Design for Resilience: mitigation, adaptation and transformative design

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ABSTRACT: From case studies of highly capitalized, architect-designed buildings confronted by natural and manmade disasters of the last decade, this paper extracts exemplary cases of mitigation, adaption, transformation design (before, during, and after) disaster instances globally. Based on resilience attributes from biology and complexity theories (Zolli and Healy, 2012), these cases, prepared with graduate students in courses on resilience and research methods, examine attributes that map onto architecture (i.e., simple cores/complex edges, modularity, etc.). Cases question how architects and designers can begin to address other resilience attributes that architecture does not (i.e. capacity for flocking/swarming). Disaster mitigation strategies of Ito and Suzuki in Sendai, Japan, adaptation design with shipping containers during 5000 earthquakes aftershocks period (2011-2012) in Christchurch, New Zealand, and transformative design strategies that changed the identity of Greensburg, Kansas via LEED designed buildings are cases abbreviated in the paper. Third, architects' roles before and after disasters have become well defined. In contrast, roles during disasters are absent from the literature and practice of architecture Efforts to better ascertain critical roles for architects during relatively predictable disaster events (i.e. hurricanes, wildfire, storm surge, sea level rise, etc.) are next.

KEYWORDS: Resilience, case study, case method

1.0. A Midwestern American Provocation

Though growing in popularity, due to the relatively modest scale of sustainable strategies globally, it is now too late for sustainable strategies alone to reverse climate change in the decades ahead. The onset of significant environmental degradation and sea level rise is well underway. The energy waste stream in making and operating buildings globally is among principal causes. Long time advocates of sustainable design, myself included (1973-present), have not achieved critical mass despite compelling scientific evidence and we will not in the foreseeable future. Evaluation of current architectural practices through the lens of the sustainability triad—environment, economy, and equity—provides ample evidence.

1. Economics: In much of the world of architecture, a disproportionately large number of firms are committed to sustainable design to the extent that their clients are--committed to sustainability in attitude but not behavior. Firms market sustainability, but upon closer inspection, offer design for sustainability as a business strategy. They do sustainable design to the extent of LEED certification, a little understood designation some clients have learned to value. At the College of Architecture and Planning (CAP), our alumni board gave the distinguished alumnus award to the principal of a major US-based international firm who told us with pride about flying to China and back just for a meeting shortly after telling a captivated audience of the firm's stand on sustainability; apparently the waste was no paradox to him.

2. Environment: Ecological footprints are not shrinking; they are growing. Collectively, humans we drive more, flying more, consuming more, etc. Locally, high school students like those at Muncie Central High School students, rarely ride a bike to school instead of driving a car though they are representative of tech-savvy, information saturated, high school students peer pressured nationally. Continuing the aforementioned paradox, several faculty colleagues advocate sustainability and net zero building design in the most compelling ways in Muncie, Indiana and then drive home sixty miles to Indianapolis daily. A visiting LEED trainer said, "LEED enables us go the wrong direction at 40 MPH rather than 80 MPH." I remind students and faculty of this selectively because it may discourage idealizing minds to hear. Globally, much of the rest of the world has aspirations of living like Americans.

3. Equity. From an equity perspective, little to no aspiration for equalizing the distribution of wealth on the planet is apparent; nor do we show signs of re-defining the meaning of wealth on the planet. Care about the first cost rather than the life cycle cost of things prevails. With each gas price increase, television media features citizens bitterly complain about rising gas costs, complaints heeded by political "leadership." Neither political party dared having a climate change related platform during the 2008 or 2012 presidential campaigns for fear of losing votes. Perhaps techno-optimists who bypass human behavioral concerns with tools and inventions offer more realistic solutions to behavioral shortcomings and their consequences. In *Hot, flat and crowded* (2009), Friedman's proposed the solution lies in the search for "cheap and easily accessible electrons." In a related vein, comprehensive anticipatory design scientist, Bucky Fuller asserted that we would only abandon our economic accounting system of what wealth is when we all feel our lives threatened (Fuller used the WWII example when our economic accounting system was suspended when the country sensed a life and death moment). Less palatably, he also warned that if totalitarianism is to return, it might do so under the banner of environmentalism.

Based on embellishing distortions of the American reality, others in the world want to live at the level at which Americans are perceived to live. The momentum of humans pumping CO^2 into the environment is actually accelerating and has now gone beyond the point of return. The consequences will be a period of unfolding human and capital loss of untold proportion.

