1. Introduction

The past three decades have seen a significant rise in the annual number of natural disasters (Wirtz & Schuck, 2013). Events such as the Christchurch and Tohoku Earthquakes and Hurricanes Katrina and Sandy remind us of the catastrophic consequences that can result when natural hazards and urban environments collide. Increasing urbanization, aging infrastructure, growing economic interdependence and the continued impacts of climate change are likely to lead to a higher frequency of such disasters in the future (Botzen & Van Den Bergh, 2009; Global Science Forum, 2012; IPCC, 2012). As a result, preparedness and mitigation activities have become that much more important for cultivating safer, more resilient cities.

The potential impacts of a disaster are myriad—injuries and casualties, infrastructure damage, environmental destruction, economic loss—and the ramifications of these can be widespread and long-lasting. Cities are complex interdependent systems, so an impact to one component can affect other parts of the system (Amendola, Ermolieva, Linnerooth-Bayer, & Mechler, 2013). A better understanding of these impacts and system interactions helps to inform planning strategies designed to mitigate future disaster-related loss.

The business sector is one of those critical components of an urban system. Businesses large and small play an integral role in the functioning of a community—tax revenue generator, employer, goods and service provider (Alesch, Holly, Mittler, & Nagy, 2001; Cochrane, 1990; Zhang, Lindell, & Prater, 2009). It is critical that a comprehensive community risk assessment include potential risks to the business sector and ways to reduce those risks as part of a broader community resiliency-building strategy.

1.1 Research Strategy

To support continued public resiliency-building efforts on the part of one community in the Metro Vancouver region--the District of North Vancouver (DNV)--a comprehensive research project was conducted to analyze and assess the earthquake risk, vulnerability and preparedness landscape of the local business community.

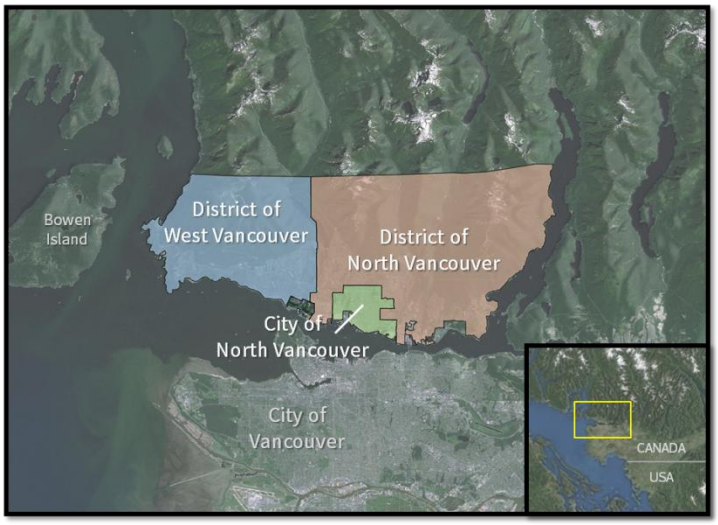
Using the lens of a magnitude (M) 7.3 Georgia Strait earthquake scenario, this research estimates potential disruption and economic loss to DNV businesses using a model adapted from previous research by Chang and colleagues (Chang, Pasion, Tatebe, & Ahmad, 2008). To investigate business risk perception and risk reduction activity, an online survey was also conducted among North Shore businesses. Model and survey findings are examined to develop recommendations to support an initiative by North Shore local government agencies to increase business disaster preparedness, as well as to identify future research opportunities in this space.

1.2 Paper Organization

This paper presents an overview of the research process and key findings. Case study characteristics and selection rationale are outlined in Section 2. Section 3 describes the economic loss model used to estimate the potential risk of disruption to the North Vancouver business community and key findings. An overview of the survey and key findings on risk perceptions and preparedness behavior of North Vancouver businesses are discussed in Section 4. Section 5 examines the implications of study findings for public policy and preparedness planning, and Section 6 discusses study conclusions.

2. Case Study Profile

This project focuses on the District of North Vancouver (DNV), both individually and in the context of its two neighboring municipalities—the City of North Vancouver (CNV) and District of West Vancouver (DWV)--which are collectively referred to as the "North Shore" (see Figure 1).



Map Source Data: GeoBC, Esri & DigitalGlobe

Figure 1. Map of the North Shore

The North Shore represents 3 of the 22 municipalities of the Greater Vancouver Regional District ("Metro Vancouver"), a region with 2.3 million inhabitants. Located north of the City of Vancouver, DNV is home to approximately 88,000 people. CNV and DWV have estimated populations of 51,000 and 44,000 respectively (BC Stats, 2013).

