



MEASURING THE RESILIENCE OF BUSINESSES FOLLOWING THE 2014 SOUTH NAPA EARTHQUAKE IN CALIFORNIA

I. Almufti⁽¹⁾, C. Kroll⁽²⁾, M. Mieler⁽³⁾, H. Tremayne⁽⁴⁾, A. Wein⁽⁵⁾, Y. Xiao⁽⁶⁾

⁽¹⁾ Associate, Arup, ibrahim.almufti@arup.com

⁽²⁾ Chief economist, Association of Bay Area Governments, CynthiaK@abag.ca.gov

⁽³⁾ Assistant research engineer, Johns Hopkins University, mmieler@jhu.edu

⁽⁴⁾ Program manager, Earthquake Engineering Research Institute, heidi@eeri.org

⁽⁵⁾ Operations research analyst, United States Geologic Survey, awein@usgs.gov

⁽⁶⁾ Associate professor, Texas A&M University, yuxiao@tamu.edu

Abstract

Following the 2014 South Napa Earthquake in California, the Earthquake Engineering Research Institute convened a small team of researchers to develop an approach for studying the resilience of businesses impacted by major earthquakes. Over the course of the next 18 months, the team developed a flexible survey tool to be used for both real-time monitoring of business recovery issues over time after an earthquake, and also for addressing longer-term research questions. In overview, the survey tool comprises a master list of questions covering a broad range of topics, from basic information about a business or building (e.g., number of employees, industry sector, annual revenue, building age, lateral system, etc.) to more detailed observations of damage, downtime, business impacts, and resilience strategies. This master list of questions serves as the basis for shorter, more focused surveys for a particular audience or situation (e.g., business managers, building owners, reconnaissance engineers, etc.). The team designed these shorter surveys to be administered multiple times after an earthquake, thus enabling a more comprehensive and longitudinal record of business recovery to be obtained.

This paper describes the survey tool in detail. It begins with an overview of the development process, which involved (1) working backwards from a comprehensive list of research and monitoring needs to create a detailed set of survey questions that can generate the necessary data; (2) reviewing existing survey tools and techniques, especially those deployed following the 2010-2011 Canterbury Earthquake Sequence, to learn from previous experience; and (3) asking researchers from relevant fields and local government officials to review a draft of the survey tool to assess whether it addresses their needs, in terms of both real-time monitoring and long-term research. The paper then describes the organizational structure and content of the survey before discussing potential deployment strategies following a major earthquake. The paper also describes the field-testing process employed by the research team, which, at the time of writing this paper, is currently underway. Currently, the team is trialing the survey tool on a diverse set of businesses throughout the region affected by the 2014 South Napa Earthquake to refine and improve the survey. After incorporating feedback from the field test, the survey tool will be ready for deployment in the next major earthquake.

Keywords: *resilience; recovery; businesses; reconnaissance; earthquakes*



1. Introduction

Following the South Napa Earthquake on August 24, 2014, the Earthquake Engineering Research Institute (EERI) convened a small team of researchers to develop an approach for studying the resilience of businesses impacted by major earthquakes. The team comprised a diverse mix of perspectives and backgrounds, including academia, federal and regional government, and private industry. The effort, which is part of the EERI Resilience Observatory Project funded by the U.S. National Science Foundation, builds on the multi-decade and multi-disciplinary EERI Learning From Earthquakes (LFE) program to develop a new vision and strategy for exploring and measuring the resilience of communities after damaging earthquakes.

One of the primary goals of the Resilience Observatory Project involves developing methods for systematic collection, archiving, and dissemination of data and findings using appropriate IT tools. Towards this end, the team developed a flexible survey tool to be used both for real-time monitoring of business recovery issues after an earthquake and also for addressing longer-term research questions. In overview, the survey tool comprises a master list of questions covering a broad range of topics, from basic information about a business or building to more detailed observations of damage, downtime, business impacts, and resilience strategies. This master list of questions serves as the basis for shorter, more focused surveys that can be developed for a particular audience or situation, and can be administered multiple times after an earthquake, thus enabling a more comprehensive and longitudinal record of business recovery to be obtained.

