

**Businesses and the Canterbury earthquakes:
how do their experiences translate to other
contexts?**

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**ECONOMICS *of*
RESILIENT
INFRASTRUCTURE**

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EXECUTIVE SUMMARY

This report describes the results of 14 case studies carried out with organisations in Christchurch and Auckland to further inform and refine the Business Behaviours Module of MERIT. The Business Behaviours Module has been developed based on extensive statistical analysis of the responses of 541 Canterbury organisations to a 2013 survey on their experiences following the 2010/11 Canterbury earthquakes. We needed to test the applicability of the Business Behaviours Module to other types of disruption and to other urban locations. To do this we undertook a series of paired case studies, in two study regions, Canterbury and Auckland. Seven organisations that completed the Economics of Resilient Infrastructure (ERI) Canterbury business behaviours survey were initially recruited. Selection was based on their reported levels of disruption and to get representation from a variety of sectors, size and type of organisations. For each Canterbury case study a corresponding 'pair' organisation in Auckland was selected, with similar demographic features. A semi structured interview was carried out with the organisations exploring their responses to a number of actual and hypothetical infrastructure disruption scenarios.

Overall, the case studies revealed few geographic differences in how organisations in Christchurch and Auckland respond to disruption. Sector had far greater significance in predicting likely response to a disruption than location. With only a few exceptions, once an initial understanding of the business had been developed, the interviewer could have answered 80% of the remaining questions accurately. This supports the idea that the Business Behaviours Module developed from the Christchurch earthquake data is transferable to other urban contexts. However, the survey and case study data are based on large urban environments and further research is needed to ensure these findings are applicable within smaller communities with a greater rural interface.

The case studies revealed areas where the Business Behaviours Module needs to change. For example, there is a need to adjust the relationships for very short-term infrastructure disruptions; in these cases the business behaviours model predicts better performance than reality in the short term, followed by a slow recovery back to full operability. In reality, short-term disruptions (e.g., a 36 hour electricity outage) creates a more pronounced impact on organisations during the period of disruption, but they are then able to recover back to full operability almost immediately after infrastructure services resume. To account for this we will adjust the Business Behaviours Module to differentiate between short-term and longer-term disruptions, with a step function included for very-short term disruptions. Another change needed is to adjust the operability curves so that once an organisation has achieved close to full operability, then full operability is assumed. Otherwise the asymptotic nature of the operability curves means that an organisation approaches, but never returns to full operability.

Through the case studies we also identified a number of subtleties around how organisations responded to the Christchurch business behaviours survey. We will now use these insights to stress test the Business Behaviours Module relationships. For example, we would like to recheck the model for the influence of relocation and temporary closure on reported levels of disruption due to water, sewage and electricity outages. We will also review the weightings of disruption levels in the calculation of experienced disruption, in particular the weighting of 'slight'. We also need to review the water infrastructure relationships for sectors not critically

dependent on water, such as transportation, postal and warehousing, professional services, wholesale trade, information, media and telecommunications, and financial and insurance services.

Taking our case study organisations through a variety of different scenarios also revealed interesting differences in how the effects of different types of infrastructure disruption are ‘felt’ by businesses. For example, disruption to port services is experienced predominantly as an increased cost of doing business, rather than as an inhibitor to an organisation’s ability to operate. As such, a better place to model the effects of port disruptions may be in the Economic Module within MERIT rather than the Business Behaviours Module. The same may apply for road based freight transport, but the overall effect of road disruption (which goes beyond just freight movements to include the inability of staff and customers to travel) needs further exploration.

The case studies also revealed a number of potential business behaviour ‘levers’ to include within MERIT. For example, our case studies emphasised the importance of the Earthquake Support Subsidy to the Canterbury recovery. The provision (or not) of government support for businesses during recovery will be an important lever to include in future versions of MERIT. There is also potential to include an on/off variable for availability of mitigation measures for particular types of infrastructure: that is if mitigation is in place, there would be no disruption to operability.

The case studies support the case for including the potential for sustained productivity improvements following disaster events within MERIT, but there is a need to better understand the extent (percent) and nature (production recipe, restructuring, staff working hours) of these productivity gains before they can be incorporated.

The next step in refining the Business Behaviours Module is to carry out the further analysis suggested in this report and implement the recommended changes. Further testing and validation will then take place when a testing version of MERIT, incorporating the Business Behaviours Module, is available in early 2016.

KEYWORDS

Business behaviour, organisational resilience, infrastructure disruption, MERIT, Disaster Recovery

1.0 INTRODUCTION

This report describes the results of 14 case studies carried out with organisations in Christchurch and Auckland to further inform and refine the Business Behaviours Module of MERIT. The Business Behaviours Module has been developed from extensive statistical analysis of the responses of 541 Canterbury organisations to a 2013 survey on their experiences following the 2010/11 Canterbury earthquakes. The purpose of the case studies is to:

- Clarify respondent interpretations of the Canterbury survey responses.
- Provide a fuller picture of recovery for the case study organisations in order to compare statistically generated relationships with complex reality.
- Test the transferability of relationships developed using Canterbury earthquake data to other geographic and socio-economic contexts.
- Test the transferability of the findings to different infrastructure disruption events.

Section 2 of this report outlines the case study methodology. Section 3 details the clarification and expansion on responses to the Canterbury earthquake survey. Section 4 examines responses to the specific four disruption scenarios used in this study and compares those to predictions made with the Business Behaviours Module. Section 5 examines specific aspects of organisational recovery, identified during the survey analysis that required additional investigation.

About the ERI Project



The Economics of Resilient Infrastructure (ERI) is a four year research project (2012–2016) funded by the New Zealand government.

The project aims to develop a new model (known as MERIT) which will:

- Quantify the economic implications of vulnerabilities to infrastructure failure from both natural hazards and infrastructure-only events, and
- Explore alternative infrastructure-related mitigation, adaptation and recovery strategies.
- Enable a high resolution assessment across space and through time of the economic consequences of infrastructure failure, business response and recovery options.

MERIT consists of a suite of interlinked modules incorporating spatial features of a region and its infrastructure networks, economic activity, business behaviours, interdependencies, and policy options. These modules can be shocked using infrastructure disruption scenarios (e.g., volcanic eruption, significant single infrastructure outage) to understand the economic impacts of such disruptions.

These include: mitigation, reduced infrastructure service levels, supply chain disruptions, staffing changes, relocation and business closure. Section 6 reviews the greatest challenges noted by respondents for the hypothetical disruptions. Section 7 summarises the impacts of the case study analyses for the MERIT model. Section 8 suggests future improvements for the MERIT model.

2.0 METHODOLOGY

A series of paired case studies, in two study regions, Canterbury and Auckland, was carried out. Seven organisations that completed the ERI Canterbury business behaviours survey were selected to participate. These organisations were purposely selected to represent a range of sectors, business sizes and types (not-for-profit/for profit, renters or property owners), who all reported average levels of disruption. We also chose organisations that had a range of experiences post-earthquake including changes to staffing levels, changes to productivity, temporary closure and/or relocation, use of the Earthquake Support Subsidy, and supplier disruptions.

For each Canterbury case study a corresponding organisation in Auckland with similar demographic features was selected. Auckland organisations were identified through an internet search. Table 1 outlines the demographic characteristics of the case study organisations.

Table 1 Demographic characteristics of respondents.

Sector	CHCH	AKLD	CHCH	AKLD	CHCH	AKLD
	No of employees		Age (years)		Ownership	
Hospitality	15	60	7	1	LLC	LLC
Retail	8.5	7	25	18	LLC	LLC
Manufacturing	12	5	40	5	LLC	LLC
Logistics	52.5	24.5	23	32	LLC	LLC
Construction	7	23	18	18	LLC	LLC
Healthcare	525	480	112	6	Charity	Charity
Professional Services	11.5	8	90	1.5	Partnership	Partnership
LLC – Limited liability company						

A semi structured interview was carried out with the organisations exploring their responses to a number of actual and hypothetical infrastructure disruption scenarios. Table 2 shows the topics covered for each region and the full interview guide is included as Appendix 1 (Christchurch) and Appendix 2 (Auckland).

The scenarios used for these interviews were developed by the authors based on the scenarios being developed by GNS Science for the ERI project. Full details of the scenarios can be found in Buxton, Wright, Daly, Timar & Mieler (2014), Deligne et al., (2015) and Robinson, Buxton, Wilson, Cousins & Christophersen (2015). We simplified the scenarios by removing some spatial and temporal details to make them easier to explain to the case study organisations. The simplified scenarios are included in Sections 4–8.

Table 2 Interview scenarios and questions.

Scenario	Scenario Type	Christchurch Case Study Organisations	Auckland Case Study Organisations
Canterbury earthquakes	Actual	Discussion of their survey responses and clarification of their experiences following the Canterbury earthquakes	N/A
Electricity outage	Hypothetical	Anticipated responses to a 24 hour rolling power outage including impact on operability, role of mitigation and biggest challenges.	
Water disruption	Hypothetical	Anticipated responses to a 6 week water disruption including impact on operability, role of mitigation, staff impacts and biggest challenges.	
Port disruption	Hypothetical	Anticipated responses to a 6 month disruption to their local port including impact on operability, supplier disruption and biggest challenges.	
Natural Disaster	Hypothetical	Anticipated responses to an Alpine Fault earthquake including impacts on operability and staffing, demand changes, biggest helps and challenges.	Anticipated responses to an eruption in the Auckland Volcanic Field including impacts on operability and staffing, demand changes, biggest helps and challenges and effects of evacuation.
General		General questions about business decision making as well as infrastructure dependence.	

Interviews with Canterbury organisations were carried out in person: lasting from 50 to 100 minutes. Five interviews with Auckland organisations were carried out in person and two by telephone. These interviews lasted from 35 to 60 minutes. Interviews were recorded with the respondent's consent; audio recordings and notes made by the interviewer were used to capture the responses. All participating organisations were provided with a report summarising their responses and suggesting potential initiatives to improve their resilience. Organisations were also invited to give feedback to confirm the accuracy of the information they provided.

2.1 LIMITATIONS

The case study process has several limitations, which are important for the interpretation of the analysis and subsequent integration into the business behaviours module.