DNV was selected as the study focus area for a number of reasons, chief among them the support of the municipal government for a comprehensive analysis of local natural hazard risks and the existence of a concurrent earthquake risk modeling pilot project conducted by Natural Resources Canada (NRCan). NRCan's pilot project is part of a broader effort to develop a national all-hazards risk assessment framework. Assessment methods are based on "Hazus," a standardized loss estimation methodology originally developed in the United States by the Federal Emergency Management Agency (Journeay, 2014). The pilot focuses specifically on earthquake risk assessment, and project results serve as inputs to this study's loss model.

2.1 DNV Business Profile

Just over 3,400 businesses are licensed in the DNV. The municipality has a wide portfolio of business sectors. As shown in Table 1, service providers are the most numerous among these, comprising more than half of all local businesses; followed by those engaged in the mining, construction, transportation, communication and utilities trades; and the wholesale and retail trade sector.

Table 1. DNV Business License Registry by Sector

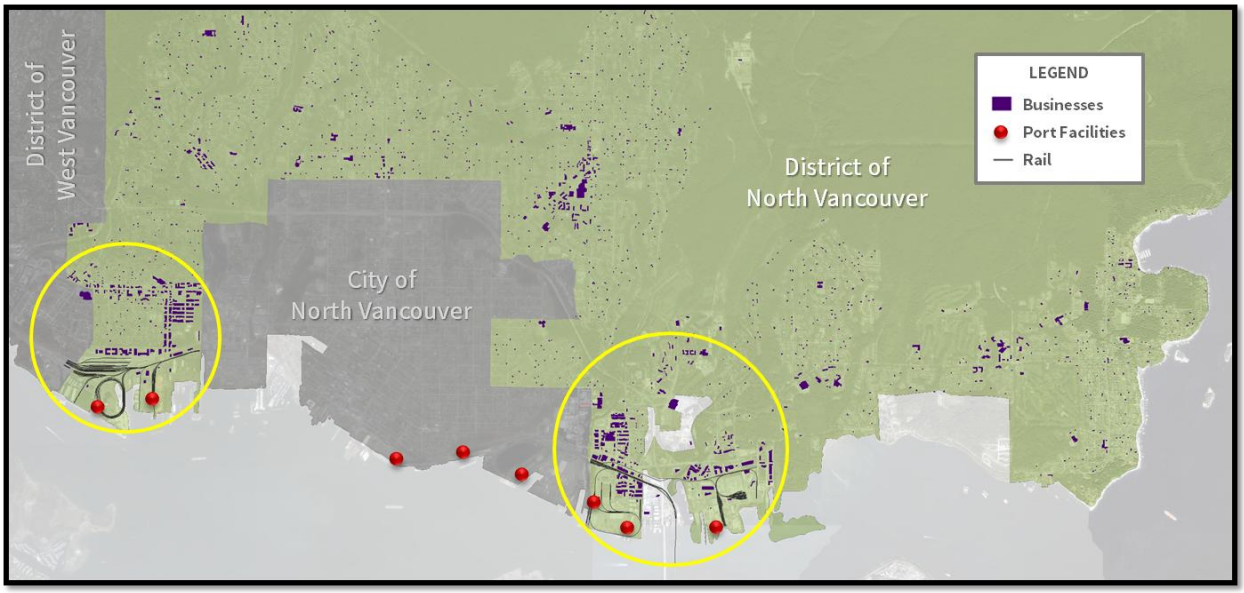
Aggregated Sector (sector code)	Count	Percent
All Other Services (**SVC**)	1780	52%
Mining, Construction, Transportation, Communication & Utilities (**MCT**)	611	18%
Wholesale & Retail Trade (**TRD**)	503	15%
Finance, Insurance & Real Estate (**FIR**)	266	8%
Manufacturing (**MFG**)	155	5%
Health Services (**HTH**)	117	3%
Total	**3432**	100%

Source: District of North Vancouver, 2011

Collectively, these businesses employ nearly 22,000 individuals (2006 Census of Canada).[1] Based on provincial annual industry employment counts and gross domestic product (GDP) data, it is inferred that the DNV business community generates an estimated annual gross regional product (GRP) of approximately $1.93 billion. A significant share of these businesses are small (fewer than 50 employees) and often home-based. This is especially relevant to community resiliency planning initiatives as small businesses typically have fewer resources available to devote to mitigation and business continuity planning than do franchised or large businesses.

It is also important to note the geographic distribution of businesses within the municipality. In addition to the proximity of other infrastructure (such as transportation networks or lifelines critical to business operations), other geographically-dependent factors such as site amplification, liquefaction susceptibility and landslide potential are important to

[1] The DNV's business license database does not include data on number of employees per business.