This paper describes the survey tool in detail. It begins with background information that helps place the survey tool in the context of previous work, including the EERI LFE program and recent efforts to study business resilience following the 2010-2011 Canterbury Earthquake Sequence. Next it documents the methodology employed to develop the survey tool and discusses some challenges faced during this process. It then describes the organizational structure of the master list of questions and presents a small sample of questions from each section of the survey. Finally, the paper discusses potential deployment strategies and describes the field test currently underway in Napa.

2. Background

In 1973 EERI formally initiated the LFE Program, which sends multi-disciplinary teams of researchers (including earth scientists, engineers, and social scientists) into the field to investigate and learn from the damaging effects of earthquakes. In general, these reconnaissance teams are deployed within several days of an earthquake and are tasked with performing rapid damage assessments of the affected region, documenting important initial observations, and identifying areas of follow-up research [1]. While these reconnaissance efforts have been important to both managing emergency response activities in the short term and improving the understanding of natural hazards in the long term, they provide only a single snapshot of what is often a complex and lengthy recovery process. Furthermore, in order to more effectively measure the resilience of communities, multiple snapshots need to be obtained after an earthquake.

Following the initiation of the 2010-2011 Canterbury Earthquake Sequence, two longitudinal studies of business issues and resilience were conducted in the affected region. The Recover Canterbury Management Team, a consortium of central and local government and economic and business agencies, documented and monitored various issues across over 7,000 businesses [2]. They tracked a rolling four-week average of the issues to help identify how to support businesses. Business issues fluctuated over time, but those that affected more than 20% of the businesses at some point in time included building/relocation, cash flow, loss of market (onshore), business operations, market strategies, business planning, and workforce. The issues of workforce and growth constraints were identified later in the monitoring process. Concurrently, Resilient Organizations with the University of Canterbury conducted a series of surveys and interviews to investigate business impacts and resilience across different sectors. They captured data from each of the first four years of the sequence [3-6]. The data has been used to compare business impacts caused by different earthquakes in the sequence. Surveys of the tourism sector and rural businesses were treated separately.



The survey tool described herein builds upon these business survey efforts. The overall intent of the survey is to provide a consistent set of questions for tracking business recovery over time after an earthquake. This consistent set of questions will also facilitate comparisons across different events, and help limit “survey fatigue” for affected business owners. Most crucially, the survey tool explicitly links earthquake-induced building damage and utility disruption to business impacts, and tracks these impacts over time. As such, the survey comprises questions that focus on documenting both the physical damage caused by the earthquake and the resulting business disruption (i.e., the initial impacts of the earthquake). In addition, the survey includes questions that focus on documenting the business recovery process (i.e., the impacts of the earthquake over time), including repairing damage to buildings and changes to business operations to cope with earthquake impacts.

3. Methodology

In overview, the development process for the survey tool involved working backwards from an exhaustive list of research needs to create a detailed set of questions capable of generating the necessary data. The team began the process by thinking broadly about potential uses of the survey tool, eventually settling on two primary uses: (1) monitoring business recovery in real-time after an earthquake and (2) providing data for addressing longer-term research needs. With these two uses in mind, the team generated a comprehensive list of research needs, both short and long term, to help guide the development of specific survey questions. [Table 1](#) summarizes the wide range of research needs identified during this process.

Table 1 – Research needs identified by the team

Research needs
<ul style="list-style-type: none">• Identify key factors or decisions that affect business continuity• Compute survival rates for different business types and sectors• Evaluate the effectiveness of different pre-earthquake preparedness strategies• Examine correlation between financial loss and duration of business disruption• Identify factors that delay the initiation of building repairs and/or lengthen the repair process• Understand which building components and systems are critical for maintaining building functionality and business continuity• Determine “cliff edge” effects for losses and downtime for different business types

