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# Lessons from the Nisqually Earthquake for Performance-Based Earthquake Engineering

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## Overview

The success of performance-based earthquake engineering relies ultimately on the ability of engineers and analysts to accurately and reliably predict the effects of earthquakes on structures and the associated costs of these effects to building owners, users, and society. Actual disasters provide important opportunities to evaluate the state-of-the-art, as well as gather new data to improve it.

The Nisqually earthquake struck the Seattle metropolitan area on February 28, 2001 (for details, see Nisqually Earthquake Clearinghouse Group, 2001). Here, we summarize findings from a study we conducted on the impact of this disaster on local businesses. We focused on two of the hardest-hit business districts in Seattle, historic Pioneer Square and the SoDo area. We conducted 107 in-person interviews with business owners and managers in 62 buildings, and attempted to gather as complete a sample as feasible of businesses in our study area. The interviews were structured to systematically gather information on property losses, business interruption, revenue loss, repair costs, and recovery financing, mitigations undertaken both pre- and post-disaster, and recovery needs. Most of businesses in these two districts are in the manufacturing, retail trade, and producer services sectors. The vast majority are small businesses.

This research summary focuses on our preliminary findings regarding business impacts and draws implications for performance-based earthquake engineering. Later stages of this research will gather information from building owners for the study area. Few, if any, of the buildings covered in our survey can be considered engineered buildings; however, a number of them had been seismically retrofitted. Moreover, we expect that our findings – particularly with regard to relating structural damage to impacts on owners and occupants – are highly relevant to performance-based design of larger, engineered buildings.

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**Business Interruption Findings**

Our survey suggests three main findings that are especially significant for performance-based earthquake engineering (PBEE):

*1. Hidden costs and consequences are very important.*

Analysts and researchers rely heavily on data from previous disasters to form expectations of future losses. However, official or documented statistics of disaster losses (e.g., from insurance claims, disaster assistance data, and Small Business Administration loans) present a very incomplete picture of actual loss. Our survey found that while the vast majority of businesses had suffered some sort of loss, very few had earthquake insurance and less than 10% had applied for loans from the Small Business Administration. Most of the clean-up, repair and recovery costs were borne out-of-pocket. In general, most businesses suffered some business interruption loss, with closings ranging from several hours to over 7 weeks. Reports of customer volume loss were also common. The majority of business losses are thus undocumented, or “hidden”. The prevalence of hidden costs suggests that careful empirical studies are essential when estimating the full range and likely magnitude of losses that might follow from earthquake damage.

*2. Structural damage is a very imprecise predictor of business impacts.*

In estimating the consequences of building damage in earthquakes, it is often assumed that structural damage is a key predictor of disruption to building occupants. Our findings clearly dispel the notion of a predictable, one-to-one correspondence between levels of building damage and extent of business disruption. Other factors besides structural damage are at least as influential. Moreover, levels of uncertainty or inherent variability in business impacts are high.

In the absence of detailed engineering assessments of the damage to buildings in our study area, information on safety inspection tagging can serve as a rough proxy for level of damage. Table 1 shows the distribution of business revenue loss (short-term) for different damage states. Businesses in red-tagged buildings clearly suffered short-term revenue loss at the highest rates. However, the table indicates that between the yellow-tag, green-tag, and uninspected categories of damage, the proportions of businesses suffering revenue loss are very similar. Thus, even as broad a damage indicator as tag color fails to provide a reliable predictor of business impacts.

**Table 1 – Short-Term Revenue Loss by Building Damage State**

| Damage State | Short-Term Revenue Loss | | | | |
|---|---|---|---|---|---|
| | Yes | No | No, with response costs | Not yet re-opened | Total (no. businesses) |
| Red | 60% | 20% | 0% | 20% | 100% (10) |

| | | | | | |
|---|---|---|---|---|---|
| Yellow | 39% | 54% | 0% | 7% | 100% (28) |
| Green | 52% | 44% | 4% | 0% | 100% (54) |
| Not inspected | 57% | 43% | 0% | 0% | 100% (14) |

Table 2 considers only those businesses that occupied yellow-tagged buildings and separates the responses by broad business sector. It is apparent that limited access to their buildings was much more disruptive in terms of revenue loss for retail businesses than for those in other sectors such as manufacturing or services. In retail, customer access to the business is critical, and loss of this access leads immediately to business interruption. Businesses in other sectors with roughly similar levels of building damage could still maintain customer contact through telephone or other means and to some degree could move operations with less disruption.

**Table 2 – Revenue Loss by Sector, Yellow-Tag Occupants Only**

| Sector | Short-Term Revenue Loss | | | | |
|---|---|---|---|---|---|
| | Yes | No | No, with response costs | Not yet re-opened | Total (no. businesses) |
| Retail | 57% | 29% | 0% | 14% | 100% (14) |
| Manufacturing or Service | 23% | 77% | 0% | 0% | 100% (13) |

*3. Externality effects from outside the business or building can be a major source of loss.*

Spatial externality effects of damage are significant, that is, businesses can be significantly disrupted by damage in their immediate neighborhood. Inspections and repairs to adjacent buildings, street closures, and traffic diversions caused additional losses to businesses. Indeed, when asked to identify the most important problem they faced in recovery, two-thirds of the business respondents cited these types of issues. Only one-third identified a problem related to their own business or building (financing, permitting for repair, dislocation) as most significant. This implies that, conversely, individual mitigation investments can have significant neighborhood-level benefits.

**Lessons for PBEE**

These observations suggest a number of lessons for PBEE:

- Selection of an appropriate "decision variable (DV)" in the PBEE framework is not only critical, but is also a highly complex and ambiguous undertaking. The DV indicates, in effect, the objective by which expected structural performance is to be judged acceptable or unacceptable by a building's owners and other stakeholders. Examples of possible decision variables that have been raised in the context of PEER's PBEE framework include annual earthquake loss and the exceedance of certain limit states such as collapse (Cornell and Krawinkler, 2000). Our findings suggest that many categories of loss should be considered (structural repair cost, business interruption, etc.), and that these are difficult to predict and only loosely correlated with structural damage states. Moreover, different stakeholder groups will undoubtedly advocate different, and possibly conflicting, decision variables.

- Even with sophisticated economic and other impact models, predicting DV outcomes will be subject to a high degree of uncertainty. That is, uncertainty is as much an issue in evaluating the decision variable as it is in preceding phases of damage and intensity measurement. Much more empirical data is needed to reduce this uncertainty and to develop more accurate and reliable models.

- The divergence between public and private objectives, or acceptable DV outcomes, is a very important issue that needs to be addressed in evaluation frameworks such as benefit-cost analysis. Our study showed that the performance objective decisions of one building owner may have major consequences for his or her neighbors. The role of the public sector in addressing such externality effects should be considered.

**For further information**

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**Keywords**

Nisqually earthquake, business interruption, loss, impact, survey, data, uncertainty, decision variable.