2.0. Design for resilience

During this critical transitional time, interim strategies must teach present and future architects to mitigate the effects of pending disasters in their buildings and environments, to successfully adapt to disasters as they are occurring and to help with transformations of built environments of all scales after disasters end. This new strategy, design for resilience, may be better attuned to our seemingly un-restrain-able behaviors. Resilience design strategies anticipate significant detrimental climate change, sea level rise, and the attendant extreme weather changes that we are already experiencing with increasing frequency. Globally, costs resulting from natural and man-made disasters are increasingly dramatically (Minnery 2011, Fisher 2012). In response, *Bloomsburg Business Week* reports that a huge construction industry is growing up around it rapidly. A Florida Emergency Response Team interviewee reported that the $60 billion federal funding for Hurricane Sandy had Florida contractors, builders, craftsmen and others leaving because they can get paid three times as much in NY/NJ area work. While civil, structural, mechanical and other engineers have been part of the decade long resilience discourse undertaking research and populating professional and scholarly meetings of government and commercial sponsorship (FEMA/NIBS/NIST and McGraw Hill for example), architects have been few in number and relatively recent arrivals. The opportunity for architects to participate has been taken up by a small growing number of market savvy firms already (I.e., AIA Firm of the Year BNIM). In the American Institute of Architects (AIA), this year for the first time, programming for the AIA Convention moved significantly from sustainability concerns to a near equal focus on resilience practice. Presenters describe significant roles for practicing architects *before* and *after* disasters and an expanding scope of potential architectural services through the World Wide Web. In contrast, roles for architects *during* disasters are poorly defined, and are one of the emphases of my current research.

Beyond resilience defined as simply bouncing back, Zolli and Healy (2012) offer patterns of resilience that emerge from biology and complexity theories. Resilient systems:

1. Have feedback mechanisms to determine when an abrupt change is nearing
2. Ensure continuity by dynamically reorganizing
3. Decouple the system from underlying material requirements
4. Have beneficial modularity: simple internal modular structure with components that plug into one another
5. Are diverse at the edges but simple at their core
6. Flock or swarm when time is right and to break into islands when under duress (See Figure 1. Svalbard Global Seed Vault)
7. Cluster, bringing resources into close proximity with one another as needed
8. Are not robust, not redundant, and do not attempt to recover to original state
9. Have failure options as essential.

Figure 1. Svalbard Global Seed Vault. Norway. Architectural “swarming”

In part, my resilience studies test these theoretical constructs and inquire which attributes successfully map on to architecture and which others hold potential for new design strategies. The past four years, I have developed the cases of a syllabus with design for resilience courseware using *case-based pedagogy*, a teaching method that empowers students to learn through decision-making. The creation of a new interdisciplinary syllabus for design and planning students will help them prepare for this rapidly emerging area of architectural practice. The course materials also aspire to better enable a critical mass of design and planning faculty to make strategic shifts in teaching design for resilience. 47 case studies of highly capitalized, architect-designed buildings, confronted by natural and manmade disasters (2001-present) have been aggregated. They cover a myriad of issues related to architecture. Representative resilience sites of the forty-seven studied include:

1. Earthquake: Christchurch, New Zealand, Sendai, Japan, San Francisco, CA, Los Angeles, Port au Prince, Haiti, Sichuan, China
2. Hurricane and storm surge: New Orleans, New York City, Miami, Kauai, Hawaii
3. Flood: Brisbane, Queensland, Nashville, TN, Des Moines, IA, Bangkok
4. Man-made: New York City, Boston, Mumbai, Chernobyl, Ukraine, Indianapolis Airport and state fair stage
5. Climate change/sea level rise: Byron Bay, New South Wales, Outer Banks, NC
6. Tsunami—Sendai, Japan and Sri Lanka
7. Tornado and windstorm sites: Joplin, MO, Norman, OK, Greensburg, KS, St Louis Airport, Dallas/Ft. Worth and Lubbock, Texas, Tuscaloosa, Alabama, Charles de Gaulle Airport, Metrodome, Minneapolis
8. Wildfire sites: Colorado and New Mexico, central Texas, Sydney, Australia

2.1. *Method of Research*

To abbreviate the case studies into teachable cases for decision-making on disaster scenarios before, during and after disasters, the following steps were taken:

