical buildings in Los Angeles, San Francisco, Portland, and Seattle designed to a FRS. If the same earthquake strikes each location there could be a wide range of recovery times depending on how well each community is able to recover. These challenges arise because resilience is an attribute of the community, not of individual buildings.

The FRS is a tool that can be used to have better performing buildings, but it needs to be used in a thoughtful way. Many of the externalities cannot be influenced by the design team and are unique to each community. It is beyond the scope and expertise of the design team to quantify the effects of the externalities on the building. ASCE 41 handles uncertainty in building materials by providing default lower bounds and procedures for testing. Conservative estimates for externalities that are applicable to all communities would likely make it impossible to achieve quick recover times. One option is to develop a series of site specific externality factors. Then an engineer can reference the local factors and apply them in their design. But even this approach has limitations because externalities can vary over time.

The ideal use for a FRS is in a broader community resilience program. Externalities related to transportation infrastructure and utilities can be managed through using an infrastructure FRS. Externalities related to adjacent building performance and community functions will be known because they were designed to a FRS. Recovery planning, outreach, and education will help reduce the impact of the remaining externalities. Figure 10 provides an overview of how a FRS can fit into a broader community resilience program. As shown in Figure 10, a FRS by itself is unlikely to create a resilient community. It is important to educate the public, get community buy-in, and develop recovery plans.