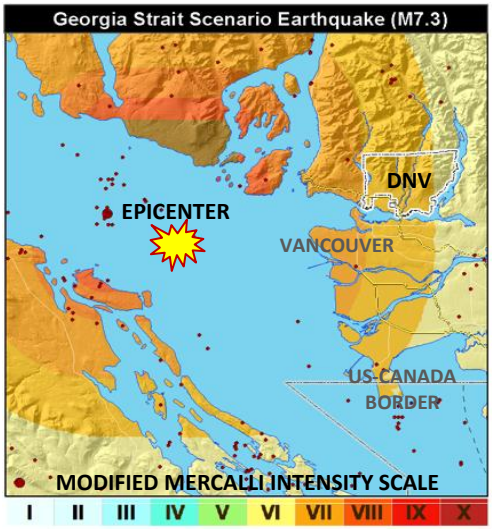
Map Source Data: GeoBC, District of North Vancouver, Port Metro Vancouver, Esri & DigitalGlobe

Figure 2. Map of DNV Buildings Containing Businesses

consider when evaluating earthquake risk. In the DNV context, two areas of highest business density are located along the waterfront area (see Figure). It is not coincidental that commercial and industrial areas are heavily concentrated in close proximity to rail and port infrastructure.

2.2 Georgia Strait Earthquake Scenario

As mentioned in the previous section, DNV and NRCan are currently piloting a risk assessment methodology focused on earthquake hazards. Using Hazus, NRCan selected and modeled four plausible earthquake event scenarios intended to represent the diversity of earthquake risks facing the region. Among these, findings indicated that a



Source: Journeay, 2014

Figure 3. Georgia Strait Earthquake

M7.3 Georgia Strait earthquake (Figure) represented the 'worst case' scenario among those tested, resulting in significantly higher estimated damage and loss (Journeay, 2014), and so it is the scenario selected for use in this study.

3. Risk Analysis

The process of modeling disaster economic loss and recovery is complex. It involves deliberate choices around what variables to include and how to operationalize them, at what geographic and temporal scales the modeling should take place, the appropriate unit of analysis, how to quantify uncertainties, and how to deal with the often prevalent challenge of data availability limitations. This section briefly describes the research methodology and process used in this study and summarizes model results.

3.1 Model Structure

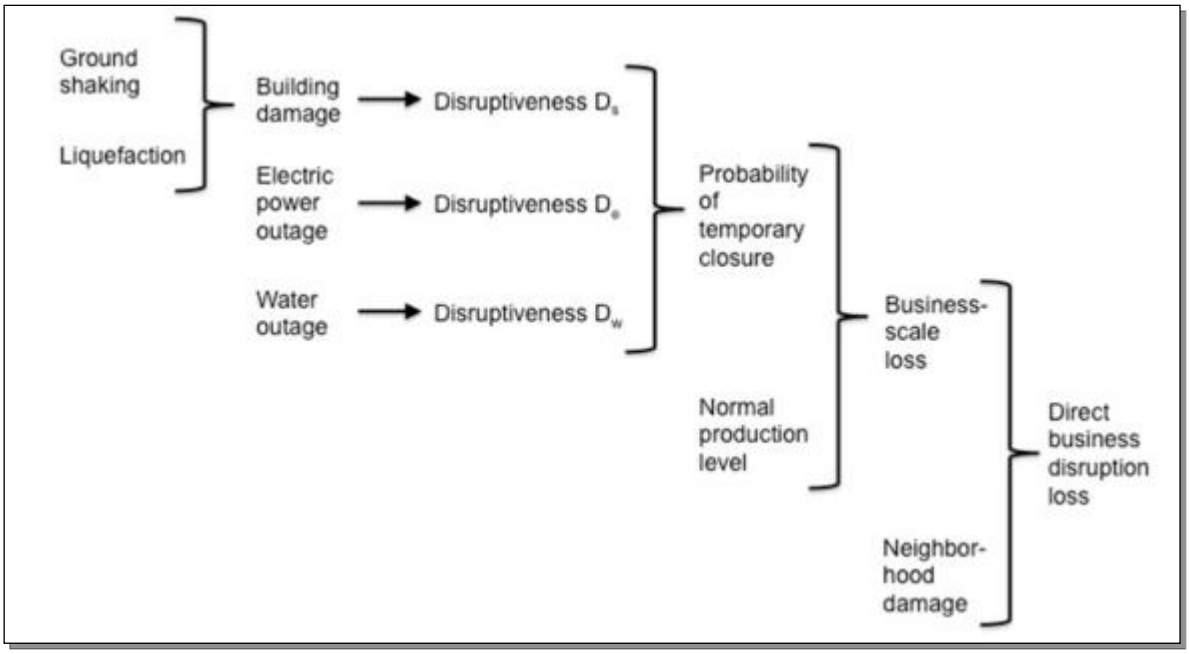
The economic loss model ["DNV model"] applied in this study estimates direct economic losses[2] of DNV business using several factors, including: business sector, average economic production level, location, building damage state and lifeline access. The DNV model makes use of NRCan Hazus building and lifeline infrastructure damage estimates in the M7.3 Georgia Strait earthquake scenario to investigate the role of various sources of disruption in total economic loss. It is based on earlier economic loss models implemented for the Memphis (Shinozuka et al., eds., 1998; Chang et al., 2002; Chang and Shinozuka, 2004) and Los Angeles ["LA model"] (Chang et al., 2008) regions. Business disruption data derived from surveys of more than 2,000 businesses after the 1994 Northridge and 1989 Loma Prieta earthquakes (provided by Tierney and colleagues at the DRC) form the empirical basis of the model.