First, respondents were asked for probable responses to hypothetical situations and their actual responses, given the fuller facts of the actual event, may result in different choices. For example, responses were based on their relationships with current staff, current overall economic conditions and present personal aspirations, all of which may impact on their decision making at the time of an actual disruption.

Second, participating organisations in this study were all New Zealand owned rather than multinational entities. The researchers suspect that large and diverse companies may answer somewhat differently, particularly with regard to the major impact scenarios. However, the intent of the case studies was to represent average businesses in New Zealand of which small and medium enterprises represent the majority form (Statistics New Zealand, 2013). Resource constraints limited the number of case studies conducted but provided sufficient numbers to find any fundamental flaws in the model.

Third and similarly, while the case studies are intended to represent average businesses, this does not mean their behaviour will necessarily be 'average'. Businesses are complex human organisations. Even if we took two, outwardly identical businesses, it is possible they would respond differently to the same disruption. The Canterbury earthquake survey responses demonstrated this large variability in recovery from disruption, see Figure 1. Consequently, the intent of the case studies is to verify the model on a conceptual level: particularly the transferability of the module between contexts and disasters. The case studies are designed to identify recovery patterns and decision drivers to ensure they align with the underlying principles of the business behaviours module and the economic module within MERIT.

The analysis and findings, herein, takes this variability and complexity into account by primarily concentrating on the trends of the case study responses rather than the absolute responses. They provide an 'order of magnitude' check on the numerical analyses to ensure that the general form and magnitude of the model is correct.

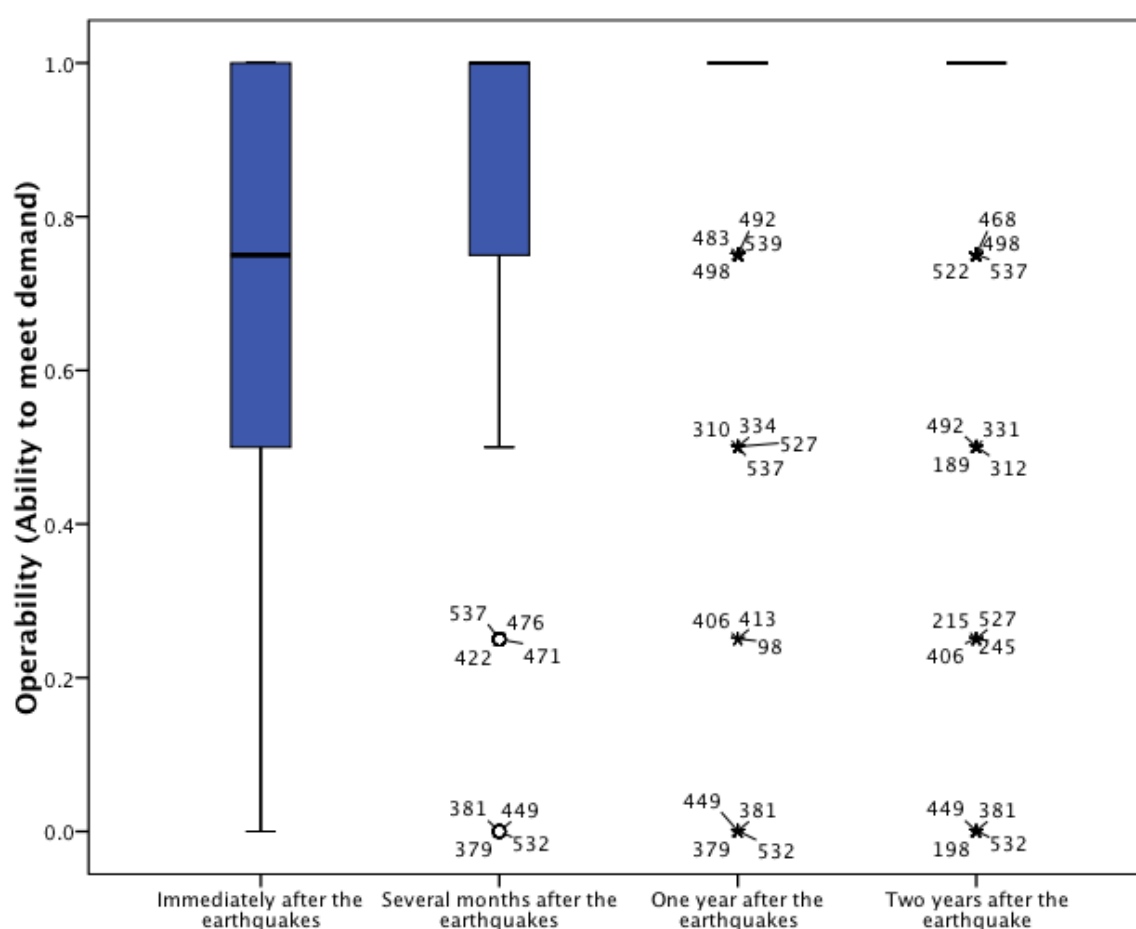


Figure 1 Reported operability following the Canterbury earthquakes (numbers indicate case numbers, retained to demonstrate the number of 'outliers').

3.0 CANTERBURY EARTHQUAKE RESPONSES

This section discusses responses from Christchurch case study organisations and seeks to clarify the interpretation of the 2013 survey responses. The aim of this section is to add further context to the survey answers and ensure that the data analysis and Business Behaviours Module fairly represents the recovery of organisations.

3.1 DISRUPTION INTERPRETATION

The case studies sought to clarify organisations' interpretations of disruption due to infrastructure and non-infrastructure impacts. For example, what does it mean to an organisation to be 'slightly disrupted': are they able to continue functioning and to what level? Disruptive is a term also used in other surveys assessing the impact of natural hazard disruption (Coomer et al., 2015) but is difficult to interpret given that it has both an emotional (how people feel in the circumstances) and a practical component of how it actually impacts on function. It is possible for something to be very disruptive (to feel bad), but to have little actual effect on operations. This distinction is important to make when using survey responses to inform an economic model that is based on actual output.

3.1.1 Infrastructure

The ERI survey asked organisations to report the impacts of infrastructure disruption by selecting 'not disrupted', 'slightly disrupted', 'moderately disrupted' or 'very disrupted' as illustrated in Figure 2. This was in addition to a question that asked 'for how long did your organisation experience disruptions to the following infrastructure services?

12c. With reference to the 22 February 2011 earthquake, how was your organisation disrupted by the loss of the following infrastructure services?

	Not disrupted	Slightly disrupted	Moderately disrupted	Very disrupted
Water supply	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Sewage	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Electricity	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Gas	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Phone networks (cell and landline)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Data networks	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Road network	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Rail	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Airport	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Port	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Fuel	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Figure 2 Infrastructure disruption question.

Interpretation of these questions varied notably. Generally, water, electricity and sewage were key issues for allowing an organisation to re-open, see Table 3. For those organisations that could not open without these infrastructure services (Manufacturing, Hospitality) or had to remain open but depended on the services (Healthcare), they noted the loss of the service as 'very disruptive'. For several organisations interviewed (Retail, Logistics, Landscaping) these services were reinstated before they were ready to resume work after dealing with

personal issues. In these cases the organisations generally noted they were ‘slightly’ or ‘not disrupted’. The one organisation that lost their building indicated that they were ‘not disrupted’ by loss of infrastructure. Therefore, when interpreting ‘not-disrupted’ responses it is possible that there are contextual issues, specific to the organisation, which may influence the responses (such as temporary closure and building damage). These should be accounted for where possible.

Impacts for MERIT

- Check the model for the influence of relocation and temporary closure on level of reported disruption due to water, sewage and electricity, outages.

Table 3 Infrastructure disruption responses and explanation.

Sector	Closure duration (Survey)	Survey – electricity disruption	Survey – water disruption	Context
Manufacturing	14 days	Moderately	Very	Re-opened once electricity and water restored – no urgency to re-open due to demand drop
Retail	Less than 1 day	Slightly	Not	Re-opened February 23 after clean-up, electricity and water restored February 22
Healthcare	Did not close	Very	Very	Unable to close – generator for electricity, water tanks obtained within 24 hours
Professional Services	Closed Permanently in survey answer	Not answered	Not answered	Lost premises, did not record answers for infrastructure disruptions as these were not relevant once premises lost
Logistics	Closed 2 days	Not	Not	Electricity and water restored February 22, Management Team on site February 23 to prepare action plan. Closure about giving staff opportunity to be with family
Landscaping	Closed for 15 days	Not	Not	Work seemed unimportant in the circumstances
Hospitality	3–5 days	Very	Very	Re-opened once owner was ready and electricity and water available

For other infrastructure categories, respondents in some instances appear to have answered with reference to the status of these services, rather than their actual impact on operations. For example, hospitality noted data networks, roads, rail, airport and port as ‘moderately disruptive’ despite these having no direct impact on their operations. Organisations appeared to use differing criteria in relation to each category of infrastructure. For example, very disruptive has been used by organisations in reference to short-lived total loss of electricity and long-lived disruptions such as road damage causing traffic delays and uncertainty over route choices.

Also apparent in organisations' descriptions was the overall sense of anxiety and uncertainty over the provision of all services previously taken for granted. This sense of anxiety was particularly heightened given the ongoing and severe aftershocks (and some aftershocks being more damaging than their predecessors). The complete upheaval caused by the earthquakes brought into question all assumptions. For example, although the airport was functional, organisations could or did not assume that this would necessarily continue. This is also reflected in responses regarding phones and roads. Phone services, particularly cell services, were overloaded due to both damage to some equipment and extremely high demand. While phone services were perceived to be unreliable, this created a degree of anxiety and difficulty in taking the steps needed to assess the situation and resume operations. Similarly, the widespread damage to roads created uncertainty with a perception of every journey over previously familiar routes being potentially challenging. Although ultimately both phones and roads were useable, their unreliability created significant uncertainty that reflected in survey responses of moderately or very disruptive for some organisations. Scenario development within MERIT includes consideration of different levels of service. Future development should also include consideration of user confidence in the service as this will impact on business decisions.