1. *Literature Review*: the body of knowledge concerning design for resilience is growing rapidly. Students and I have been engaged in continuous reading, to maintain currency and search for emerging resilience solutions globally

2. *Case study* related modes of inquiry that developed these cases include:

a. *Historical methods*, particularly archival search

a. *Observation*: On-site professional observer studying 3 phenomena: disaster mitigation evident in anticipatory design, disaster adaptation evident in functioning building design during event, and disaster transformation evident in new building and community design following an event. In addition to visual observation, photography and videography were used to record data.

b. *Interviews* with key informants: Structured interviews with questions specifically focused on mitigation, adaptation, and transformation strategies that enabled design and planning professionals make more effective decisions

3. Data collection and analysis: data (text, photographs with captions, transcriptions from recorded interviews, etc.) is aggregated chronologically into 3 categories/phases—mitigation, adaptation and transformation. Each case had one or more underlying themes related to the

course (i.e. operating rationally within chains of command and standard operating procedures, operating politically in relation to control of decision making or resources, etc.). The underlying themes for the case emerged as the case unfolded. For each category/phase, critical decision-making events in which two or more compelling alternatives were present were identified (i.e. staying in place versus evacuation). From this smaller data subset within the category, the critical events was attributed a theme/lesson tag (life safety, business interruption, etc.). The themes/lesson tags were prioritized as it/they related to the overall emerging theme of the case. The single most salient event per phase (the one that best relates to the overall theme of the case) per phase was selected to be the decision point. Thus, three decision points for discussion became the subjects of discourse and decision within each case.
4. Findings: in the form of cases. Format for each case has been consistent:

1. Phase 1 intro: Pre-mitigation data presented in case format (data set 4-8 pages of text and/or visuals in multiple media)
2. Phase I decision point/discussion: Mitigation decision point reached in which there are two or more compelling answers requiring student discussion and decision making (D/DM)
3. Phase 1 conclusion: What actually occurred revealed. Associated resilience attributes discussed.
4. Phase 2 intro: Pre-adaptation data presented in case format (data set 4-8 pages of text and/or visuals in multiple media)
5. Phase 2 decision point/discussion: Disaster adaptation decision point reached in which there are two or more compelling answers requiring student D/DM
6. Phase 2 conclusion: What actually occurred revealed. Associated resilience attributes discussed.
7. Phase 3 intro: Pre-transformation data presented in case format. (Data set 4-8 pages of text and/or visuals in multiple media)
8. Phase 3 decision point/discussion: Transformation decision point reached in which there are two or more compelling answers requiring student D/DM
9. Phase 3 conclusion: What actually occurred revealed. Associated resilience attributes discussed.
10. Case Conclusion—discussion with students of the meaning of the case, its related decision and summary of resilience attributes.
11. Endnotes and References

3.0. Representative Cases of the three phases of resilience

Sections of cases will be presented, but It is not possible to present the entire case in this brief report. Representative mitigation, adaptation and transformation decision points (steps 2, 5 and 8 above) have been singled out in three exemplary cases.

3.1. *Case 1: Sendai Mediatheque (1995-2001) and the 2011 Tohoku earthquake (3/11/2011)* excerpt.
Case topic: mitigation through taking design risk as resilience
Part 1.1 At the *mitigation decision point* (step 2 above): competition entry architect/engineer team, Toyo Ito and Mutsuro Sasaki, had to choose between equally compelling design choices: either state of the art *shin taishin* (anti-seismic) structural design strategies as presented in the Japanese building code with no potential legal upside in the event of an earthquake or the risk of a relatively untested design alternative that offered a new aesthetic and structural design model. Is this design alternative an acceptable risk? Are they exercising the legally required "reasonable standard of care?" If you were a member of the selection team, would it be responsible to select a design departing from prevailing wisdom?
Part 1.2 Outcome. After considerable deliberation, they decide (step 3 above) to pursue an alternative to convention and bring biomimicry in structural design at building scale. (Figure 2 below).
Part 2.1 Ten years later, the 2011 Tohoku earthquake (magnitude 9.0 Mw), the most powerful earthquake to ever strike Japan occurred in the ocean a short distance away. Nearly 1 million buildings, including hundreds of highly capitalized multi-storied buildings were damaged or destroyed. In the earthquake, (Step 5--adaptation decision/discussion point) how did this building perform?). Will its experimental design strategy be its undoing, needlessly harming