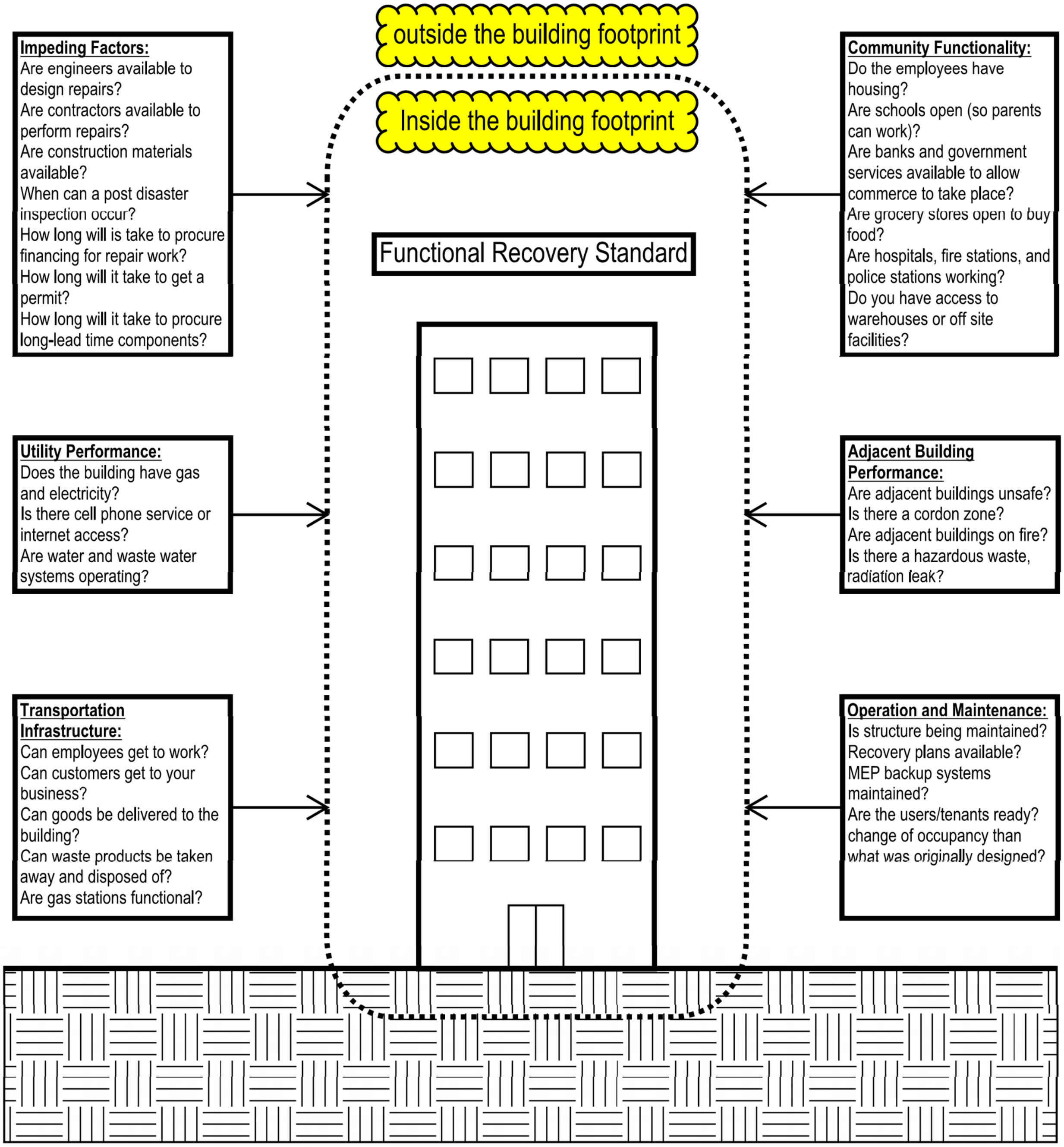

Figure 9 – Potential externalities influencing an individual building's functional recovery.