After developing the list of research needs, the team reviewed existing survey tools that have been used in past disasters to document building damage and business impacts, including those deployed following the 2010-2011 Canterbury Earthquake Sequence and Hurricane Sandy in 2012. The team reviewed these surveys not only for their content but also for insights into potential sample selection and deployment strategies. In particular, the team reviewed a series of surveys developed by Resilient Organizations and the University of Canterbury to catalog the effects of the Canterbury Earthquake Sequence on Christchurch organizations [\[3-6\]](#). Survey questions cover a wide range of topics, including questions about utility disruption, relocation, suppliers, customers, staff, insurance, organizational changes, and operational recovery. The team also reviewed the Small Business Credit Survey developed by the Federal Reserve Bank of New York to document the performance of small businesses and their experiences obtaining financing and credit [\[7\]](#). In 2013, following Hurricane Sandy, a new section was appended to the survey to gather information on the storm’s financial impact on small businesses. It includes questions on the following topics: changes in revenues, expenses, debt, and assets after the storm; total financial losses or gains caused by the storm; and percentage of losses covered by insurance. Lastly, the team reviewed a survey of businesses affected by the 1989 Loma Prieta earthquake centered near the San Francisco Bay Area, which provided guidance on implementing a post-disaster business survey in the local area [\[8\]](#).



Following this review, the team compiled a draft list of survey questions for measuring business resilience after a major earthquake. The questions were designed broadly enough to cover different time periods, from immediately after an event to later intervals, up to several years later. The team then distributed the draft list of questions to a diverse group of researchers, practitioners, and government officials for a technical review to assess whether it addressed their needs, in terms of both monitoring business recovery in real-time and addressing longer-term research questions. The team used the feedback from the technical review to both modify the overall structure of the survey and amend the wording of specific questions.

One particularly challenging issue in developing the survey involved how to accommodate the wide range of business structures and configurations. The most straightforward situation is a local business inhabiting a single building within the earthquake-impacted region. However, a local business may inhabit several buildings within the impacted region: for example, a restaurant with multiple locations or a manufacturer with a factory, warehouse, and administrative offices. Furthermore, a business within the affected region may be a branch of a large national or international corporation, and therefore might have resources and support unavailable to local businesses. The team tried to consider these different business structures and configurations when designing the survey. The field test in Napa, which is described in [Section 7](#), will provide valuable feedback as to whether the survey tool possesses the requisite flexibility.

4. Survey organization

The resulting set of questions that emerged from the process described in the previous section is organized into nine major sections, as shown in [Table 2](#). In overview, Sections 0 and 8 are administrative in nature, gathering information about the survey respondent and evaluating his or her willingness to participate in future surveys. Sections 1 and 2 capture generic information about buildings and businesses, respectively, prior to the earthquake. Sections 3 and 4 document the impact of the earthquake on buildings, while Sections 5, 6, and 7 focus on the impact on businesses.

These nine sections can be combined selectively to develop shorter, more focused surveys to be deployed to specific audiences at particular points in time after an earthquake. [Table 3](#) presents one potential strategy for doing so following a major earthquake. It comprises four distinct surveys. The first survey, Survey A, takes place within one or two weeks of the earthquake and focuses on recording detailed information about building damage. Given the technical nature of its questions, this survey should be completed by an engineer as soon as practical after an earthquake due to the perishable nature of damage data.

The second survey, Survey B, takes place between three weeks and two months after the earthquake and focuses on documenting the initial impacts of the earthquake on individual businesses. A representative of the business with intimate knowledge of its finances and operations (e.g., owner, manager, etc.) should complete this survey. Survey B comprises two distinct modules, one focusing on business disruption, recovery, and financing (i.e., the business module), the other focusing on building downtime and recovery (i.e., the building module), where the questions within this module have been designed such that a non-engineer can complete them. Both modules contain “baseline” questions that are asked only once and “monitoring” questions that are repeated in follow-up surveys (i.e., Surveys C and D). Within the business module, most questions refer to a business as a single entity that includes all related locations, buildings, and sites within the earthquake-impacted region only. The module also includes several questions that ask a business to document any assets or locations outside of the affected region. In contrast, the building module asks a business to provide downtime and recovery information for each building it occupies within the earthquake-impacted region. Consequently, the survey should be able to accommodate a diverse range of business structures and configurations, and should also facilitate stronger links between building damage and business impacts.

