RESILIENCE: CHALLENGES AND OPPORTUNITIES

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Abstract

The definition of resilience used by the Rockefeller 100 Resilient Cities is "the capacity of individuals, communities, institutions, businesses, and systems within a city to survive, adapt, and grow no matter what kinds of chronic stresses and acute shocks they experience." This process is focused on policies and planning to reduce recovery time after natural disasters, while earthquake engineering has typically focused on limiting losses through code improvements and design changes. In the past 30 years, California has invested about $50 billion US dollars on seismic improvements in transportation systems, public buildings, universities, and water systems. Japan has national building and planning regulations and has made significant public investments after recent earthquakes. Similarly, New Zealand has made investments and policy changes after the Christchurch and Kaikoura earthquakes. The last decade has seen numerous resilience planning efforts and legislation in San Francisco, Los Angeles, Wellington and other cities focused on building retrofits, performance-based design of new construction and integrated lifeline coordination. In the small nation of Estonia, a 20-year effort has been underway to transform the country from a "backward state" into a digital society. Lessons from these public investments can help shape current engineering research and practice for disaster resilience. The challenge is to adapt our design thinking and methods now to be relevant for the future. The opportunity is to create a more systematic and public approach to land and building transactions as well as infrastructure operations in order to be better equipped to face any future disasters.

Introduction

The famous English philosopher, Thomas Hobbes (1588-1697) is best known for the phrase, "…the life of man [is] solitary, poor, nasty, brutish, and short" (Wikiquote 2018). Borrowing this phrase, with all due respect to Hobbes, it might be said that: Earthquakes are mean, nasty, brutish, and short. Earthquake recovery, however, is mean, nasty, brutish, and LONG! All of our experiences with disasters in the past 30 years would suggest that the process of recovery from natural disasters is slow, costly and difficult for impacted individuals, for communities and governments. Often, chronic stresses, such as high unemployment, disinvestment, aging infrastructure, aging populations, etc., can exacerbate the impacts of natural disasters and slow recovery even further.

Disaster resilience goes beyond limiting loss and reducing recovery time, to address long-term social and economic issues and to use planning to think smarter about the future. When long range plans (including public and private capital investments and development policies) address multiple challenges the result often improves services and saves resources. This is known as the resilience dividend—the net social, economic and physical benefits achieved when designing initiatives and projects in a forward looking, risk aware, inclusive and integrated way (Rockefeller Foundation 2018). The recovery experiences after the 2011 events in Christchurch, New Zealand, as well as those after the Great Eastern Earthquake off the Pacific coast of Tōhoku, Japan, highlight the need for resilience planning, in order to avoid some of the kinds of losses, social disruption, and cost, experienced in future events.

Lessons from California

California had two moderate earthquakes in 1989 and 1994 (Loma Prieta in the San Francisco Bay Area and Northridge in the Los Angeles area) 25 - 30 years ago. Reconstruction in Los Angeles was completed in 4-5 years due to a number of factors: damage was concentrated damage in the largely residential San Fernando Valley, where 80% of single family homes carried earthquake insurance because of their experience in 1971 San Fernando earthquake. Multi-family apartments were experiencing a 10% vacancy rate at the time of the earthquake, so it was relatively easy to re-house renters in the short term, and city government focused Department of Housing and Urban Development (HUD) federal assistance on rebuilding apartments. The economy was in recession, so there was plenty of excess construction capacity, and the national government infused significant cash into the recovery economy, as it was an election year. In addition, damage to freeways and larger public and private buildings was relatively limited, and relatively easy to repair or replace. For example, there was damage to a freeway overpass, but not miles of double decker freeway. Individual buildings, such as city hall, a medical building and a shopping center and others were damaged but the damage was not concentrated in a large urban center. Even the Cal State Northridge Campus, which was at the epicenter of the event re-opened for students in 30 days, using temporary building and outdoor services.