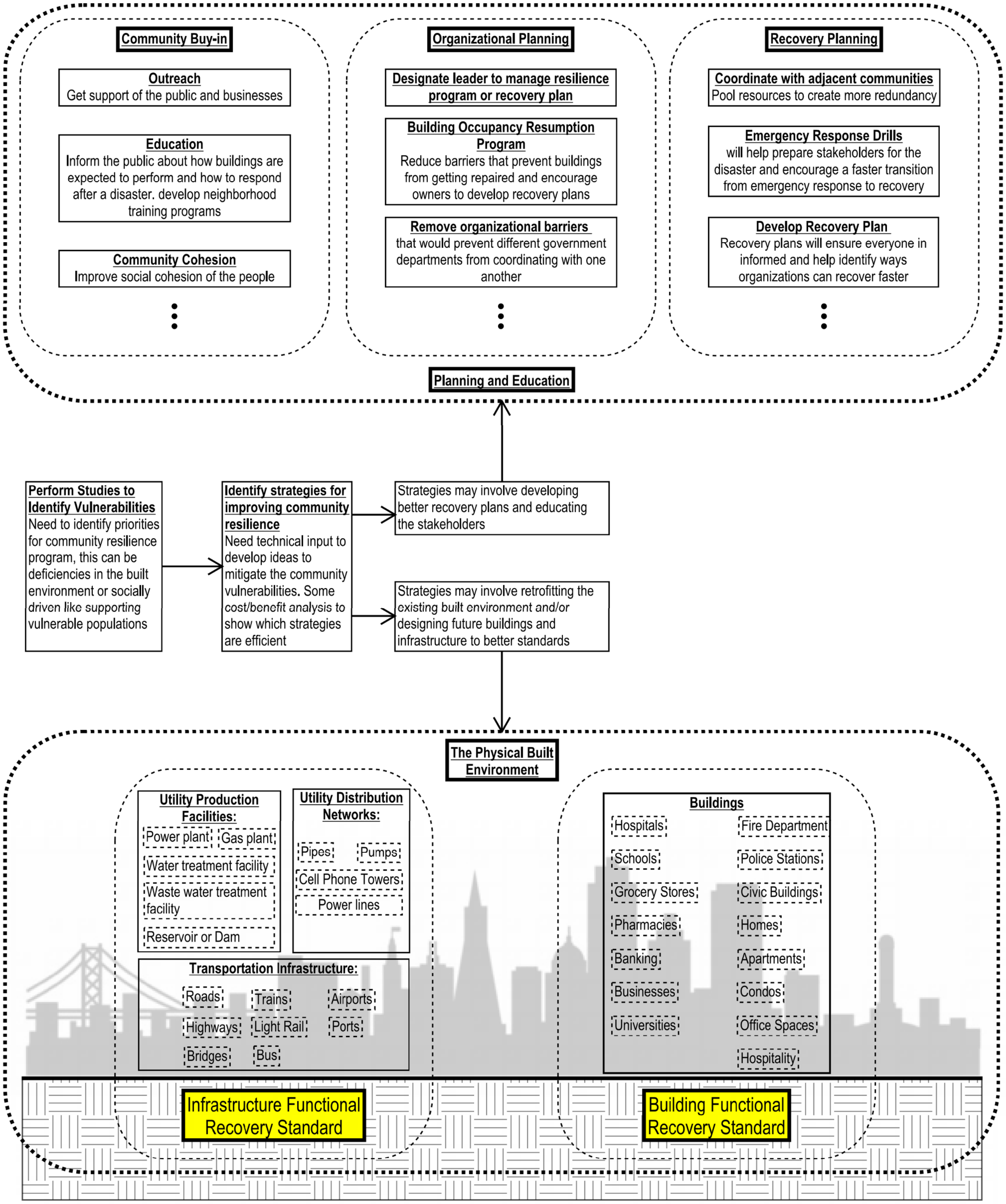

Figure 10 – Functional recovery standard, community resilience context.

Future Challenges

Existing Buildings Discussion

Discussions up to this point on a FRS have focused on new construction because it is much easier than retrofitting existing buildings in all three issue categories (Technical, Policy, and Implementation). While it makes sense to focus on new construction to develop a FRS, it is important to remember that buildings in a community already exist. Even if a new FRS is enacted today, it will likely take decades before the building stock turns over enough to improve the resilience of the community. To reduce recovery times for the built environment in the near future, existing buildings need to be addressed.

Many jurisdictions are already implementing mandatory retrofit programs targeting buildings with known seismic vulnerabilities like wood-frame buildings with soft, weak, or open fronts and non-ductile concrete buildings. While these programs are often described as contributing to community resilience, they are actually focused on life-safety. Life-safety retrofit programs of course provide a good service to society by making communities *safer*, but they do not necessarily improve recovery times or meet a community's expectations.

The main policy question for existing buildings is what performance objective is appropriate. For life-safety design it is common to accept a lower performance target, usually to 75% of current code or ASCE 41 reduced hazard. This is done because the building has a short life, it is more cost effective, and it means new buildings will not be rendered inadequate after each code cycle (ref: ASCE 41-13 C2.2.1). This similar approach may be appropriate for a FRS. See group 3A in Figure 11 as an example. The community may desire a 4 to 8 week recovery time for that particular group. It might be best to design new buildings to a slightly higher objective and accept a lower performance for existing buildings. This lower level may occur based on practical limitations of how much an existing building can be efficiently retrofitted.

Discussion of Performance Objectives

When discussing community resilience it is important to distinguish between performance objectives defined by building owners and the community because they may not be the same. Figure 11 identifies target performance objectives based on community needs. An owner of a building in Group 1B decides to do a voluntarily retrofit "O." Reducing the recovery time from 4 months to 4 to 8 weeks is an improvement in performance, but it falls short of what the community desires. Contrast that with an owner of a Group 2A building who decides to retrofit their building up to a level that meets the community's expectations.

The engineering community should differentiate these two scenarios. This paper proposes using the terms below to describe the performance objectives:

- Recovery Based Design – design utilizing a performance objective defined by time to restore a building to a functional recovery state after a disruptive event. The maximum time to functional recovery is defined by the building owner.
- Resilient Based Design - design utilizing a performance objective define by time to restore a building to a functional recovery state after a disruptive event. The maximum time to functional recovery is defined by the community. The community may decide to have different objectives for new and existing buildings.

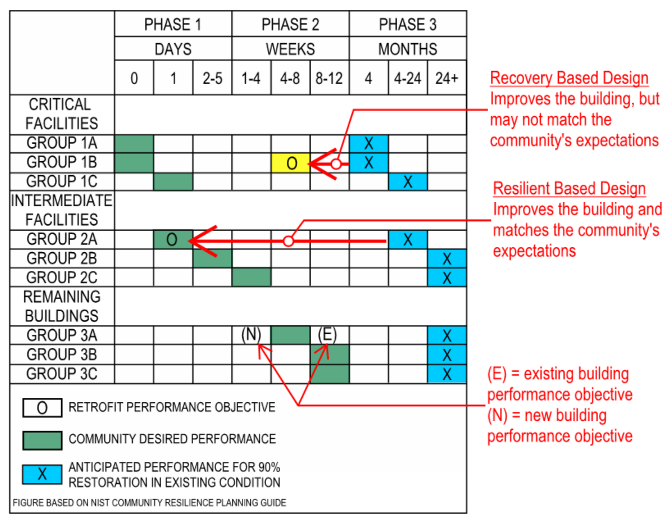

Figure 11 - Example schematic of performance objectives for Critical, Intermediate, and Other Facilities.