The third survey, Survey C, takes place at two different times: between two and six months and between six and twelve months. Survey C is a follow-up to Survey B, asking mostly the same questions except for “baseline” questions. As with Survey B, Survey C should be completed by a business representative. The final survey, Survey D, takes place between twelve and eighteen months after the earthquake and contains the same questions as Survey C plus additional questions about business resilience.



Table 2 – Organizational structure of the master list of questions

Section	Description	Question topics
0	Survey respondent information	Contact information; role within business
1	General building information	Address; number of stories; age; construction material; lateral system; square footage
2	General business information	Year established; number of employees; building location(s); annual revenues; profitability; growth rate; ownership structure; line of business; customer base; owner profile
3	Building damage	Extent and severity of structural, nonstructural, and content damage; status of mechanical and electrical systems; initial building inspection and placarding
4	Building downtime	Status of building placard; factors preventing building repairs; cost of repairs; time required to hire contractor/engineer and make repairs; permitting issues; site access restrictions; utility disruption
5	Business disruption and recovery	Current status of business operations (e.g., closed permanently, closed temporarily, reduced operations, etc.); changes to building location(s), number of employees, annual revenues, profitability, growth rate, line of business, customer base; factors affecting operational status (e.g., building damage, utility disruption, site access, customer issues, workforce issues, supplier issues, etc.)
6	Funding and financing	Insurance coverage before and after the event; status of insurance claims; sources of money for business recovery
7	Business resilience	Previous disaster experience; factors that mitigated earthquake impacts (e.g., backup utility supplies, relationships within community, internal and external resources, preparedness, etc.); steps taken to improve resilience after the event
8	Concluding questions	Willingness to participate in future surveys

Table 3 – Strategy for surveying businesses following a major earthquake

Survey	Description	Sections	Audience	Timeframe
A	Building damage	0, 1, 3, 8	Engineer	1-2 weeks
B	Business impacts (initial survey)	0, 2, 4 [#] , 5 [#] , 6, 8	Business representative	3 weeks – 2 months
C	Business impacts (follow-up survey)	0, 4 [*] , 5 [*] , 6, 8	Business representative	2-6 months AND 6-12 months
D	Business impacts (final survey)	0, 4 [*] , 5 [*] , 6, 7, 8	Business representative	12-18 months

[#] comprises both “baseline” and “monitoring” questions

^{*} comprises only “monitoring” questions

The proposed strategy in [Table 3](#) can be adjusted according to the severity of the event. For example, if a particularly damaging earthquake occurs, Survey C can be deployed more than twice to document a recovery process that could easily extend more than one or two years. Survey D can even be repeated several times as needed. On the other hand, for a less damaging earthquake, Surveys B, C, and D can be combined into one or



two surveys. As discussed in previous sections, the data generated by repeated surveys can be used to address long-term research questions and also to monitor business recovery issues in the weeks, months, and years following an earthquake. For monitoring applications it is crucial that the survey (in particular Survey C) be deployed multiple times after an earthquake.

5. Sample survey questions

The master list of survey questions developed by the team comprises over one hundred questions. In the interest of space, this section presents only a small sample of the most unique survey questions. Fig. 1 shows a question that documents changes to various aspects of business performance relative to before the earthquake, including revenue, debt, profit, employee productivity, and customer demand. This question is repeated throughout Surveys B, C, and D to enable monitoring of business performance over time across different sectors, which has many potential uses. For example, government officials can use the data obtained from the question to develop targeted policies and/or programs designed to speed business recovery. Fig. 2 presents a question that asks businesses to identify the various issues they are currently facing or have faced since the earthquake, including property damage, utility disruption, workforce issues, supplier issues, and relocation issues. Fig. 3 presents a companion question to the question in Fig. 2. It documents the degree to which a particular issue, in this case property damage, is currently impacting business operations. Similar follow-up questions have been developed for each business issue. These questions are repeated throughout Surveys B, C, and D in order to monitor the major issues impeding business recovery across different sectors. Data obtained from these questions can, among other things, be used by businesses to better understand their vulnerabilities and to develop more effective disaster response and recovery plans. Fig. 4 presents a question that documents delays associated with finding and hiring a contractor to make building repairs. Data obtained from this question can be used to improve engineering models of building downtime. Lastly, Fig. 5 presents a question that documents insurance claims and payments.