In the earlier Bay Area event, by contrast, reconstruction was a 10-20 year slog. Infrastructure represented 50% of the damage value and the extensive freeway reconstruction in Oakland and San Francisco as well as the replacement of the Bay Bridge went on for two decades. In addition, San Francisco re-designed and reimagined the waterfront as public open space and neighborhoods such as the Civic Center and Hayes Valley were revitalized once the freeway was removed and boulevards were built. Housing loss was concentrated in multi-family dwellings, The housing in the wealthy Marina district was rebuilt and re-rented quickly, but the housing lost in poor neighborhoods in San Francisco, Oakland, Santa Cruz, and other communities required significant efforts by not-for profit developers with public financing assistance. After 10 years, only 75% of pre-quake damaged units were replaced (Comerio 1998).

The difference between the experiences of the two cities can be thought of as a combination two critical factors: 1) the need to rethink complex urban design and infrastructure issues in multiple neighborhoods and cities in the Bay Area vs. the targeted rebuilding of individual buildings and infrastructure components in Los Angeles; and 2) more federal assistance was available in Los Angeles following a series of national disasters that brought awareness to post-disaster needs.

While Loma Prieta demonstrated the recovery difficulties in even a moderate event, it is important to note the forward thinking state and local policies resulting from these two events: The State of California and local governments have invested on the order of $50 billion in seismic improvements in: (Hudnut et al. 2018)

- Retrofitted freeways and bridges
- Improved water systems—reservoir dams, pipes crossing faults in Oakland, San Francisco, and Los Angeles (and a long term plan for improving water and power delivery systems in Los Angeles)
- Retrofit of the Bay Area Rapid Transit (BART) system
- Retrofits of buildings in the University of California system, particularly Berkeley, as the oldest campus of the system, but other campuses received state funding as well
- Seismic upgrades of fire and police stations, libraries, city halls in many local governments

In addition to the physical improvements, more recently, there has also been a significant commitment to resilience planning in both San Francisco and Los Angeles. The Community Action Plan for Seismic Safety (CAPSS) began in 2000 when the Applied Technology Council (ATC) was awarded a contract to develop a work plan for reducing earthquake risks in San Francisco. The CAPSS plan was envisioned as a wide-ranging program involving citizens and experts in studies and policy making. The next phase developed a detailed estimate of potential losses in four earthquake scenarios, and was followed by technical studies of soft story buildings and repair and retrofit requirements (ATC 2000-2010). In parallel, SPUR, a civic group, undertook a large planning program on resilience, which resulted in five reports defining resilience as well as building safety, housing, lifelines and land use (SPUR SF 2009-13). These reports made policy recommendations directly to the city and led to the enactment of a retroactive code for soft-story apartments and creation of a Lifelines Council. In Los Angeles, an intensive one year planning effort, led by Dr. Lucy Jones, on loan to the Mayor's office from USGS led to the publication of Resilience by Design (City of Los Angeles, 2014) and retrofit ordinances for soft-story apartments, concrete buildings, and water and communications infrastructure. Some smaller cities such as Berkeley and Santa Monica have also passed retrofit ordinances, but the majority of cities in California have not pursued such policies despite extensive efforts by regional government agencies such as the Southern California Association of Governments (SCAG) and the Association of Bay Area Governments (ABAG).

Despite those efforts, the USGS scenarios for potential losses from the Hayward (Hudnut 2018) or San Andreas (Perry 2008) faults, suggest there is much more required in order to really lessen the impacts of a major disaster. California is the 6th largest economy in the world, and it is thriving, which puts stresses on growth, housing availability and affordability, and income disparity, as well as transportation and infrastructure. People are thinking about these everyday issues, not about earthquakes, or even fires, despite the recent tragedies in both northern and southern California.