[2] Losses resulting from disruption to business operations caused by damage at the business's location

Based on the survey data, the LA model developed an algorithm to evaluate the combined disruptiveness of three factors—building damage, electric power outage, and water outage—by producing an overall indicator of disruptiveness measured in terms of probability of temporary business closure. A Monte Carlo simulation approach is used to estimate number of businesses closed based on closure probabilities.

The DNV model includes a refinement over its predecessor models by incorporating neighborhood damage. Damage to the surrounding areas, particularly when it impedes employee and customer access, has shown to be a significant factor in affecting business operations following a disaster (Kroll, Landis, Shen, & Stryker, 1991; Webb, Tierney, & Dahlhamer, 2000; Chang & Falit-Baiamonte, 2011). This 'neighborhood effect' is represented in the model through the use of a scenario specifying that if the percentage of businesses closed within a defined neighborhood in the initial scenario exceeds a certain threshold level, then all businesses in that neighborhood are considered closed in the neighborhood effects scenario.

Scenarios are run with and without lifeline disruption and neighborhood effects to estimate how losses can be attributed to these various factors. In each scenario, resulting closure rates and normal daily production levels are used to estimate direct business disruption loss. Figure illustrates model inputs and overall structure. Models outputs include the percent of businesses open and associated daily production loss in dollars and as a percent of GRP. Note that indirect economic losses (i.e., those due to economic interdependencies, such as damage to a business's supplier rather than to the business itself) are outside the scope of this analysis.



Source: Chang & Lotze, 2014 (adapted from Chang et al., 2008)

Figure 4. Outline of the DNV Model

3.3 Simulation Approach & Model Scenarios

A Monte Carlo simulation approach is used with 100 simulations run for each scenario and the results averaged to estimate likely outcomes. As water and electric utility infrastructure damage estimates were not yet available from NRCan at the time of this study, lifelines were either considered fully functional or fully nonfunctional depending on the scenario modeled. In scenarios where lifelines were nonfunctional, the model projected associated disruptiveness levels for each business. Using the cumulative impact of modeled disruption sources, businesses were then estimated to be open or closed. If closed, the business's estimated normal daily production was considered a loss. Cumulative production loss is totaled for each simulation run to estimate aggregate business economic loss in dollars and as a percent of DNV daily GRP.

Several scenarios were simulated. The 'baseline' scenario accounted for building damage only. Results are a lower bound estimate of loss as no lifeline outages or neighborhood damage were considered. A second scenario included the impacts of building damage and complete lifeline outage ('building damage + no utilities' scenario). Service loss of this magnitude is unrealistic but provides a hypothetical upper bound estimate of lifeline-related losses (a real-life scenario would fall somewhere between the baseline and no utilities scenario). Baseline and 'building damage + no utilities' scenarios were then run again with the neighborhood[3] effect applied. For this study, 50% or greater businesses closed in the predecessor scenario was used as the threshold. 100 simulations were run for each scenario.

3.4 Key Findings

Table 2 summarizes businesses by sector estimated by the model to be open the first day of the disaster in each scenario, averaged over 100 simulations.