33. Please indicate the current status of the following aspects of your business relative to before the earthquake. Select "N/A" if a particular aspect does not apply to your business.

	Decrease by 100%	Decrease by 75%	Decrease by 50%	Decrease by 25%	Decrease by 10%	No Change	Increase by 10%	Increase by 25%	Increase by 50%	Don't know	N/A
Revenue	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Costs of doing business	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Profit	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Debt	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Prices charged to customers	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Hours of operation	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Hours worked from home	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Inventory	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Product and service output	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Employee productivity	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Customer demand	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Number of Employees	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Fig. 1 –Survey question for monitoring changes to various aspects of business performance over time



44. Has your business experienced any of the following since the earthquake?

	Currently Experiencing	Not currently experiencing but did experience previously	Did not experience
Property Damage	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Site access Issues	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Utility Service Disruption	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Customer/Market Issues	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Workforce Issues	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Supplier Issues	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Financial Issues	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Business Operations Issues	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Relocation/Reconstruction Issues	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Regulatory Issues	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Fig. 2 –Survey question for monitoring various business issues over time

45. If your business is currently experiencing or has experienced property damage, please indicate the degree to which it is impacting or has impacted business operations (or lack of operations in cases of temporary or permanent closure). Select “N/A” if your business did not experience property damage after the earthquake, and “No Impact” if you are currently experiencing or have experienced property damage but it is not currently affecting your business.

	No Impact	Minor Impact	Major Impact	N/A
Structural damage	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Nonstructural damage	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Inventory damage	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Equipment damage	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Contents damage	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Ground surface damage	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Other (please specify)

Fig. 3 – Companion question to Fig. 2 for assessing the degree of impact of a particular business issue, in this case property damage



63. Please answer the following questions about finding and hiring a contractor.

	Less than a week	1 week to 1 months	1 month to 3 months	3 months to 6 months	6 months to 1 year	Greater than 1 year	Not Started	Started, but not yet complete	N/A
How long after earthquake did you start searching for a contractor?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Once you started searching, how long did it take for you to find and hire a contractor?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Once the contractor was hired, how long did it take for them to begin repairs on site?	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Fig. 4 –Survey question for documenting delays associated with finding and hiring a contractor

62. Have you made insurance claims and received any payments as a result of the earthquake? If you have no policy, enter “N/A”. (Note: NFIP stands for National Flood Insurance Program)

	Made No Claim	Made Claim, Claim Was Rejected	Made Claim, Still Waiting To Hear	Made Claim, Claim was Accepted But No Payment Received	Made Claim, Received Partial Payment	Made Claim, Received Full Payment	N/A
Property insurance on the building structure (non-NFIP*)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Earthquake insurance on the building structure and contents	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Flood insurance on the building structure (NFIP)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Business property insurance on contents	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Business income interruption insurance	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Business liability insurance	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Fig. 5 –Survey question for documenting insurance claims and payments

6. Deployment strategies

Key elements of survey deployment include identifying the business to be sampled, selecting the mode or modes for survey deployment, and coordinating timing with the survey segments deployed. The following subsections describe these elements in more detail.

6.1 Sampling

In order to document the impact of an earthquake on a population of businesses in the area, the survey sample needs to cover a wide range of businesses, including those that have experienced physical damage to their site



and/or inventory, those in the neighborhood of damage that had only minor or no direct physical effects, and those in the same general market area but more distant from physical damage. Towards this end, the building damage survey (i.e., Survey A) can be used as a screening tool to identify the necessary range of affected businesses. The survey can be deployed as part of door-to-door canvassing typically conducted by engineers after an earthquake. The information obtained from these initial damage surveys, including the location and severity of earthquake damage, can then serve as the basis for selecting a sample of businesses whose buildings have been affected to varying degrees.