Even after 30 years of loss reduction efforts, the USGS and other scenarios project staggering losses in M 7 earthquakes on any of our major urban faults. Cascading infrastructure failures on non-redundant transport systems, power outages, building damage, fires, etc., will make it hard for people to get to work or to get anywhere. Housing losses could include 40,000 single-family homes and 20,000 multi-family buildings, displacing anywhere from 150-200,000 households (ABAG 2018). Only 10% of Californians have earthquake insurance (Hudnut 2018), so this will pose a financial recovery crisis the likes of which California has never seen.

The significant lessons from the past 30 years of risk reduction and resilience planning efforts in California are the following:

- We cannot build resilience in an ad hoc, one city-, one project-at-a-time way; we have to approach resiliency in a systematic and comprehensive fashion with a focus on housing and infrastructure.
- We need to build new buildings to a higher standard, to insure they are useable post-earthquakes.
- We need to decide what subset of buildings actually needs to be retrofit (so we invest for a purpose) and what subset could remain as is, with insurance.

Some of these ideas being explored in policy proposals and in research, but none are fully implemented:

- AB 1857 (Nazarian) proposed in the California Assembly to require Immediate Occupancy in the state building code and require that strength and stiffness requirements be increased by 1.5 in the current designs until the code is adopted (California Legislative Information 2018).
- SB 827 (Wiener) proposed in the California Senate would require cities to allow four- to eight-story apartment and condo buildings in residential areas if they are within a half-mile of major transit hubs,

such as a BART or Caltrain station. It would also mandate that cities allow such buildings within a quarter mile of highly used bus and light-rail stops. The bill would strip local governments of their ability to reject taller and denser apartment and condominium buildings if developers want to put them near public transit stops (California Legislative Information 2018).

- A recent report by the National Institute of Standards and Technology (NIST) on research needs in preparation for Immediate-Occupancy Standards for multi-hazards lays out a blue print for what is needed to change building codes to a higher performance standard (Sattar et al. 2018).
- Recent research on the effective performance of existing code buildings provides a benchmark for evaluating and comparing proposed standards to existing performance.

Coordinated long-range plans for a resilient future are possible, but it will require state- or country-wide policies and plans that include housing, infrastructure, and land use, as well as building codes.

Lessons from Japan

In Japan, political power is vested in the national government, which oversees prefectures, cities and local governments. National legislation governs local planning and building activities. Most significantly the City Planning Law establishes the basic ground rules for planning and zoning; and, the Building Standards Law establishes nationwide minimum standards for building construction, linked to land use categories in the City Planning Law. As such, Japanese local governments do not play a direct role in code enforcement, in contrast to the United States. The Land Readjustment Law provides a critical planning tool for redevelopment. This complex, multi-step process involves modification of property boundaries for future road widening, open space or other public facilities. In this model, each landowner gives up some land area in exchange for improved access and/or increased property value.

The national planning models are important, as they were created conceptually after the 1923 Great Kanto earthquake, when the national government assumed a major leadership role in planning, financing and implementing post-disaster rebuilding. The precedent of centralized government planning and land readjustment set the stage for the modern laws governing all planning and building. These were used after the 1995 Hanshin-Awaji earthquake, which devastated large sections of the city of Kobe, and the 2011 Great Eastern earthquake and tsunami (Johnson and Olshansky 2017).

The regulations were not designed for post-disaster recovery and often slowed reconstruction and recovery despite the creation of a national Reconstruction Agency after 2011. Further, the 2011 losses demonstrated weaknesses in the nation’s power supply grid, and raised questions about the dependency on nuclear power. Like the United States, Japan is learning from these experiences rethinking its overall approach to policy and disaster management. Unlike the United States, the national models for building standards and land use planning have provided a modern built environment that is largely well built and reasonably safe. Japan offers a model for coordinated nation regulation of building and land use planning.