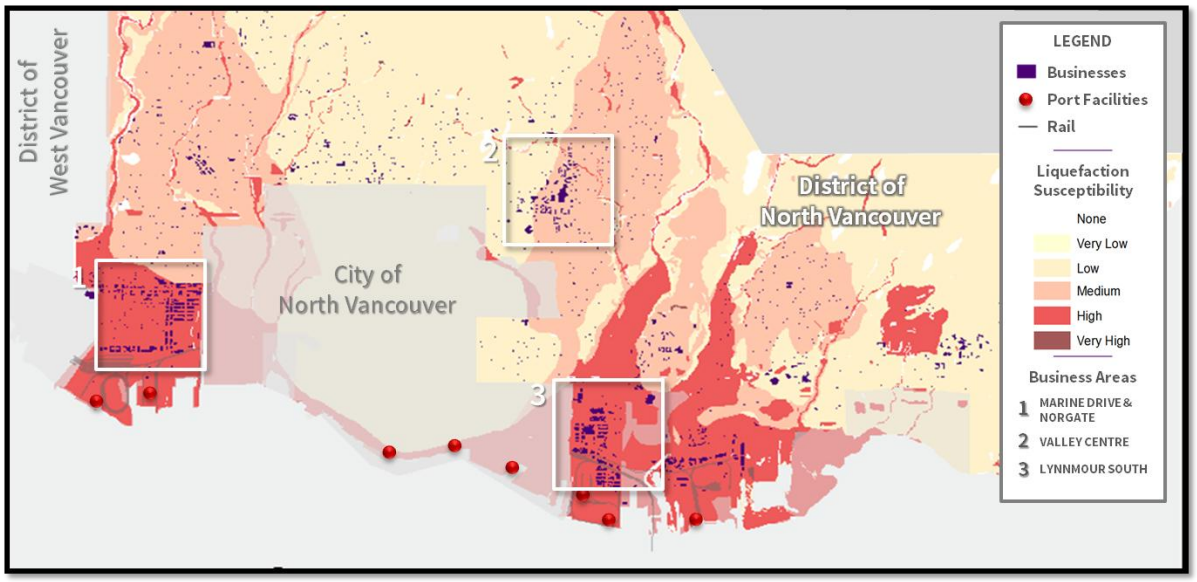
At the aggregate level, the baseline scenario estimates that 69% of businesses will remain open on the first day after the disaster if accounting only for the impact of building damage. The application of a neighborhood effect to this scenario produces a minor reduction of 5% in the average open rate for all industries. Open rates decline precipitously when lifeline outages are included in the model. The average open rate in the 'building damage + no utilities' scenario falls to 28%. When all sources of disruption are considered, just 15% of businesses are estimated to remain open.

[3] No standard definition of a "neighborhood" exists so three different sets of criteria were developed to delineate different neighborhood patterns based on factors such as pedestrian traffic, building proximity, natural barriers and zoning classifications. The results from simulations run using these criteria were very similar, so loss estimates from only one set are reported here. Criteria used for this neighborhood definition included: 1) minimum cluster of 5 or more zoned commercial/industrial/mixed use buildings, 2) use of natural barriers and major thoroughfares as boundaries in in areas with large clusters, and 3) consideration of pedestrian traffic patterns.

Table 2. Percent of Businesses Open in Different Damage Scenarios, by Sector *M7.3 Georgia Strait Earthquake*				
Aggregated Sector*	**Damage Scenario**			
	Building Damage [Baseline]	**Building Damage + Neighborhood Effect**	**Building Damage + No Utilities**	**Building Damage + No Utilities + Neighborhood Effect**
FIR	**65%**	**59%**	**25%**	**10%**
HTH	**75%**	**72%**	**21%**	**8%**
MCT	**72%**	**68%**	**33%**	**25%**
MFG	**58%**	**51%**	**22%**	**2%**
SVC	**71%**	**66%**	**28%**	**18%**
TRD	**65%**	**57%**	**25%**	**4%**
Total	**69%**	**64%**	**28%**	**15%**

** HTH = health services; FIR = finance, insurance, real estate; MCT = mining, construction, transportation, communications, utilities; MFG = manufacturing; SVC = all other services; TRD = wholesale and retail trade*

When examining disruption at a sector level, the manufacturing and trade sectors are estimated to have the greatest degree of vulnerability to closure when all three disruption sources are modeled.



Map Source Data: Natural Resources Canada, GeoBC, District of North Vancouver, Port Metro Vancouver, Esri & DigitalGlobe

Figure 5. Map of DNV Businesses & Liquefaction Susceptibility

The spatial distribution of business disruption is also important to note. Figure overlays the business map shown earlier with liquefaction susceptibility as modeled by NRCan. Events

like 2011 Christchurch Earthquake demonstrate that liquefaction can cause substantial damage and disruption (Wilkinson, et al., 2013). Two of the three areas with the highest business concentrations are located in zones highly susceptible to liquefaction.

Table 3 summarizes estimated economic loss associated with a single day of business closures as described in the previous section, both in dollars and as a percent of normal DNV economic activity. The difference in estimated loss from the single-source disruption scenario to the scenario considering all sources is substantial; the 'building damage + no utilities + neighborhood effect' scenario estimates $4.35 million/day in economic loss, an increase of 165% over the baseline estimate of $1.64 million/day. The former figure

Table 3. Business Disruption Loss* in Different Damage Scenarios
M7.3 Georgia Strait Earthquake

Average Daily Loss	Damage Scenario			
	Building Damage [Baseline]	**Building Damage + Neighborhood Effect**	**Building Damage + No Utilities**	**Building Damage + No Utilities + Neighborhood Effect**
Dollar loss [$ million]	$1.64	$1.95	$3.63	$4.35
% difference from baseline	--	+19%	+121%	+165%
Loss as a % of GRP**	33%	39%	73%	88%

** According to percent of businesses closed, averaged over 100 simulations*
*** Gross regional product, where region is DNV*

represents 88% of DNV normal daily production. Prolonged business disruption at this level would have a severe impact on the local economy. Comparing differences between the one- and two-source disruption scenarios also highlights the relative impact of each disruption source: lifeline outage (if utility loss was complete) accounts for greater economic loss ($1.99 million) than either building damage ($1.64 million) or neighborhood effects ($0.31 million).