Alternatively, businesses in the general region can be identified through a sampling process, and the building damage survey then targeted to building owners or managers of the buildings occupied by the selected business sample. The research team identified several strategies for sample selection in its review of existing survey tools. In these earlier studies, the sampling approaches ranged from solicitation of participation via the web in the Hurricane Sandy survey to relying on business organizations such as chambers of commerce in the Canterbury Recovery and Loma Prieta surveys. Resilient Organizations sampled from a business-to-business marketing database of organizations in the affected areas within selected sectors and used telephone numbers listed in the database to invite organizations to complete the survey by phone, online, or hardcopy. Two phone call reminders were made at two-week intervals.

6.2 Deployment modes and timing

Considering the full time frame of the event in which the survey could be distributed, deployment may need to rely on multiple and/or combined approaches. In the first few weeks following an event, the survey may be useful as a tool for identifying the types and locations of businesses most affected, the kinds of immediate effects, and the greatest need for assistance. At the same time, electronic means of communication, and even postal service may be disrupted. Physical copies of the survey could be distributed as businesses are identified through aid workers and local business councils, if they are in operation. While it is important to obtain the immediate impacts of an event, for longer term studies, researchers may need to build a more comprehensive, representative sample from the resources mentioned above as early as possible and to reach a broader set of businesses within the first few weeks or month, either through in person interviews or using electronic means of communication, such as web surveys, when internet service has been restored. Later follow-up surveys will have easier access to electronic means of communication and postal services, but may also require phone and personal interview follow-ups to maintain continuity over time with the business sample.

7. Survey field testing in Napa

Currently, the team is preparing to launch a field test of the survey tool on a diverse sample of businesses throughout the region affected by the 2014 South Napa Earthquake. The general purpose of the test is to obtain feedback from respondents to improve the applicability, clarity, and brevity of the survey.

In order to compile a diverse list of businesses for the field test, the team attempted to identify businesses across a range of sectors that experienced different earthquake impacts, including those that had closed and/or suffered building damage. The team identified closed businesses from a list provided by the City of Napa, and identified damaged businesses from both damage assessments by the Applied Technology Council and permit data from the city. To ensure the list of businesses represented a wide range of sectors, the team used the North American Industry Classification System (NAICS) to identify underrepresented business categories and subsequently performed sectoral searches on Onesource Global Business Browser [9] to fill in the gaps. The Onesource database includes both firms currently in operation and those that have closed, though it is likely less comprehensive on closed businesses, as a major purpose for the database is to allow searches for customer or supplier networks. Businesses for the field test range in size from under twenty employees to several hundred, and include businesses currently in operation as well as several that have closed. Sectors covered in the sample include: construction; manufacturing (wineries); wholesale, transportation and warehouse; retail; information; finance, insurance and real estate; professional and business services; accommodation; education; health; food and beverage; arts and entertainment; religious organizations. The team plans to distribute the survey electronically via Survey Monkey and conduct follow-up telephone interviews to obtain detailed feedback from



respondents on the clarity of survey questions, concerns about how to respond, and time commitment. The team will use this feedback to guide a final round of edits, after which the survey will be ready for deployment in the next major earthquake.

8. Conclusions

This paper has described a survey tool developed by a team of researchers as part of the EERI Resilience Observatory Project. The survey tool aims to study the resilience of businesses following a major earthquake, and can be used both for real-time monitoring of business recovery issues over time and also for addressing longer-term research questions. Towards this end, the team designed the survey to cover different time periods, from immediately after an event to several years later. The team also designed the survey to accommodate a wide range of business configurations. Data from the survey can be used for many purposes, including developing targeted policies and/or programs that speed business recovery after an earthquake, developing more effective disaster response and recovery plans for businesses, and improving engineering models of building downtime.

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