Lessons from Estonia

What can we learn from a country that is about the size of the South Island of New Zealand (physically and in terms of population) and has limited experience with earthquakes? A brief look at their ambitious approach to becoming a “digital republic” holds important lessons for thinking differently about resilience. Estonia is a small Baltic country (1.3 million people, 4 million hectares half of which is forest) that was conquered by Russia five times since the 11th century. (Germany and others did their share of invading as well). In 1991 Estonia recovered its independence again. It had little in the way of technology and less than half the population had a phone. The first Prime minister, Mart Laar, pushed the country through a period of modernization. Essentially, they ditched legacy systems of government bureaucracy and went paperless (Heller 2017, Lufkin 2017).

Previously, its best-known industry was logging, but Skype was built there using mostly local engineers, and Estonia has become a hub for many start-ups. E-Estonia, launched in 1997, is a coordinated governmental effort to transform the country from a very backward state into a digital society. What that means is that citizens can file taxes on line, obtain medical prescriptions and test results, sign documents, and even vote from their laptops or challenge parking tickets, all from home (Heller 2017).

It means paramedics get an injured person's medical records en-route to the hospital, and the hospital, will be waiting for them. It means the courts become unclogged because lawyers and judges all have access to the same digital case information. Business and property records are public. The concept is for all data to be entered once, using a data platform called "X Road" which works on blockchain technology to prevent tampering. This is essentially a publicly accessible digital ledger where an individual "owns" and controls their data and can keep certain records private, and since every query is logged, they can see whenever anyone (doctor, police, banker) looks at recorded information about them (Wikipedia 2018).

Estonia sees a future in making it easier for its citizens to function in their jobs and in their life, making it easier to manage money, pay taxes, execute business contracts, and recruit people to work there. It is an interesting and visionary approach to technology, statehood and the future. Instead of technology that (as in the U.S.) takes the approach of personalization and information privatization for competitive advantage, the Estonian model is less about the gadgetry or marketing, and more about the culture and society, and what the government can enable it's citizens to do.

What relevance does this have to earthquake engineering and resilience? The Estonian experience suggests two important principles that could (and perhaps should) be incorporated into our fields with respect to resilience planning:

1. Central coordination of critical public services, such as management and planning for infrastructure, as well as public information on geotechnical data, land use and other building regulations allows for coordinated long-range strategic and multi-hazard resilience planning that can be more effective than piecemeal efforts by small, underfinanced, and often understaffed local jurisdictions or local infrastructure service supply systems.
2. Centrally coordinated public services can offer users (taxpayers) easier day-to-day access to government service and information, making the long-range benefits of "resilience investments" useful everyday to citizens.

As such, the centralized service model provides both the opportunity to incorporate long-range planning into regular operations and provides better service delivery at the same time. This is the approach adopted by Los Angeles Water and Power (the largest municipal utility in the U.S.) in their 50-year resilience plan which includes a) improvements to water delivery across fault-lines, b) upgrading over time of the water delivery system with better performance, and c) diversification of the water supply through conservation and other efforts (City of Los Angeles 2014; Davis 2018). Many of the current research efforts in New Zealand suggest similar approaches could be easily adopted.

Building on Recent Experiences in New Zealand

There has been a large government investment after the Christchurch earthquake, not only in rebuilding that city, but also in research on the built environment, codes, planning and government services. The funded research includes: Quake Center (http://www.quakecentre.co.nz/), QuakeCoRE (http://www.quakecore.nz/), and many of the Science Challenges but particularly, Resilience to Nature's Challenge (https://resiliencechallenge.nz/). There are crown research entities such as GNS Science, which developed RiskScape, a loss-modeling platform and other analytic risk modeling programs (https://www.riskscape.org.nz/). In addition, there are crowd-sourced projects like the Christchurch geotechnical database that has morphed into the national geotechnical database (NZGD 2018).