3.1.2 Non Infrastructure

The ERI survey asked organisations to report the impacts of non-infrastructure disruptions in the first three months by selecting 'not applicable', 'not disrupted', 'slightly disrupted', 'moderately disrupted' or 'very disrupted'. These impacts have been grouped into damage to premises (e.g., building, inventory, equipment damage), damage to neighbourhood (e.g., damage to adjacent buildings, damage to pavements, access difficulties), and effects on staff (e.g., emotional well-being, availability, health and safety issues). Table 4 illustrates the survey responses for damage to premises.

Table 4 Non Infrastructure damage – premises summary.

Premises						
Q.s	Structural Damage	Non Structural	Machinery	Office equipment	Difficulty accessing IT	Inventory/ stock
Manufacturing	Moderately	Slightly	Slightly	Slightly	Slightly	Moderately
Retail	Very	Slightly	Moderately	Moderately	Moderately	Moderately
Healthcare	Very	Very	n/a	n/a	Not	Not
Professional Services	Very	-	Very	Very	Very	Very
Logistics	Slightly	Slightly	Slightly	Slightly	Not	Slightly
Landscaping	Not	Not	Not	Slightly	Not	Not
Hospitality	Very	Moderately	Moderately	Slightly	Not	Slightly

The interpretations of each category are consistent with the level of reported damage and resulting disruption reported by the organisations in their detailed stories. 'Slight' and 'moderate' have been used to indicate minor repairs with little function lost, and 'very' to indicate a total loss. Structural damage was the key driver within the category. For retail, initial assessments after the event were of only 'slight' to 'moderate' damage, congruent with their 'slight' and 'moderate' internal damage. However, not noted in their survey response is a structural assessment 15 months after the event which led to closure due to structural

faults; indicating that some significant longer term disruptions that affected businesses were not captured in the survey. Hospitality had multiple venues, some inaccessible within the CBD cordon. They have indicated 'very' to reflect the closure of these venues, but have answered 'moderately' and 'slightly' to some questions in relation to their venues that were able to re-open.

The MERIT model is currently based on an initial event and the consequent economic impacts over the following three months. As observed following the Canterbury earthquakes, disruptions following large scale events (such as damage assessments, regulation changes, market changes etc.) can affect organisations over a much longer term. Increased economic activity can also eventuate from recovery efforts. A valuable improvement for MERIT would be to include a reconstruction module for large scale events which can model these longer term impacts.

Impacts for MERIT

- Test the sensitivity of the Business Behaviours Module to different weighting of 'slight' disruption to confirm current interpretation is appropriate.

Future Improvements

- Develop a reconstruction module for use in MERIT to reflect the economic stimuli of repair and rebuilding programmes.

Table 5 summarises the survey responses in relation to damage to the neighbourhood.

Table 5 Non Infrastructure damage – neighbourhood summary.

Neighbourhood				
Q.s	Ground surface	Adjacent buildings	Local neighbourhood	Access to premises
Manufacturing	Not	Not	Very	Not
Retail	Moderately	Very	Slightly	Slightly
Healthcare	Slightly	Very	Not	Slightly
Professional Services	-	-	-	Very
Logistics	Slightly	Not	Not	Slightly
Landscaping	Not	Not	Not	Not
Hospitality	Slightly	Very	Slightly	Very

Responses here are a little less consistent. Manufacturing referred to being something of an island of unaffected land surrounded by extensive liquefaction; however this did not impact on their ability to access their premises. Their response of 'very' appears to indicate that the local area was extensively damaged, rather than this actually impacting directly on their operation. For both retail and hospitality, their 'very' for adjacent buildings refers to the impact nearby closures had on customer numbers or foot traffic in their vicinities.

Table 6 summarises the survey responses in relation to staff impacts.

Table 6 Non Infrastructure damage – staff impacts.

Staff Impacts					
Q.s	Health & Safety	Availability	Perception of building	Emotional	Total Score
Manufacturing	Moderately	Not	Very	Moderately	7
Retail	Not	Slightly	Moderately	Slightly	4
Healthcare	Moderately	Moderately	Very	Moderately	9
Professional Services	Very	Very	-	Moderately	8
Logistics	Slightly	Slightly	Slightly	Slightly	4
Landscaping	Not	Not	Not	Not	0
Hospitality	Slightly	Slightly	Slightly	Moderately	5

Responses are reasonably consistent with the higher ranking of these impacts by the professional services firm reflecting that the respondent was injured in the February 22 event. 'Very', has been used by manufacturing and healthcare, and 'moderately' by retail for their perceptions of building safety reflecting that these organisations occupied buildings that were later deemed to be in need of structural repair. Responses for emotional wellbeing reflect the organisations stories with regard to the need to support, nurture and care for staff as well as some lost time for those unable to function after large aftershocks. The aggregated total of these responses for each organisation are consistent with the long term recovery trajectories. Healthcare, with the highest overall reported disruption from staff impacts, has the largest workforce and has been coping with temporary relocations and disruptions whilst a repair program is under way. Professional services, who rank second for staff impacts were city centre occupiers with the related emotional trauma. Third ranked manufacturing occupies a building that has not been inspected and is thought to have possible structural damage.

3.1.3 Non Infrastructure – Customer Issues

Customer issues are not included in the business behaviour module but rather are accounted for in the supply – demand relationships in the CGE economic module. Customer issues were rated as one of the highest impacts by four of the case study organisations with increases in demand relevant for Professional Services and Healthcare and decreases important for Construction and Manufacturing.

3.2 CHRISTCHURCH EARTHQUAKE MITIGATION

In the ERI survey, respondents indicated the importance of backup/alternatives to water, sewage, electricity and communications on a scale of 'not important', 'slightly important', 'moderately important', and 'very important'. Each organisation's response and their interpretation of the question are shown in Table 7.

Table 7 Importance of backups to water, sewage, electricity and communications following the Canterbury earthquakes.

Sector	Survey Response	Interpretation
Retail	Slightly	No mitigation in place
Professional Services	Not answered	No mitigation in place
Healthcare	Moderately	Respondent stated should have been 'Very' due to it allowing continued function
Logistics	Very	Did not use but realised importance of
Manufacturing	Moderately	Refers to the provision of tanked water and portable toilets by Christchurch City Council
Construction (Landscaping)	Not	Had none and did not need
Hospitality	Very	Refers to water from rural well

Respondents answered the same question in relation to backups/alternatives to IT and these responses and interpretations are shown in Table 8.

Table 8 Mitigation/alternatives for IT disruption following the Canterbury earthquakes.

Sector	Survey Response	Interpretation
Retail	Moderately	Did lose IT function and backup was not totally adequate
Professional Services	Slightly	Lost IT function and had no backup, retrieval of individual hard drives from damaged building to restore
Healthcare	Very	Did not have to use but recognised near miss in that backups were not adequate in current form
Logistics	Very	Did not lose any IT function but realised importance of backup
Manufacturing	Slightly	Did not lose any IT function but realised importance of backup
Construction (Landscaping)	Not	Did not lose any IT function – did have a backup
Hospitality	Moderately	Did not lose any IT function – efficacy of backup system questionable

Here we see very different interpretations of this question with two organisations rating the importance of mitigation as 'very important' due to their new understanding of its importance, rather than its actual use post-earthquake. 'Slightly' and 'moderately' are used by organisations that both did and did not have to use any backup systems. Generally, the case studies have shown that the survey responses on the importance of mitigation may be inconsistent and, therefore, somewhat unreliable. This, alongside the level of damage relative to available mitigation measures, helps to explain why mitigation was not found during data analysis to have a significant impact on level of disruption felt by organisations.

3.3 INTERPRETATION OF OPERABILITY

Many Canterbury respondents discussed doing, or being able to do, everything. For example, from the retailer, “there was nothing that we could not provide”. However these same organisations indicated in the survey that their ability to meet demand was only 60–80% or ‘mostly’. Table 9 shows the survey responses to operability alongside the understanding of these gained from interviews.

Table 9 Operability Responses and explanation.

Sector	Survey Responses – Ability to Meet Demand		Case Study Explanation
	Immediately after the earthquakes	Several Months after the earthquakes	
Retail	Mostly	Completely	Fully open – able to provide all services
Professional Services	Completely	Completely	No premises, working from homes, still able to do anything urgently needed
Healthcare	Mostly	Mostly	Fully operational, unable to complete lower priority tasks
Logistics	Mostly	Completely	Some jobs unable to complete due to customer closure
Manufacturing	Mostly	Completely	Temporarily closed immediately after earthquake due to no customer demand
Construction (Landscaping)	Mostly	Completely	Temporarily closed immediately after earthquake due to no customer demand
Hospitality	Mostly	Completely	Closed for 3–4 days; once reopened was unable to keep up with demand initially

When interpreting these questions, respondents seem to have focused on the words, rather than the numbers. The case studies suggest that mostly should not be interpreted to mean 20% of demand was not met, but rather that organisations were not achieving ‘normal’ operations but were meeting the majority of demand. The difference in the way that an organisation and an economic model view ‘ability to meet demand’ is an unavoidable limitation of the current model.

Ultimately, the answers for immediately seem to reflect the challenges of operating in the initial uncertain environment with the ‘completely’ after several months reflecting either adaptation or rectification of initial problems.

3.4 PRODUCTIVITY CHANGES

The ERI survey (*ERI Results Bulletin 2015-K07-1*) found nearly 50% of organisations experienced a gain in productivity. A statistically significant correlation was found between sectors experiencing demand rises and those reporting productivity gains. Productivity gains were discussed with Canterbury organisations in order to add greater context to those findings.

3.4.1 Hospitality

During business as usual, productivity for hospitality is greatly influenced by the number of customers, i.e. by demand rather than efficiency. An empty café is still fully staffed and there is little those staff can do to be productive without customers. For our case study café, the loss of many hospitality venues across the region led to an enormous increase in the amount of custom in its two, and later only one, operational venue. Whilst this did require higher staffing levels, the level of custom resulted in staff being constantly busy rather than the prior lulls in trade that are usual. This organisation consequently reported a slight increase in productivity; however this was not expected to be sustained as new and re-opened outlets create a new equilibrium in the hospitality market.