In summary, the DNV model highlights a number of vulnerabilities for consideration by both researchers and policymakers. From an industry perspective, the manufacturing and trade sectors demonstrated the highest levels of vulnerability. Spatially, businesses located in close proximity to the waterfront are the most susceptible to disruption. In terms of lost economic production, the service and finance/insurance/real estate sectors collectively accounted for 71% of estimated loss when all disruption sources are considered, signifying a 62% GRP loss.

As this section demonstrates, there are many different ways to analyze and interpret risk and vulnerability. How they are subsequently prioritized and addressed at the community level is a policy question.

4. Risk Perception & Preparedness Behavior - Business Survey

To better understand the North Shore business community's attitudes regarding natural hazard[4] risks, as well as their current level of preparedness activity, an online survey was conducted among municipally-licensed businesses. This survey was part of a larger project undertaken by the author—the North Shore Business and Employer Emergency Preparedness (BEEP) project—in partnership with the North Shore Emergency Management Office (NSEMO).

4.1 Survey Development

The North Shore Business Preparedness (NSBP) survey was designed to address factors demonstrated to influence risk reduction behavior adoption and business characteristics shown to correlate with preparedness and recovery levels in previous studies. Survey

[4] Though earthquake hazards were highlighted in a small number of questions, the survey took an all-hazards approach to better support NSEMO all-hazard planning efforts.

content was also informed by several earlier business disaster preparedness surveys, including: Jackson County, Oregon's Business Recovery Questionnaire (2006), National Federation of Independent Business's (NFIB) National Small Business Poll (2004), and the DRC business surveys (an overview of the DRC surveys can be found in Webb, Tierney, & Dahlhamer, 2000).

NSBP survey questions were intended to enable several avenues of inquiry, including: examination of any relationships between business characteristics and preparedness activities, evaluation of community preparedness levels, identification of preparedness gaps for NSEMO to address, and the identification of what businesses perceive as barriers to adopting risk reduction and what resources would help motivate them to act.

The survey was distributed via direct email, electronic newsletters and social media to licensed North Shore businesses by NSEMO and municipal and business community partners. The NSBP survey received 51 valid responses from North Shore businesses. Though the small sample size limits generalizability and the level of analysis that can be performed[5], survey results nonetheless provide interesting insights into the views and behaviors of a portion of North Shore businesses and can help to inform future research and decision making in this area

4.2 Key Findings

This section highlights a few key survey findings relating to risk perceptions, business characteristics, preparedness behaviors, and the associations between them.

[5] Results are analyzed at the aggregate North Shore level due to small response rate.

In terms of earthquake occurrence likelihood, responses ranged across all probability categories, though a slight plurality indicated that they believe there is an 80-100% chance of damaging earthquake occurring in the next 50 years.

NSBP survey respondents identified losing power service, losing telecommunications service, building damage, damage to the transportation network and employees unable to come to work as their chief five disruption concerns, displaying some consistency with model results that indicate utility loss to be most disruptive to businesses.

When asked to consider their financial resilience, nearly half of respondents (45%, n=24), believed they could remain closed for a week or more as the result of disaster-related disruptions before experiencing serious financial difficulties.

NSBP survey participants also expressed somewhat mixed opinions regarding the importance of risk assessment information:

- 29% (n=31) said it plays a very or somewhat important role in their preparedness planning process,
- 76% (n=35) indicated they would be somewhat likely to make changes to their preparedness plans if exposed to information stating a hazard was twice as likely to occur as they had previously believed, and
- 84% (n=35) felt it would be very valuable in supporting their planning efforts.

The overall lack of a written preparedness plan among North Shore businesses in the survey—only 25% (n=13) reported having one—is moderately consistent with recent surveys by various research and industry organizations.

Though the small sample size limits the level of analysis that can be performed, comparisons of survey answer frequency do indicate potential associations of some business characteristics and risk perceptions with having a written preparedness plan among respondents. Table 4 provides an overview of selected business characteristics and risk perception attributes with the corresponding percentages of respondents who stated they had a written preparedness plan.