The research is wide ranging but it includes a focus on applications such as how to improve building and infrastructure performance, as well as how to manage land use and planning regulations:

- Better understanding of reparability (for different construction systems) as well as residual capacity in damaged buildings
- Better capacity to quantify downtime and its impacts
- Better access to ground motion data from QuakeCoRE's "Seisfinder"
- Better understanding of interoperability among infrastructure systems through the Rural Co-Creation Lab (Resilience Challenge)
- Better approaches to managed retreat from sea level rise, with work in the Edge Co-Creation Lab
- Sophisticated Economic Impact analysis tools

In addition to all the research data generated, there are numerous activities in practice by professionals and by government. These include:

- The National Geotechnical Database (NZGD 2018).
- The SCIRT Legacy Project to apply the framework developed in Christchurch for use across infrastructure systems nationwide (https://scirtlearninglegacy.org.nz/about).
- The availability of LIMs (Land Information Memoranda) public files for property and the on-line E-Planner in Wellington (https://wellington.govt.nz/services/rates-and-property/property/reports/lim). And, the development of sophisticated city maps, not only for soil conditions, but also depth to bedrock, sea level inundations by city engineers based on GNS data.

There may be other smart-data sets available, but in looking at what is being developed by the Resilience program in Wellington, as well as in the research sphere, it seems that detailed geotechnical information can be combined with sophisticated building models to produce an excellent risk profile on a parcel-by-parcel basis. Further, such data will influence land management, which is critical to resilience. Together this allows planning to integrate multi-hazard safety with planning for jobs, housing, transit, communications, financial services, etc. Similarly, integrated infrastructure data and management allows for better maintenance and renewal, greater efficiencies, and improved repair times after disruptions.

The New Zealand Prime Minister, Jacinda Ardern, announced an agreement in March 2018 to test autonomous airplanes (a two person driverless air-taxi that can travel about 62 miles). She said, "our doors are open for people with great ideas…we have an ambitious target of being net carbon zero by 2050…and projects like this will make that happen…" (Sorkin 2018). The same political and social will to make safer (and more cost and energy efficient) buildings and infrastructure is needed. To achieve that, we need to have realistic risk data on property, to insure we are not creating risk though poorly planned and designed projects. There are some limited market-driven choices being made for lower-risk real estate in Wellington as well as Christchurch, as renters demand a minimum of 67% New Building Standard (NBS) buildings. Neither localized markets, nor single city policies alone are enough to make resilience a reality. Resilience requires a national or regional coordinated effort. Project-by-project, or even jurisdiction-by-jurisdiction efforts cannot really impact regional outcomes in a major disaster.

In New Zealand, there is an opportunity to use the data that is already being developed on land and buildings, infrastructure and the environment to make New Zealand more efficient and citizen friendly, *and* more resilient by using the E-Estonia concept focused on infrastructure, land and buildings. With central government leadership, existing research data could be combined into a centralized land-planning and infrastructure data system that would allow all citizens to look up hazards on their homes, workplaces and infrastructure. A centralized building regulation (combined with higher building code standards for at least some building types) could, over time, allow for a sufficient portion of buildings and services to be available and re-useable after earthquakes and other disasters. Additionally, a national infrastructure management system could provide better service and more resilient long range planning.

Conclusion

The research and data-sets we develop in earthquake engineering could and should be used for the public good, and could make everyday business and transactions more efficient and more transparent. Why not harness the methods and models we are developing and make New Zealand (as well as Japan and California) stronger economically, attractive to investment, and at the same time more disaster resilient?

> "There is no point in wasting good thoughts on bad data."
> John Sulston, Nobel Prize winner, DNA Sequencing

The research community can provide good data, but to take on resilience planning systematically suggests a significant culture change in practice. The way we practice professionally (engineering and architecture, as well as real estate development and law) has been traditionally focused on the private client, and the lowest-cost bid. If we think about a future with public access to risk information and simplified land transactions, and if we think about data systems to improve the everyday inter-operability of our infrastructure, then we can modernize the way we practice our professions, providing more, but different professional work, as well as the possibility that we could make a real difference in a national approach to land, infrastructure and buildings. This is how we can contribute to a better society—better today and better equipped to face any future disaster.

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