3.4.2 Retail

The retail organisation reported productivity as slightly increased and related this to not only the impacts of the earthquake but also trends within their industry. The respondent explained productivity improvements as the effect of doing a better job with less people. Both the combination of an industry downturn, earthquake and insurance impacts on cash flow and profitability led to a renewed focus on creating a lean operation. This organisation has sustained their productivity improvements.

3.4.3 Logistics

Logistics also reported slightly increased productivity and state that this has been sustained. In their industry this relates to doing lots of small tasks more efficiently. The respondent related this to the shock of the earthquakes shaking the organisation out of complacency, creating a new mind-set of always looking for better ways to achieve tasks.

3.4.4 Healthcare

Healthcare reported a slight decrease in productivity in the survey. This was due to the ongoing impacts on their business of increased road travel times that reduced the number of home visits that could be achieved in a day. This decrease is still ongoing at the time of interview. However, they also note that other areas of the business have experienced ongoing productivity improvements, with space constraints encouraging a review and improvement in efficiency of administration procedures.

3.4.5 Professional Services

The slight increase in productivity reported by professional services has been sustained. However, little in the way of process or efficiency gains were mentioned by the respondent. This increase in productivity appears to be a result of working longer hours rather than more efficiently.

3.4.6 Construction

The slight increase reported by this respondent has been sustained. The respondent made one poor performing staff member redundant as a result of an initial demand drop following the earthquakes and explains that productivity improvements are a result of no longer having this employee “dragging the chain”.

3.4.7 Summary

The survey data analysis indicated the potential for sustained productivity improvements to occur following disaster events; the case studies do not disprove this. If this is the case, it would suggest that in MERIT some change in the production recipe for most sectors is needed following disaster events. Given the economic model outputs are highly sensitive to changes in productivity any change would need to be made with caution. There is a need to better understand the extent (percent) and nature (production recipe, restructuring, staff working hours) of these productivity gains before they could be integrated into the MERIT model.

Future Improvements

- Further investigate the case for including in MERIT sustained productivity adjustment following large scale disruptions

3.5 EARTHQUAKE SUPPORT SUBSIDY

The case studies sought to add further understanding of the role and effectiveness of the earthquake support subsidy (Fischer-Smith, 2013) . The Earthquake Support Subsidy (ESS) was utilised by 6 out of the 7 organisations – although only 5 indicated this in the survey. The healthcare organisation was not eligible for the subsidy.

Interviewees were asked to rank the ESS on a scale of importance from 1–10. Their responses are illustrated in Figure 3.

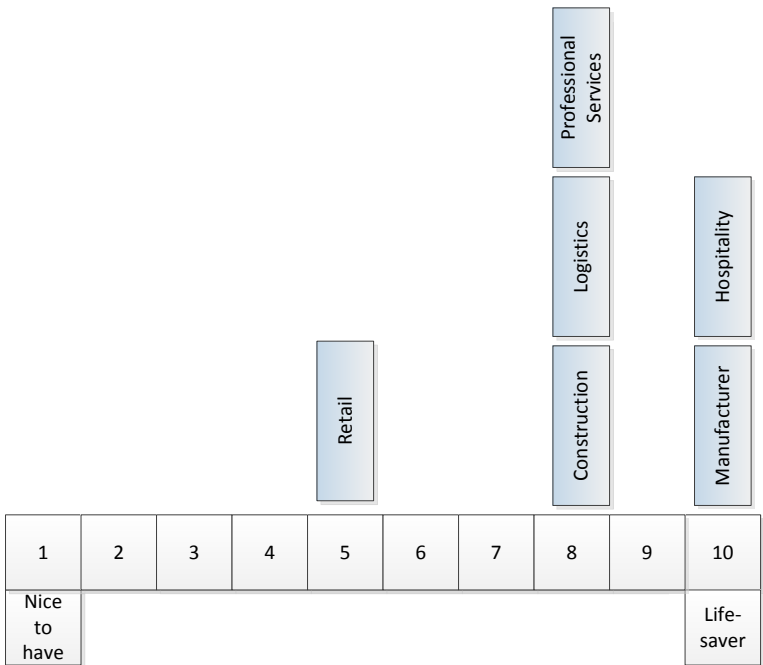


Figure 3 Importance of Earthquake Support Subsidy.

Overall, respondents were very grateful for the provision of this support. Hospitality stated that “they probably would have gone under” without this subsidy. Construction would probably have “laid-off staff”. The manufacturer “would have really struggled”. Both Professional Services and Retail expressed confidence that their businesses would have survived but with a greater need for bank funding. The logistics company believed the biggest benefit of the subsidy was the increased business confidence in the wider region, rather than the specific cash impact for the organisation. The provision of the subsidy gave this organisation greater confidence that debtors would resume operation and be able to meet their obligations. The need for organisations to clean up and restore operations, along with the need to communicate who was operating and from where, resulted in an effective freeze on inter-company payments. Multiple respondents indicated that this cash injection helped not only with their own cash-flow issues but with broader confidence with regard to the recovery of customers and suppliers.

While this is only a small sample of organisations, this indicates the high importance of the ESS and the likely impact it had on the recovery of Canterbury organisations. The Business Behaviours Module relationships have therefore been developed with the assumption of an ESS or similar business support scheme in place. Future analysis should endeavour to quantify the impacts of the ESS so that economic impacts with and without this assistance could be compared.

Impacts for MERIT

- The Business Behaviours Module relationships include embedded within them an assumption that an ESS or similar business support scheme is offered in the case of widespread disruption.

Future improvements

- Attempt to quantify the effects of the Earthquake Support Subsidy (or similar aid programmes) so that a Government Support ‘lever’ can be included in MERIT. This would allow economic effects to be modelled with and without business support being implemented.

4.0 BUSINESS BEHAVIOUR MODULE TRANSFERABILITY

To test the transferability of the Business Behaviours Module to other scenarios and urban contexts, case study organisations were asked to hypothesise their response to five different infrastructure disruption scenarios. This section describes their predicted responses and compares these to the business behaviours model; in particular the operability curve.

4.1 ELECTRICITY OUTAGE SCENARIO

All respondents were presented with the following scenario:

*There is a problem with the region's electricity network. Within two hours of the power cut you are notified that, in order for repairs to be carried out, your organisation's premises will be subject to **3-hourly rolling power outages for 24 hours**. Approximately 20% of the region is affected.*

Responses are summarised in Table 10.

Table 10 Electricity Outage Responses.

Sector	Location	Open or Close?	Approximate % of normal operation during outage	Mitigation	Greatest challenge
Retail	Auckland	Open	50%	Able to access generator within 2 hours	Eftpos access
	Christchurch	Open	50%	Natural light & manual systems	Operation of cash tills and computers
Professional Services	Auckland	Open – working from homes with office closed	70%	None	Ensuring staff have what they need to work from homes
	Christchurch	Open	50%	Natural light	Getting further behind
Healthcare	Auckland	Open	80%	None	Running scheduling system through Australian parent company
	Christchurch	Open	90%	Generator for some facilities	Administration staff functionality
Logistics	Auckland	Open	90%	Generator	No challenge
	Christchurch	Open	90%	Generator	Paperwork completion

Sector	Location	Open or Close?	Approximate % of normal operation during outage	Mitigation	Greatest challenge
Manufacturing	Auckland	Open	50%	None	Scheduling/organisation to use machinery during on period
	Christchurch	Close	5%	None	Recapture lost production
Construction (Landscaping)	Auckland	Open	80%	Generator	No challenge
	Christchurch	Open	90%	None	No challenge
Hospitality	Auckland	Open	80%	Gas for cooking and boiling	Manual system for communicating orders to kitchen, cash handling procedures with no tills
	Christchurch	Close	0%	None	Preserving perishable goods

Only 2 from the 14 businesses would temporarily close with the majority able to maintain at least 50% of normal operations. The businesses that would close are heavily reliant on electricity for operations and have no other power source. Once the electricity disruption has finished, all organisations indicated that they would return immediately to full operation.

The operability predicted by the case study organisations for this scenario was compared to the operability predicted using the business behaviours model. The results are graphed for each sector, for example see Figure 4 (see Appendix 3 for other sector graphs). All the graphs show that the existing model operability function does not represent this short disruption very accurately. The model predicts a recovery that has low initial impact but with a very slow recovery, whereas the case study results show an immediate, and for some sectors severe, short term impact but with no lasting affect after the disruption has ceased. As shown in Figure 4, even though the case study organisations experienced very different operability during the disruption, they both returned to full function immediately after power was restored (Day 2).

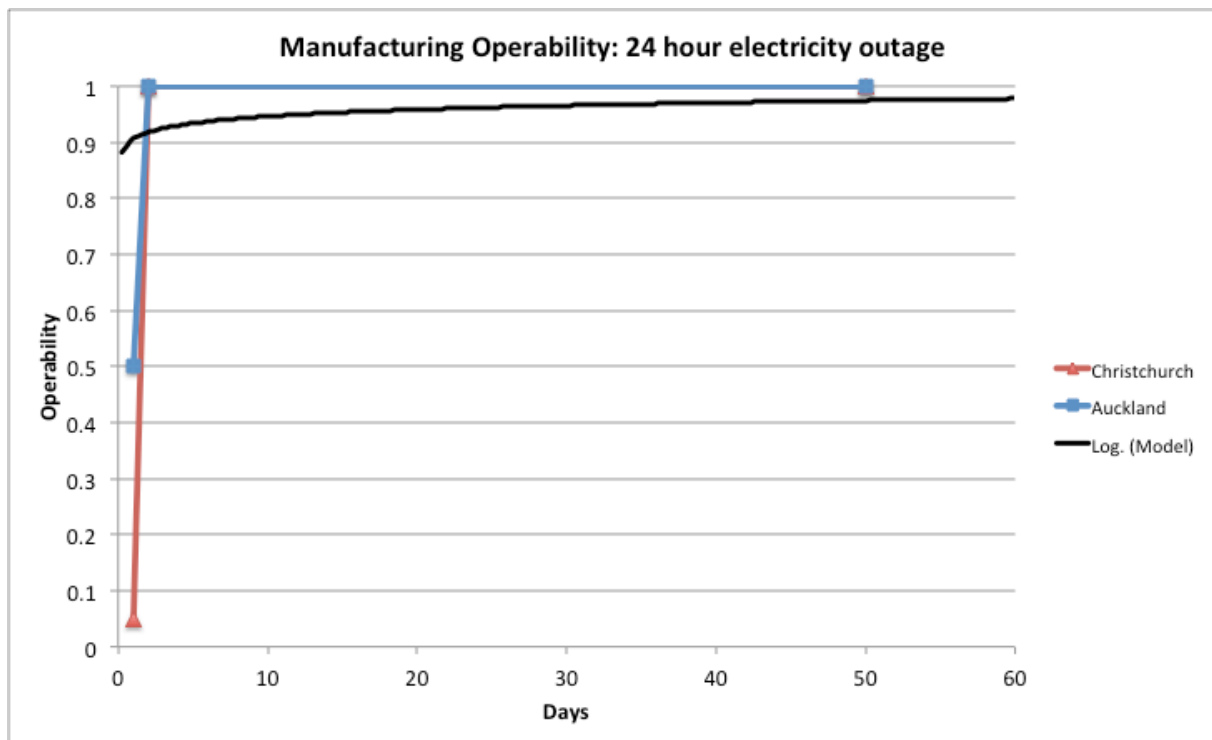


Figure 4 Electricity disruption: comparison of recovery predicted by case study organisations and business behaviour model.