untold numbers of people in its effort to advance a design idea? http://www.youtube.com/watch?v=heh5ITmYbRs.
Part 2.2 Outcome. Damage was limited to broken glass on the first and third floors, part of a window on the double-glazed south side, a section of ceiling that had fallen on the top floor, solar equipment, and a rooftop air duct (Huxtable 2011).
Part 3. By August 2013, over 1000 aftershocks had struck Japan. Transformation discussion questions include: Which resilience attributes readily map onto the Sendai Mediatheque? Will the success of this alternative design strategy have impact: on Japan's building code? On other architects/engineers to replicate its structural system? To transform even further? To test other new aesthetic ideas? To improve survivability in countries without the expertise of Japan? (See OpenQuake at Global Earthquake Model).

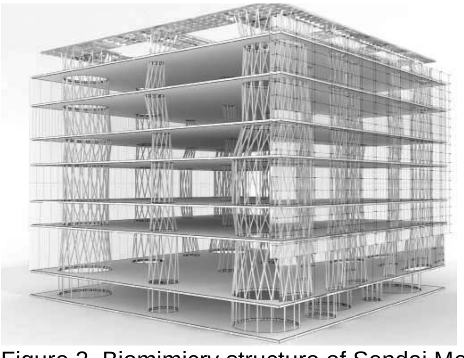


Figure 2. Biomimicry structure of Sendai Mediatheque. Ito and Suzuki

Case 2: Christchurch, New Zealand aftershock. Adapting to 5000 aftershocks to the 9/4/2010 earthquake. Case topic: Business decisions and urban design scale resilience.
Part 1.1. Mitigation question for seminar discussion: evacuation to new sites/locations distant from seismic activity or rebuild/remain in place? Precedent: a story of profound building performance adaptation failure at the Superdome fiasco in New Orleans.
Part 1.2. Christchurch, New Zealand story stands in fairly stark contrast. On 9/4/2010, a magnitude 7.1 earthquake struck the Canterbury region. Shortly thereafter, a mitigation strategy for damaged buildings remediation/preparation for any future events included upgrading existing building code and the prioritization of structures that needed immediate remedy, second order structures, tertiary, etc. The time between initial earthquake and major aftershock was too short for significant implementation. Efforts to shore up effected properties had only begun when 2/22/2011 aftershock of 6.3 magnitude occurred, effectively destroying a square mile of Christchurch's central business district's (CBD) already weakened building stock.
Part 2.1. Adaptation decision/discussion point (step 5 above): 5000 or more aftershocks followed in the year after the devastating earthquake 2/22/2011. Like post Katrina New Orleans, some residents have moved away, but most residents and businesses have elected to remain despite living in sustained disaster mode with periodic aftershocks of varying magnitude.
Decision point question: As an architect and building owner, what do you do amidst continuing series of aftershocks to resume business operations:

a. Evacuate CBD due to poor sub-soils, continuing aftershocks, inadvisability of investing in commercial/institutional grades architecture/highly capitalized buildings when there are more commodious sites outside the CBD or

b. Remain in place and take risk in alternative design strategy?

Outcome. In Christchurch, they have designed and built an interim/provisional CBD zone--an adaptation of shipping containers shopping zone (See Figure 3). In the parlance of Zolli and Healy, this is the modularity resilience attribute at urban design scale. Further, early signs are that this project will be transformative.

Part 3. Transformation discussion: Many/most of Zolli/Healy resilience attributes can be found in this design response. More work is following of similar creativity suggesting transformation implications of what has been done: Shigeru Ban cardboard Cathedral of Canterbury (see figure 3b)

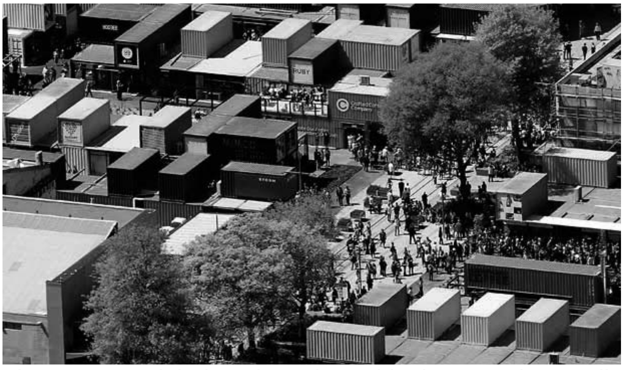


Figure 3a. Modularity adaptation. Shipping container mall, Christchurch New Zealand, 2012.