The state mandated URM programs in California have an important lesson. All jurisdictions were required to develop a URM program, but the specifics were left up to the local jurisdiction. While some jurisdictions put together thoughtful programs that addressed the seismic vulnerability, others did the bare minimum and accomplished very little. Now there is a wide spectrum of URM retrofits and we cannot say the problem has been resolved.

It is appealing to imagine a grass roots effort where owners are educated about building performance and they voluntarily choose to design or retrofit their building to better than code. If owners choose any objective between the "X" and the community's goal, it is unclear how much the community is improving their resilience.

More Research and Validation Needed

New tools like FEMA P58 give engineers the ability to estimate repair costs and downtime to help improve seismic performance in new building design and existing building retrofit. FEMA P58 in particular supports the individual building component for FRS through rigorous building-specific and site-specific downtime analysis, this is in contrast to prescriptive solutions which provide an unknown level of benefit to downtime and limit tailoring of performance goals based upon specific building function.

The ultimate goal of resilience is to restore community back to normal before people permanently leave the area and businesses permanently close. Research needs to be done to better understand how building design parameters (i.e. downtime) can influence community consequences (outmigration and business closures). This information will help communities set performance objectives (filling in the table shown on figure 8).

Liability Discussion

Switching our design goals from life-safety to recovery time is a dramatic shift in practice. Life-safety code provisions have been refined over time based on observations from earthquakes. Engineers are not required to explicitly state the building will not kill anyone. The term life-safety is vague and does not imply a specific performance to a non-technical audience.

Recovery based design is the exact opposite. There is not a plethora of recovery data from past earthquakes. Information related to repair cost and downtime is private and much more difficult to get than public information like how many buildings got an unsafe placard after inspection. While a FRS has not been created yet, many suggest the design should explicitly state recovery time to improve transparency. Lastly, restoring functions creates more expectations from a non-technical audience than life-safety.

Liability can be created when the client's expectations are not met. A FRS increases the expectations of the client and the public. Communication of performance objectives and uncertainty is the most important aspect of managing your client's expectations. The engineer should be knowledgeable of all the uncertainties in their analysis model and the externalities that may influence the building performance. This information should be presented to the owner in a manner that they can understand.

Developing and adopting standards will also help reduce the liability of the design professional. Standards represent the best knowledge of the profession and can provide commentary on the expectations and limitations of design. When developed using a consensus based process, and becomes widely used, they often reflect the standard of care.

Education of the public

Education is key to improving the resilience of our communities. The public needs to become knowledgeable about how their building will perform under extreme events. This will enable them to make thoughtful decisions on where they live and work. Until they become informed they will have no incentive to improve the performance of the buildings where they live and work. Guidelines like FEMA P58-7 and tools like rating systems are useful aids in this communication process.

Jurisdictional Authority and Community Resilience

Each level of government has authority to govern over specific aspects of the country. The constitution identifies the role of the federal government and all other task are left to the state who can further delegate it to local jurisdictions (cities and counties). How the authority is split will vary from state to state. In some instances, local jurisdictions may have limitations on what they can and cannot do.

Community resilience programs are going to require innovation by local governments. It would be beneficial for states to grant authority to local jurisdictions to pursue a community resilience program and design buildings and infrastructure to a FRS. This will allow proactive communities to take the first steps and blaze a trail for others to follow.

Conclusion

Community resilience is the ability of a community to prepare and plan for, absorb, recover from, and more successfully adapt to adverse events. When disaster strikes, communities need to recover their functions within a reasonable time frame to ensure people do not move away and businesses permanently close. Structural engineers play a critical role in the recovery process by designing buildings and infrastructure to meet the needs and expectations of the community.

Using the information presented in this paper our profession can begin discussing and presenting the concepts of functional recovery performance objectives with our clients, building owners, and architects for all new and existing building retrofit designs. Educating the public and policy makers on the expected performance of the built environment will empower them to choose design objectives to meet their needs.

Policy makers at the national, state, and local levels understand the importance of increasing the resilience of our communities. They are turning to the structural engineering profession to help them improve our built environment against natural disasters. We now have the experience, awareness, and tools that allow structural engineers to begin designing buildings to meet the recovery goals of our clients and the community. Structural engineers need to take this opportunity to become leaders in community resilience movement.

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