These short terms disruptions would potentially be better described by a step function; where operability is affected during the disruption but not beyond. There is likely to be a threshold effect where disruptions cause long terms effects. Determination of this tipping point would be a valuable addition to the future development of MERIT.

As a first step in identifying a tipping point, organisations were asked how long they could function without electricity. The results shown in Table 11 indicate the point at which organisations have to consider adaptation to the disruption and possible ongoing challenges in operation. Further research into this is needed.

Table 11 Comparison of ability to function (electricity) and specific outage scenario.

Sector	Location	Ability to function without power
Retail	Auckland	Days
	Christchurch	Days
Professional Services	Auckland	Hours
	Christchurch	Days
Healthcare	Auckland	Weeks
	Christchurch	Weeks
Logistics	Auckland	Weeks
	Christchurch	Weeks
Manufacturing	Auckland	Hours
	Christchurch	Minutes
Construction (Landscaping)	Auckland	Days
	Christchurch	Days
Hospitality	Auckland	Days
	Christchurch	Minutes

Impacts for MERIT

- For very short-term, single infrastructure disruption scenarios, consider adjusting the operability curve function to a step function, with reduced operability (level is based on sector) for duration of outage, but full operability being restored immediately after services are restored.

Future improvements

- A threshold level for very short infrastructure disruption durations should be established to enable identification of outages that do not create ongoing operability issues.

4.2 WATER OUTAGE SCENARIO

All respondents were presented with the following scenario:

*There has been a significant disruption to the water supply to your organisation's premises. Within 6 hours of the damage to the water supply occurring you are notified that you will have **no water for 3 weeks**. **At 3 weeks** you receive full water service but the water is **non-potable** (requires boiling or treatment before consumption). After 5 weeks, your water is fully potable. The rest of the city is also affected. 30% of the city has no water for 3 weeks. It takes 6 weeks for potable water to be supplied to all areas again.*

Responses are summarised in Table 12.

Table 12 Water Outage Responses.

Sector	Location	Impact on demand	Ability to meet demand Day 1	Ability to meet demand Week 2	Mitigation	Greatest challenge
Retail	Auckland	-60%	Mostly	Limited	Stored water at home	Ensuring stored water lasts
	Christchurch	-33%	Mostly	Mostly	Water filtering equipment & access to well	Ensuring sufficient water supply to equipment
Professional Services	Auckland	No change	Partially	Completely	None	Getting access to sufficient water
	Christchurch	No change	Unable	Completely	None	Inconvenience
Healthcare	Auckland	No change	Mostly	Completely	None	Ensuring adequate care to vulnerable clients
	Christchurch	No change	Completely	Completely	Water Tank	Extra work
Logistics	Auckland	+2%*	Completely	Completely	Water Tanks	Assisting staff without water
	Christchurch	-50%*	Completely	Completely	No but easy access	Getting alternative supplies set up
	*Auckland assumed an increase in demand due to water tank and bottle cartage. Christchurch assumed a decrease in demand due to the closure of other businesses in the region.					
Manufacturing	Auckland	-35%	Mostly	Limited	None	Planning and coordinating site work
	Christchurch	-50%	Unable	Partially	None – assumption that council would provide	Access to water supplies

Sector	Location	Impact on demand	Ability to meet demand Day 1	Ability to meet demand Week 2	Mitigation	Greatest challenge
Construction (Landscaping)	Auckland	-50%	Limited	Limited	None	Cashflow
	Christchurch	-15%	Mostly	Mostly	None	Co-ordination of worksites
Hospitality	Auckland	-50%**	Mostly	Partially	None	Hygiene
	Christchurch	+50%**	Unable	Partially	Home well	Compliance rather than assistance focused approach of local authorities
	**Auckland assumed a drop in demand because they presumed customers would think they were closed. Christchurch assumed an increase in demand because people could not access food and drinks in their homes.					

Table 12 reflects the very different approaches to this scenario with significant differences in perceptions of demand impacts. In part, this reflects that the respondents seemed rather less prepared for this scenario than the electricity outage and were unsure of the flow on effects such as availability of toilets and health and safety requirements. Organisations either assumed an initial shut down, with operability rising as adaptation measures are put into place, or the inverse, with operations able to initially continue using existing supplies or performing tasks that do not require water, with a reduction in operability over time as a backlog of tasks requiring water accumulates.

Each organisation's response has been compared with the sector operability curves produced by the business behaviours model. For example, the graph comparing case study and model predictions for the retail sector is shown in Figure 5 (the remainder can be found in Appendix 3). This particular graph shows the varying predicted response of the two case study organisations: one predicts a more favourable, and the other a less favourable, recovery than the model. The responses are a reminder that the operability curves are intended to represent the 'average' organisational recovery trajectory. Within sectors there will be a wide range of responses and variability is expected.

No organisations anticipated disruption to their operations past the end of the disruption event. This is in line with observations of the electricity disruption scenario. In both these scenarios, the organisations anticipated few community or economy level disruptions that would have long term impact on their business: they assumed business as usual would return at the time of full reinstatement of services. Therefore, it is recommended that the water disruption scenario also be represented by a step function. As for the electricity step function, a reduced level of operability during the disruption will need to be defined.

Three of the sectors interviewed indicated limited or no disruption due to water outages: health care, professional services and transportation. . The health care providers interviewed for the case studies were primary care givers that rely on water for their essential services and also have to, unconditionally, met their patients' needs. They both had mitigation (or assumed mitigation) that would help them respond. These are a particular sub-sector of the health care and social services sector represented by this model. Therefore, it is not reasonable to adjust the model based on their responses alone. However, for professional services and transportation and warehouse services there may be a case to adjust the operability curve. These services have almost no need for water (apart from employee health

and safety) and could reasonably be expected to maintain close to full function. This should also potentially be extended to other non-water dependent sectors such as wholesale trade; information, media and telecommunications; and financial and insurance services.

To explore these effects further, we are undertaking further analysis on the dependence of particular sectors on different infrastructure types – see Giovinazzi et al. (2015). This analysis will reveal if a change in some sector operability curves is required.

Another potential model adjustment highlighted by this analysis is the need for the operability function to return to full operability or ‘one’ at some point. The current model is asymptotic – which means that although it approaches ‘one’ it never reaches ‘one’. A threshold needs to be included in the model, above which the organisation is assumed to have returned to full functionality.

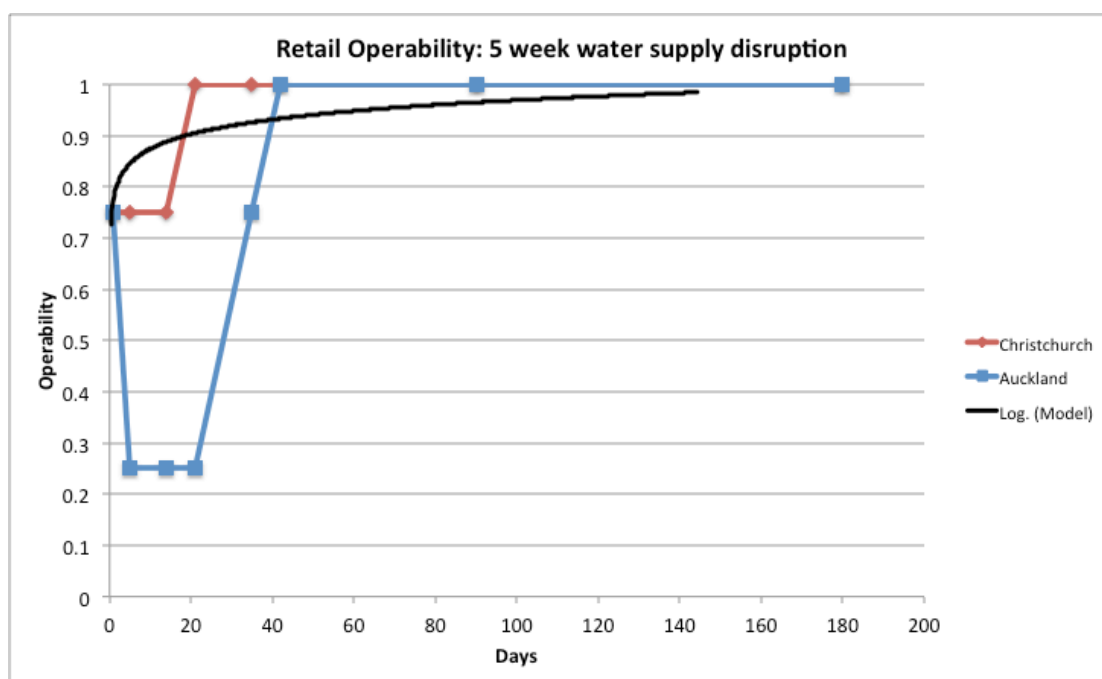


Figure 5 Water supply disruption: comparison of recovery predicted by case study organisations and business behaviour model

Impacts for MERIT

- A step function for the water scenario needs to be defined, including suitable reduced operability levels for the duration of the infrastructure disruption.
- Further explore the dependence of particular sectors on different infrastructure types to see if adjustments to the operability curves are required. Confirm with other analysis that these results are valid for water and check other sectors and infrastructure types using criticality paper.
- The operability model needs to include a threshold, beyond which organisations are assumed to have resumed to full operability. This threshold could be related to a particular value (e.g., >95% operability) or could be relative to the outage duration (e.g., >3x the outage duration).