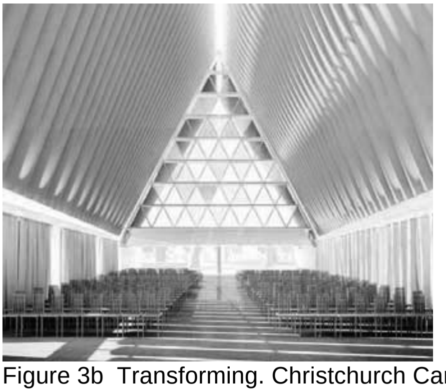


Figure 3b Transforming. Christchurch Cardboard Cathedral replacement, Shigeru Ban 2013.

Case 3: Greensburg, Kansas and the tornado 5/4/2007. Identity and transformation. Case topic: Disaster, sustainability and identity at city/town scale as resilience.
Part 3.1. An EF-5 tornado destroyed conventionally built town with little architecture. Due to the nature of the disaster event, a tornado, there was no time for adaptation. The town was leveled. (See Figure 4). Transformation stage decision point choices (step 8) are:

a. Leave this destroyed town site, take replacement dollars, and move to nearby towns where the infrastructure and community structure is still intact.
b. Take the risk of reinvestment of replacement dollars in rebuilding the town the look the way it was before the tornado (the post World War II Dresden solution, and one adopted in Joplin, MO) to re-establish historic identity
c. Take risk of reinvestment of replacement dollars in new architectural language for the town.

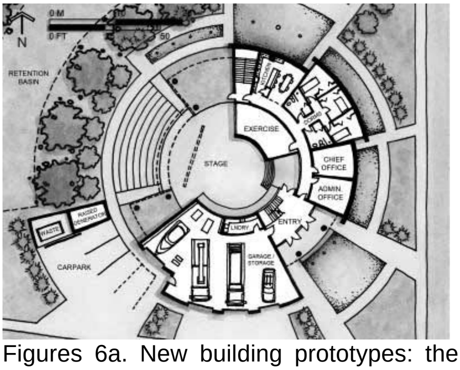
Part 3.2 Outcome: Change Greensburg, Kansas identity via LEED designed city/town scale. Figure 4.
Resilience attribute discussion: Greensburg ensured continuity by dynamically reorganizing. Among its other resilient systems, feedback mechanisms determine when an abrupt change is nearing, clustered its design strategies around LEED, bringing resources into an alignment with one another that has re-invented the town which as now become a tourist destination. Notably, this new configuration defies engineering-based resilience definitions: is not robust, not redundant, and does not attempt to recover to original state.

Figure 4. Aerials of Greensburg, KS, before and after tornado.

Figure 6b. dispersible unit of a pod system-a flocking/swarming strategy

4.0 Summary

Testing Zolli/Healy's theoretical constructs has yielded new understandings of architectural potential in resilience. Over time and more comprehensive development of these cases, multiple levels of risk and decision-making emerge. Indeed many of the studied hazards are not single hazard, but multihazard events (Sendai—earthquake and tsunami; Hurricane Sandy—wind and storm surge; Katrina—wind, man-made levee collapse, and flood, etc.) necessitating more comprehensive programming before designing responsive buildings. As one result, in courses that have used the cases as design precedent, the move to multihazard design response has been accompanied with design studies for a new building prototype, the *multihazard response and refuge center*. Starting from a fire station, additional community hazards historically addressed by a widespread array of facilities in a region are consolidated into single modular structures or flocks of structures. (Figures 6 a, and b).



Figures 6a. New building prototypes: the multihazard response and refuge center-fire station archetype.