Table 4. Comparison of Business and Risk Perception Attributes with Having a Written Preparedness Plan

Attribute	Subgroups	Have Plan	*N**
Size:	1-19 employees	15%	*6/41*
	20+ employees	70%	*7/10*
Age:	0-9 years	36%	*4/11*
	10+ years	21%	*8/38*
Earthquake Likelihood Belief:	0-60% Chance	15%	*4/26*
	60-100% Chance	32%	*7/22*
Value of Risk Assessment Information:	Very valuable	20%	*4/20*
	Somewhat valuable	18%	*3/17*
	Already have enough	60%	*3/5*
Role of Risk Info in Planning:**	Very important	31%	*4/13*
	Somewhat important	28%	*5/18*
	Not at all important	25%	*2/8*
Would Change Plans Based on New Risk Info:**	Very likely	50%	*4/8*
	Somewhat likely	37%	*10/27*
	Not at all likely	20%	*1/5*

**Number of subgroup respondents with a preparedness plan)/(Total number of subgroup respondents)*
*** 13% (n=6) of respondents to this question answered Unsure/Don't have a preparedness plan*

Establishment size appears to be most strongly associated with having a written preparedness plan among NSBP survey respondents, as only 15% (n=6) of businesses with fewer than 20 employees reported having an emergency plan, whereas 70% (n=7) of businesses with 20 more employees indicated they had one. This is consistent with other studies that found business size to be among the strongest predictors of preparedness behavior adoption (e.g. Dahlhamer & D'Souza, 1997; Webb, Tierney & Dahlhamer, 2000). Age also appears to have some correlation with preparedness plan adoption among respondents; those in business less than 10 years were somewhat more likely to have a plan than those in business 10 years or more.

Survey respondents who expressed a greater belief in earthquake likelihood were also more likely to have a preparedness plan. There may also be some association between having a preparedness plan and the importance respondents attribute to the role of risk information in their preparedness planning--the more importance is attributed to risk information, the more likely respondents are to have a preparedness plan.

In summary, while the sample size for the NSBP survey is small and not generalizable to the wider North Shore, it does provide a useful window into the mindsets and actions of a portion of local businesses. Overall, participating businesses reported being generally unprepared for a disaster. Businesses indicate being most concerned about utility loss. Lack of knowledge was identified as the greatest barrier to preparedness plan adoption for those who had not done so, but they also indicate a degree of receptiveness to risk information that may encourage greater preparation activity.

5. Risk Management - Recommendations for Public Decision Making

One of the challenges facing local decision makers with regard to risk management policy development is a “lack of available time to thoroughly analyze and evaluate long-term planning options due to the large number of daily decisions that require immediate action;” providing decision tools to aid in this analysis is critical to supporting the ability of local governments to make effective risk management decisions (Kunreuther & Miller, 1985). One of the goals of this research is to develop a clearer picture of the local business risk, vulnerability and preparedness landscape to better support North Shore public decision making processes around community risk management. This section offers several recommendations based on study findings.

Infrastructure & Land Use Planning

Spatial vulnerability patterns, especially identification of high liquefaction risk areas near the waterfront, can serve as inputs into future land use decisions. If estimated risks exceed levels deemed acceptable by the community, then local leaders may wish to consider changing the type and intensity of use in these areas through zoning code adjustments and other future development decisions. Vulnerability data can also help to inform decisions on local infrastructure maintenance and improvement strategies; for example, knowing which areas are likely to suffer the greatest business disruption and subsequent economic loss as a result of lifeline outages could help prioritize infrastructure upgrades in those areas.

Response & Recovery Planning

Knowledge of where building damage and lifeline outages are most likely to occur can also help guide the development of response and recovery strategies. For example, if critical facilities—like healthcare— are especially susceptible to disruption from utility loss, then identifying those vulnerable facilities in advance can aid in ensuring service is restored to priority areas first. Loss estimation model data can also be used to inform restoration strategies in order to decrease economic losses; for example, a study by Rose and Benavides found that economic losses following a New Madrid Earthquake could be substantially reduced if electricity restoration was prioritized based on the GRP contributions of affected sectors (Rose & Benavides, 1999).

Strategic Vulnerability Targeting

Model and survey data can also aid decision makers in determining where to best direct business risk education and preparedness planning support. Given limited municipal

budgets, risk managers want to target efforts to where they will be the most effective. As previously discussed, there are several vulnerability attributes for local leadership to consider when developing risk management strategies.

From a business characteristics standpoint, past disaster events have demonstrated that small businesses—which are the vast majority of businesses on the North Shore—are typically more vulnerable to the impacts of disasters, and have fewer preparedness and recovery resources at their disposal, than their larger counterparts. Study results confirm this in the context of NSBP survey respondents, providing further evidence that local risk managers may want to consider efforts to bolster preparedness among North Shore small businesses. From an industry perspective, the DNV model indicated that the manufacturing and trade sectors are the most vulnerable to closure as a result of earthquake-related disruptions. In terms of GRP, service and finance/insurance/real estate sectors represent the majority of estimated loss. These are all perspectives for risk managers to consider when determining direction for preparedness support efforts.