4.3 PORT OUTAGE SCENARIO

Respondents were presented with the following scenario with Auckland or Lyttelton named as the relevant port:

*The regional port is inaccessible (both for incoming and outgoing goods) **for 6 months**. Fuel supplies are unaffected by the disruption. It takes 2 days for the Port Company to advise the likely duration of the disruption.*

Responses are summarised in Table 13.

Table 13 Port Outage Responses.

Sector	Location	Impact on demand?	Ability to meet demand – week one	Ability to meet demand – month one	Greatest challenge
Retail	Auckland	None	Completely	Completely	Ensuring supply
	Christchurch	None	Completely	Completely	No challenge
Professional Services	Auckland	Slight (5%) increase	Completely	Completely	No challenge
	Christchurch	None	Completely	Completely	No challenge
Healthcare	Auckland	None	Completely	Completely	No challenge
	Christchurch	None	Completely	Completely	No challenge
Logistics	Auckland	None	Partially	Completely	No challenge
	Christchurch	None	Completely	Completely	Cost and time of re-routing
Manufacturing	Auckland	None	Completely	Limited	Ensuring supply
	Christchurch	Slight (5%) decrease	Completely	Completely	Being organised enough to place orders to suppliers earlier
Construction (Landscaping)	Auckland	None	Completely	Completely	No challenge
	Christchurch	None	Completely	Completely	Unsure of supply chain ramifications
Hospitality	Auckland	None	Completely	Partially	Ensuring supply
	Christchurch	None	Completely	Completely	Ensuring supply

Canterbury businesses seem very confident that there is great substitutability within New Zealand's freight networks and the removal of any one node, such as a port, will be easily overcome. Only the logistics companies noted that there will be extra costs associated with additional road and/or rail transport from other ports. It is unclear whether other sectors are aware of potential cost implications. Consequently, most organisations indicated no impact on operability as a result of a port disruption.

Two of the Auckland organisations (manufacturing and hospitality) are less confident in the availability of alternate supply routes or suppliers and predicted their operability would lower after one month as a result of supply shortages.

The Business Behaviours Module for the port disruption scenario predict a much higher disruption than that assumed by case study organisations. Figure 6 illustrates the business behaviours model predictions for operability. Apart from the organisations that predicted longer term supply issues, a port disruption did not seem to affect the operability of any organisations. However, as noted, cost increases are likely due to changes in supply routes. As a result, in collaboration with the economic modellers on the project, it has been decided that the disruption to the port will be modelled based on increased working costs (of alternative supply routes) within the economic model. Future versions of MERIT would benefit from a more detailed analysis of the effects of supply route disruptions. Port outage and port disruptions will now be accounting for in the MERIT model purely through pricing mechanisms.

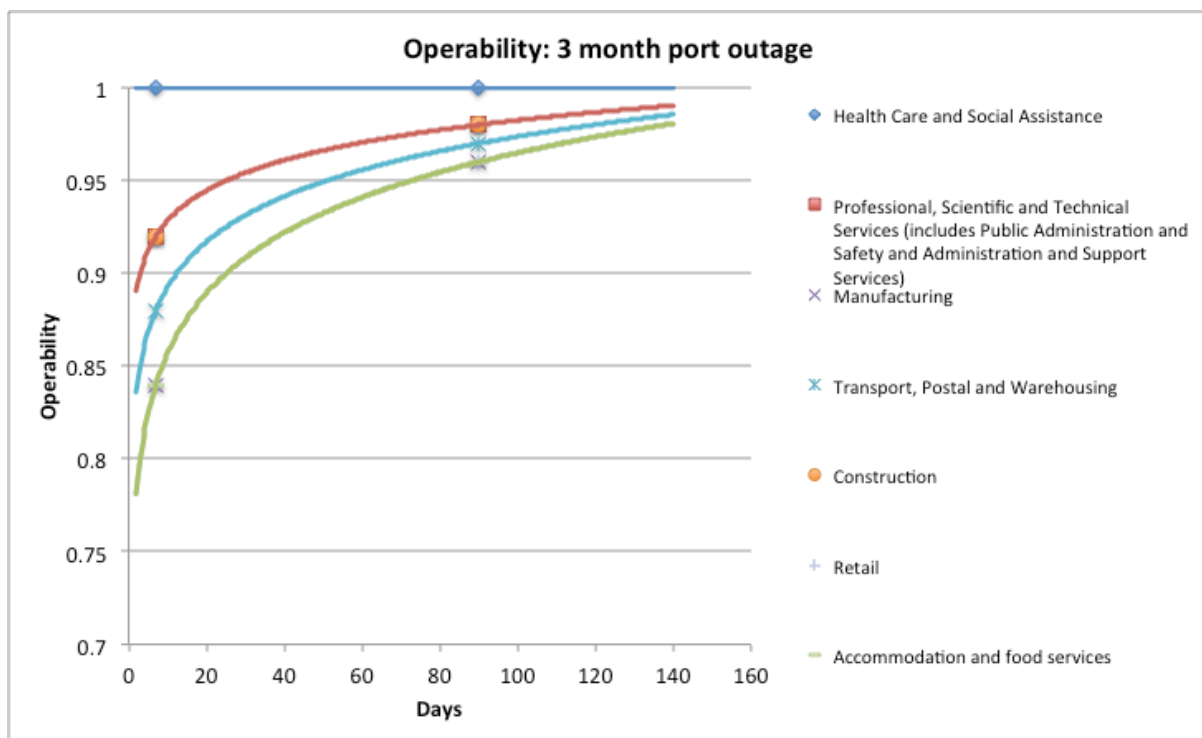


Figure 6 Business behaviours modelled operability following port outage.

Impacts for MERIT

- The effect of port disruption on businesses should be modelled within the economic module of MERIT as a cost increase, rather than a form of disruption.

Future improvements

- Future versions of MERIT would benefit from more in depth analysis and modelling of supply chains.

4.4 ALPINE FAULT EARTHQUAKE SCENARIO

Canterbury respondents were presented with the following scenario:

The Alpine Fault has ruptured generating a Magnitude 8 earthquake, causing a 400 km rupture running from Milford Sound to east of Greymouth. Shaking is felt in Canterbury, but there is only MINOR damage within the region. The majority of the effects are felt on the West Coast. (See Appendix 1 for full details of impacts displayed to respondents).

Responses are summarised in Table 14.

Table 14 Alpine Fault Scenario Responses.

Sector	Impact on demand	Ability to operate	Biggest challenge	Biggest help
Retail	Slight reduction -5%	Completely	State of Mind	Staff and customer loyalty
Professional Services	Slight increase +2%	Completely	Maintaining positive attitude, potential population flight	Positive thinking
Healthcare	Increase +20% over 6 months	Completely	Client visits a little longer and harder due to anxiety increase	Good communication with emergency response agencies
Logistics	No change	Completely	Getting through the emotional impact	Organised CDEM response, quick road fixes
Manufacturing	Slight reduction	Partly for initial month rising to mostly at 2 months and completely at 5 months	Financial survival and emotional impact	Government assistance such as the Earthquake Support Subsidy
Construction	Reduction -25% over 6 months	Completely	Drop in demand	Accurate information to help confidence e.g., aftershock probabilities
Hospitality	Initial increase: +50% over 1st few weeks then dropping slightly before resuming normal around 6 months	Mostly, rising to completely at 1 month	Potential personal disruption	All working together

Although this scenario has little direct impact on Christchurch, both retail and construction expect an overall loss of psychological confidence to impact on demand for their discretionary products. Healthcare and professional services both expect an increase in demand. For professional services this represents direct West Coast clients. For healthcare,

this is due to a general overload on the medical system which is expected to result in greater needs for in-home care. With the exception of the construction sector respondent, all of the respondents were concerned about the ability of Cantabrians to rebound from the emotional impacts of another disaster if this were to occur in the near future.

Comparison of these organisations responses with modelled operability (see Appendix 3) shows a lesser expected impact than modelled and with a shorter duration. Almost all organisations indicated little or no drop in operability. The one exception was the manufacturing organisation. As a small owner operated business their response, in part, indicated their desire or motivation to operate rather than their ability, and given an expected lack of demand.

As a result, the operability function for the Alpine Fault needs to be modified. Given there are no (or only minor) infrastructure disruptions in this scenario, the model operability was primarily calculated based on the level of shaking expected (or MMI) and consequent non-infrastructure disruption. At MMI=5 the model predicts some non-infrastructure damages. However, the infrastructure impact team that prepared this scenario indicated that there would be limited damage. Therefore, it seems that the non-infrastructure damage function for earthquakes may need a lower bound. For example, for MMI<6 assume that there are no non-infrastructure damages. Given the non-infrastructure damage function is derived based on one event (the Canterbury earthquakes) future verification and calibration of the function is recommended.

Impacts for MERIT

- For the earthquake event non-infrastructure disruption function within the Business Behaviours module (which is calculated based on MMI), include a lower bound value below which no non-infrastructure damage is expected.

Future improvements

- Carry out further calibration of the non-infrastructure damage function for earthquake events.

4.5 AUCKLAND VOLCANIC FIELD ERUPTION SCENARIO

All of the Auckland respondents were presenting with the following scenario:

There has been a volcanic eruption in Auckland City. Mandatory evacuations commence on 8 March with Map One indicating the maximum extent of evacuations reached on 15 March. Evacuation areas reduce from 16 March to 1 May when a permanent exclusion zone (Map 3) is created. You can assume there was a warning and sufficient time to evacuate people prior to significant damage occurring (but not physical material such as documents, equipment, or stock). By 1 May – 8 weeks later, the volcanic activity has settled (see Appendix 1 for maps and full details of impacts displayed to respondents).