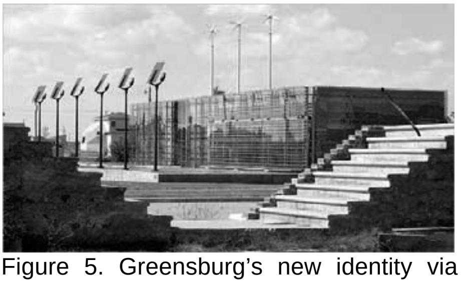


Figure 5. Greensburg's new identity via LEED buildings replacing conventional buildings

5.0 Conclusions: Roles for Architects

Architects have had continuing roles in disaster assistance historically. Concurrently new roles are emerging now as an industry is birthed in response to the need and as some perceive it, the "opportunity of disaster." (Gunewardena 2008). Mitigation roles before disaster are substantially well defined. Already many architects participate on design and planning commissions with resilient community goals; serve on building codes advisory groups, undertake site specific **r**esearch for preventative requirements in place, are active in **t**raining, and advise clients on resilience strategies. Roles after disaster (transformative and otherwise) are similarly well-defined. Architects with abiding commitments to their communities help clean up debris, offer damage assessment through, manage communications with a multitude of constituents and those affected. In some cases, architects are outspoken and attempt to lead communities from shock into visions of a future. Entities like the National AIA Disaster Assistance teams have state and international equivalents.

In contrast, roles during disasters seem relatively undefined. Despite the strong positive correlation between disasters and building failure, architects are rarely in the public eye during disasters. For the most part, architects are absent from the literature and practice of disaster adaptation. Several reasons readily emerge. Architects may be perceived as a reactive profession, one that responds to client interest and a need of our work. Frequently, architects are not seen to command relevant data for the related disaster. Admittedly this varies among disaster types and there is a strong positive correlation between the type of disaster and the likelihood of architect's making strategic intervention to save life and/or property. Hurricanes, earthquakes, sea level rise, wild and manmade building fires, and some instances of terrorism have time frames in which architects readily respond. Tornadoes, tsunami and other disasters of short unpredictable time frames do not. The architect's relationship to the community is also paramount. Will people listen? Can you mobilize others to help? Architects' relationships to location's leadership (governmental, religious, etc.) seem directly related to consulting in ways that make a difference. Functioning under the extreme stresses of disaster situations tests the capacity to cope and an architect's mental and physical capable of assisting.

Conversance with readily available technology transfers for temporary shelter/building solutions and technology for communications may limit an architect's participation. The genius of crowdmapping in Ushahidi Haiti (2010. See https://crowdmap.com) was the capacity of digital native college students to mobilize and sustain a global phone network needed to ascertain a data-filled map of Port au Prince long before government institutions. Some architects are resolute in their commitment to payment for services. They may see "giving it away" pro bono services like these as undermining the profession. In other cases, the law is the problem in that it affords no protection to architect from lawsuit for any damage done. Trial attorneys in half the states block Good Samaritan laws. Unfortunately, some architects have also used the post Hurricane Katrina opportunity to pass out business cards in unbecoming situations.

According to Zolli and Healy, to work in resilience design, effective participants have several attributes. First, they must have the capacity for trust and collaboration. Second, they must be capable of forming informal networks under a wide array of circumstances. Thirdly, among them must be translational leaders who bring the capacity to read and articulate the environment and its potential are essential in compelling ways. These attributes are well within the architect's grasp as they are essential parts of professional preparation and practice. During this critical transitional time, teaching future architects to design to mitigate the effects of pending disasters in their buildings and environments, to successfully adapt to disasters as they are occurring and to help with transformations of built environments of all scales after disasters end seems a goal worthy of our attention.

References

Gunewardena, N and Schuller, M., ed. Capitalizing on Catastrophe: Neoliberal Strategies in Disaster Reconstruction. Lanham, MD: Altamira Press, 2008.

Huxtable, Ada Louise. "Why One Remained Standing." *Online.wsj.com*. Wall Street Journal, 10 May 2011. Web.

Oskin, B. *An Earthquake GEM: Big Data May Prevent Deaths*. *livescience.com.* Live Science, 22 August 2013.

Sasaki, Mutsurō, Toyoo Itō, and Arata Isozaki. Morphogenesis of Flux Structure. London: AA Publications, 2007. Print.

Vervaeck, Amanda, and James Daniells. "Japan – 366 Days after the Quake… 19000 Lives Lost, 1.2 Million Buildings Damaged, $574 Billion." *EarthquakeReportcom*. N.p., n.d. Web. 07 Dec. 2013. http://earthquake-report.com/2012/03/10/japan-366-days-after-the-quake-19000-lives-lost-1-2-million-buildings-damaged-574-billion/

Zolli, A .and Healy, A.M. Resilience: Why things bounce back. New York: Free Press, 2012.