Business Continuity Education

Life safety is traditionally emphasized in business preparedness planning, and rightfully so as ensuring employee and customer safety is always the first priority in an emergency. However, this type of preparedness is typically insufficient to protect businesses' operational capabilities. To address this challenge, North Shore risk managers should focus on communicating business continuity-oriented preparedness information. In particular, preparedness measures that address lifeline outage should be highlighted, as both previous studies and findings from the DNV model demonstrate that they are a significant source of disruption and loss for businesses.

Financial Contingency Planning

Public risk education efforts should also address the financial resource component of vulnerability. In British Columbia only one government program exists to make recovery funding available to affected businesses following declared disasters, and program requirements narrow the pool of eligible businesses considerably. Survey results indicate the high level of interest among North Shore businesses in government funding sources, highlighting the importance of sufficient public education around government assistance funding so that businesses are aware of the limitations and eligibility requirements and can make appropriate financial contingency plans.

Another important aspect of post-disaster financial resources is insurance coverage. A survey of small businesses following the 1994 Northridge Earthquake indicated confusion surrounding insurance coverage was a significant barrier to recovery, with many owners assuming they had much greater coverage than they had in actuality (Alesch & Holly, 1998). Given the contrast between the relatively high percentage of NSPB respondents who believe they can weather closures of a week or more without serious financial loss and very low percentage (7%, n=3) of respondents who indicated they already had enough information regarding relevant insurance coverage options, it would be beneficial for North Shore risk managers to incorporate insurance-related education into their risk communication program.

7. Summary & Conclusions

Using a loss model that considers simultaneous disruptions to DNV businesses in the form of building damage, lifeline outages and neighborhood damage following an M7.3 Georgia Strait earthquake event, this study estimates that the community could experience

potential GRP losses of between 33% and 88% on the first day following the disaster (depending of the magnitude of lifeline outage and neighborhood effects). Lifeline outage is demonstrated to be a more significant source of business disruption than building damage. The model also highlights areas of particular vulnerability from sector, spatial, and economic perspectives.

This research also investigates the risk perception and preparedness behavior landscape of the North Shore business community through an online survey. The survey indicates a generally poor level of disaster preparedness among respondents. However, respondents demonstrate some receptiveness to risk assessment information, and there are indications that better education of the business community on relevant preparedness measures would lead to increased adoption of preparedness behaviors.

7.1 Research Goal

One primary aim of this research is to support the development of effective public risk reduction strategies, sharing the view that loss estimation should not be conceived as a "passive pursuit, but one with the major objective of actively reducing negative impacts either through mitigation or post-disaster private decisions and public policies" (Rose, 2004b, p. 31).This paper demonstrates several ways study findings can inform community-level risk policies. In particular, this study suggests the use of findings to inform public land use and planning decision making processes, and to target the most vulnerable business populations for risk management and preparedness support efforts (especially small businesses). These findings can be integrated into a larger Business and Employer Emergency Preparedness (BEEP) project currently underway on the North Shore.

Ultimately, study findings highlight both risks and opportunities for reducing them within the North Shore business community.

7.2 Future Research Opportunities

The other primary goal of this study is to support future research into hazard risk and reduction opportunities on the North Shore. Findings and limitations of the current study suggest a number of areas for future inquiry that would make valuable contributions to both the body of natural hazard risk research and the practice of managing risks on the North Shore. Briefly, these include improvements to both the model (e.g. incorporation of: modeled lifeline damage data, scenarios representing mitigation measures, various levels of economic production, transportation network impacts) and the survey (e.g. acquiring a representative sample population, consideration of potential mitigation measures, better capturing of decision stages, longitudinal benchmarking to capture preparedness level changes over time and monitor the impacts of public education initiatives). Pursuing such avenues in the future would produce more robust modeling and survey results to better inform public risk management efforts.

7.3 Conclusion

As natural disasters are expected to continue to increase in frequency, the importance of fostering more resilient urban systems cannot be overstated. This study sought to contribute to resiliency-building in the North Vancouver context in by examining the potential vulnerability of the North Vancouver business community to earthquake hazards and suggesting several potential measures for addressing identified vulnerabilities, seeking to explicitly connect research to practice. This paper briefly summarized patterns of vulnerability identified by model and survey findings and offered several

recommendations for addressing them from a public risk management perspective. Along with the future research opportunities highlighted in this section, this research also illustrates how study outputs can contribute directly to public decision making. This approach offers a way to not only improve the value of future risk studies to communities but also enable communities to better contribute to future study efforts by developing deliberate, iterative connections between risk research and management.

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