Responses are summarised in Table 15.

Table 15 Volcanic Eruption Scenario Response Summary.

Sector	Inside evacuation zone?	Impact on demand	Biggest challenge	Biggest help
Retail	Outside	-75% for initial 8 weeks slowly increasing to below pre event levels	Security (looting, crime, violence)	Martial law, extra police (military) to keep order
Professional Services	Outside	no change in level (change in type)	Emotional wellbeing	Good communication from support organisations e.g., CDEM, government
Healthcare	Inside	-90% Day One then to – 50% over the 2 months, gradually increasing but to below event levels	Communication with staff and clients, just knowing who stays and who goes	Structured internal planning, support from CDEM, MOH, and Australian parent company
Logistics	Inside Permanent Exclusion Zone	Increase – due to loss of competitors who are less prepared + extra demand to move goods to replace those destroyed in warehouses	Mental – keeping desire to keep going	Cooperation from insurance, availability of land to relocate
Manufacturing	Outside	-100% gradually increasing over months to 50% below pre event	Staff Willingness to work	Financial support to close temporarily
Construction	Outside	-100%	Cashflow	Financial support
Hospitality	Outside	-80% growing after 8 weeks to -20% for sustained period	Everything	People striving to get back and keep operating

Only one of the Auckland organisations (construction) believes their business would cease as a result of this event. The remainder of the organisations believe they are likely to continue operating in a reduced form. The ceased business believes that demand would cease entirely over a long period and consequently the business would go into recess before slowly re-starting as consumer confidence rebuilds. Figure 7 illustrates interviewee organisations' perceptions over time of their organisation's ability to operate. Most organisations show a progressive increase in operation over time; however, the healthcare provider indicated a more turbulent recovery. Their response was impacted by the size of their workforce and their perceived ability to scale back up staff resources as clients who evacuated the area return (estimated between 2–3 months after the event).

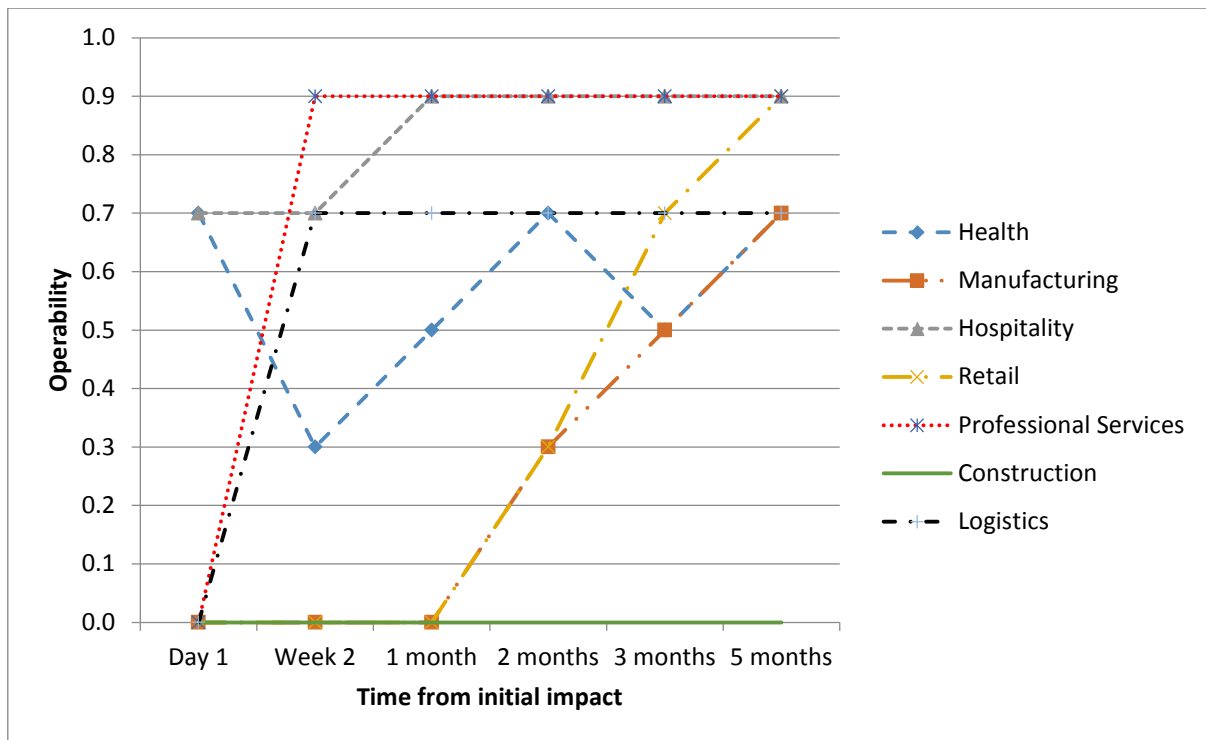


Figure 7 Auckland organisations ability to operate during and following Auckland volcanic eruption scenario.

All the organisations believe there would be significant impacts on demand. Professional services were the only sector where overall demand was predicted to remain unchanged: with distressed businesses taking the place of lost customers. The majority of organisations thought that demand would remain lowered for years following the event.

Two of the responding organisations would be forced to relocate. The healthcare provider envisaged a co-operative endeavour with other health support agencies: in the form of provision of temporary space for administrative staff during the evacuation period. Logistics, who are forced to relocate permanently, predict they will set up temporary premises wherever there is a site available.

Six of the organisations felt that this scenario would be very disruptive for staff availability, emotional wellbeing and perceptions of safety. Logistics felt that staff impacts would be moderately or slightly disruptive noting that staff members within the permanent exclusion zone would need additional support including accommodation.

Perceptions of supply chain impacts ranged from a belief that they would be incapable to completely capable. All sectors seemed confident that they would find a way to adapt to supply chain issues. Alternative suppliers and longer lead times were two specific measures that would be used.

Due to the extensive road disruption in this scenario and the lack of comparable data in the Christchurch earthquake data, Auckland respondents were asked what impact disruption to road freight travel would have on their business. The construction organisation was most sensitive to this issue suggesting they would cease operating when travel times doubled. Logistics and Manufacturing suggested they would cease operation at 5 x normal travel times. Their answers assumed that disruption was a temporary event over weeks or months rather than any kind of new normal situation. The remainder of the organisations were unconcerned about freight travel times. The results do indicate some sensitivity to freight

times, but the nature of this sensitivity is unclear. For MERIT it is recommended that freight travel impacts be reflected in the economic model through increased cost of working. Further research to identify the tipping point for when increased freight travel times become unmanageable would be a valuable addition for future versions of MERIT.

Auckland respondents were also asked how disruptive increased travel times for people (including both staff and customers) would be for the organisation. Figure 8 illustrates their tolerance for road disruption with 0 representing not disruptive, 1 being slightly disruptive, 2 being moderately disruptive, 3 being very disruptive.

For most sectors, organisations expect maximum disruption once travel times triple. For hospitality, maximum disruption is expected when travels times quadruple. This may reflect the predominantly local clientele drawn to each of their venues. Professional services perceive local roads to be more important than State Highways due to the location of the majority of their staff and clients.

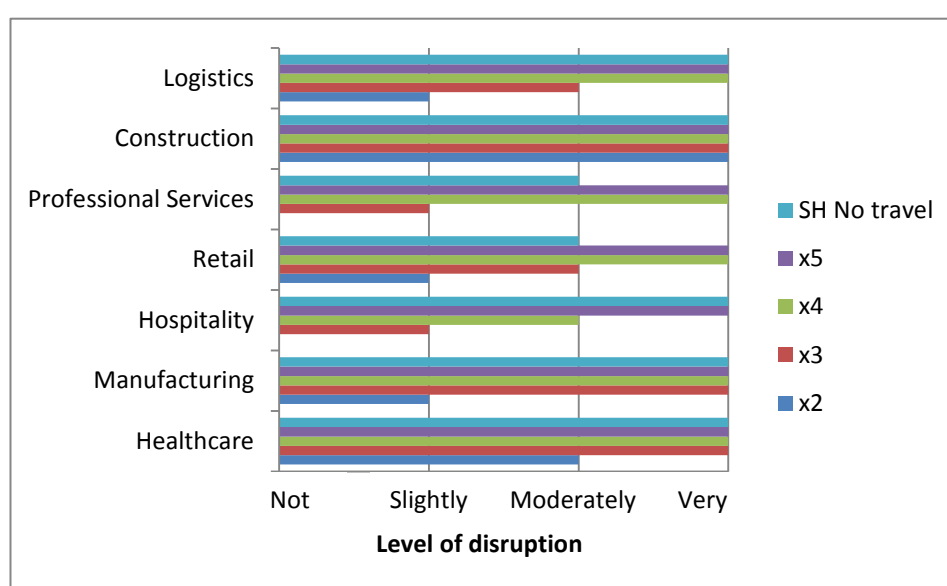


Figure 8 Auckland Disruption from extended road travel times (people).

Table 16 shows Auckland respondents' views of the impact of this scenario on their staff.

Table 16 Volcanic scenario staff Impact.

Sector	Impact on Staff Availability	Impact on Staff Emotional Wellbeing	Impact on staff perceptions of safety
Retail	Very Disruptive	Very disruptive	Very disruptive
Professional Services	Not Disruptive	Very disruptive	Very disruptive
Health	Very Disruptive	Very disruptive	Very disruptive
Logistics	Moderately Disruptive	Moderately disruptive	Slightly disruptive
Manufacturing	Very Disruptive	Very disruptive	Very disruptive
Construction	Very Disruptive	Very disruptive	Very disruptive
Hospitality	Very Disruptive	Very disruptive	Very disruptive

Respondents assessed staff availability by considering people evacuating the region and also their own need to make arrangements for their residences and families. None of the respondents expected large population flight (and therefore staff movement) and anticipated that they would be able to offer at least a limited level of operation within 2 months of the event. Four of the respondents indicated that the state of mind of both employees and the broader community would be one of the greatest challenges.

Before we can compare the organisations' responses to the model predicted operability, we need to develop a function for non-infrastructure disruption. During the initial development of the business behaviours model, non-infrastructure impacts (split into premises, neighbourhood and staff impacts) were determined using a measure of earthquake strength. Part of the purpose of the case studies was to develop a function to estimate non-infrastructure disruption. The function needs to relate to a measurable feature of the volcanic scenario to allow transferability to other volcanic events. Three key variables were considered and discussed with case study interviewees to develop this function:

- Location relative to volcanic cone and evacuation zone
- Increased travel time
- Depth of ashfall

In terms of the location relative to volcanic cone and evacuation zone, the organisations were split into five categories: permanent exclusion zone; within 3km from volcanic cone, temporary evacuation zone (>3km from volcanic cone), <10km from evacuation zone; and >10km from evacuation zone. 10km was chosen as a cut-off as this approximately represents the upper quartile commuting distance in Auckland (Statistics New Zealand, n.d.).

We have assessed the interview responses and scored their level of disruption to premises, neighbourhood and staff (see Table 17). The aim of the assessment is to identify if there are any patterns between disruption type and location relative to evacuation zone.

Table 17 Volcanic Eruption Scenario disruption relative to location (unless noted, as assessed by authors).

Sector	Inside evacuation zone?	Premises disruption	Neighbourhood disruption	Staff disruption (as assessed by interviewees)
Retail	<10km from evac zone	0.2	0.4	1
Professional Services	<10km from evac zone	0.2	0.2	0.66
Healthcare	Within 3km of volcanic cone (not permanent exclusion zone)	0.8	0.8	1
Logistics	Inside Permanent Exclusion Zone	1	1	0.55
Manufacturing	<10km from evac zone	0.2	0.4	1
Construction	>10km from evac zone	0	0.6	1
Hospitality	<10km from evac zone	0.2	0.4	1
0 is not disrupted, 1 is very disrupted				

The majority of building damage is expected in the permanent exclusion zone and within 3km of the volcanic cone. Neighbourhood damage is strongly linked to location (with disruption increasing with proximity to evacuation zone / exclusion zone). Staff disruption does not appear to be dependent on location at all. All sectors in all locations indicated there would be a high level of disruption to staff.

Based on the questions relating to disruption due to increased travel times for staff, there appears to be some sectoral trends in the level of disruption. However, based on such a limited number of organisations it is difficult to confidently identify trends that would predict this disruption by sector. The ashfall depth largely corresponds to the above defined locations: for this scenario (due to the wind direction) ashfall greater than 3km from the volcanic cone is expected to be <5mm and would cause only minor disruption. Organisations essentially did not consider these impacts or could not conceptualise the disruption that may be caused due to ashfall clean-up at their premises.

Given the limited, and solely hypothesised data available for this scenario, we propose using a simple disruption scenario based on location relative to exclusion zone. At this stage the function the function does not differentiate impacts by sector. The expected disruption values are shown in Table 18. Future development of this function will differentiate the disruptions by sector and using ashfall depth also.

Table 18 Proposed non-infrastructure disruption function values for volcanic scenario (based on location) for MERIT.

Location	Expected disruption to premises	Expected disruption to neighbourhood	Expected disruption to staff
>10km outside evacuation zone	0	0	1
<10km outside evacuation zone	0.2	0.2	1
Inside evacuation zone (greater than 3km from volcanic cone)	0.4	0.8	1
Within 3km of volcanic cone (outside permanent exclusion zone)	0.8	0.9	
Permanent exclusion zone	1	1	1

Using the newly developed non-infrastructure impact model, the organisations' responses were compared with the model predictions, see Figure 9. Compared to the other scenarios there is far more variability between the organisations' responses and the predicted disruption. For both food services and professional services organisations, the interviewees predicted better performance compared to the operability model. For all other sectors, the model over-estimated how well they performed. There does not appear to be any pattern between where the organisation is located and whether the model is conservative or not. Several reasons have been identified for the differences between the model and the predicted responses. Firstly, the non-infrastructure disruption function is based on limited data; and secondly the organisations' responses are based on a complex hypothesised scenario. It is unknown how accurate their predictions would be.

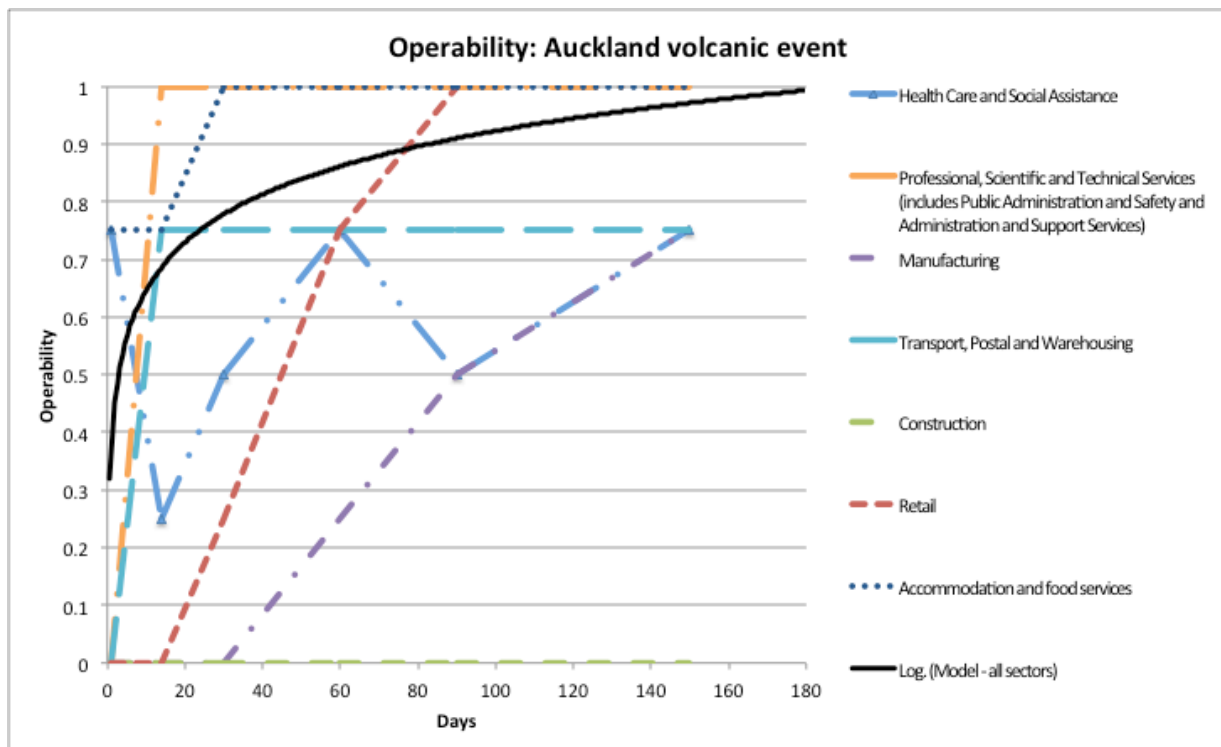


Figure 9 Auckland volcanic scenario: comparison of recovery predicted by case study organisations and business behaviour model.

Impacts for MERIT

- Consider removing road disruption from the infrastructure function for volcanic scenario (and possibly others).
- Model disruption due to freight through cost increases in the economic model.
- Update the volcanic non-infrastructure disruption function based on organisation location relative to volcanic cone and evacuation zone.

Future improvements

- Determine a tipping point for increased freight times and impacts on businesses (for all scenarios).
- Further refinement of the non-infrastructure disruption function including sector variation, ashfall depth and road travel time disruption.

4.6 TRANSFERABILITY OF CHRISTCHURCH DATA TO OTHER GEOGRAPHIC LOCATIONS

Overall, there appeared to be few geographic specific differences between the case study responses to the scenarios. Sector had far greater significance in predicting likely response to a disruption than location. With only a few exceptions, once an initial understanding of the business had been developed, the interviewer could have answered 80% of the remaining questions accurately. This supports the idea that the Business Behaviours Module developed from the Christchurch earthquake data is transferable to other contexts. However, note that the survey and case study data are based on large urban environments and further research may be needed to ensure that these findings are applicable within smaller communities with a greater rural interface.

Impacts for MERIT

- The case study findings and process supports the transferability of the module to other urban contexts

Future improvements

- Extend of the Business Behaviours Module to be applicable to rural contexts

5.0 OTHER GENERAL BUSINESS BEHAVIOURS RELEVANT TO MERIT

5.1 MITIGATION

An interesting finding from the initial business behaviour model development, and analysis of the Canterbury earthquakes data, was that mitigation to infrastructure disruption was not a significant predictor of level of disruption. As discussed in Section 3, the authors believe this may have been due to the scale of the Canterbury earthquakes and the inconsistencies in how organisations answered the question. The case studies sought to understand what mitigation measures respondents have in place and how effective these are expected to be, particularly for critical infrastructure disruption.

5.1.1 Electricity

Table 19 shows the mitigation measures in place for electricity outages.

Table 19 Mitigation in place for electricity outages.

Sector	Christchurch		Auckland	
	Type	Longevity/Coverage	Type	Longevity/Coverage
Retail	Natural light and manual sales systems	Short duration, local outage which does not affect Mall being able to open	Generator at home	Mid to long term duration (2 hours to retrieve and set up)
Professional Services	None (but with ability to work from different location)	Any duration, local outage	None (but with ability to work from different location)	Any duration, local outage
Healthcare	Generator	Indefinitely	None	Power only required by Admin
Logistics	Generator	Indefinitely	Generator and Gas	Indefinitely
Manufacturing	None		None	
Construction (Landscaping)	None		Generator at home	Power only required by Admin
Hospitality	None		Regard gas as partial mitigation	Short duration, any outage

Half the organisations interviewed reported not having mitigation in place. Many of those explained that they would proceed in a limited fashion with tasks not requiring electricity for as long as possible. Both the manufacturing and Christchurch hospitality respondents believe mitigation by way of a generator is unachievable given their high power requirements. The two professional service firms have the potential option of working from residential homes if the power outage is not widespread. Generally, for those that have mitigation measures in place, most believe they could function indefinitely without power. This indicates that electricity mitigation may be able to completely offset electricity disruptions and could be a valuable variable to include in MERIT.

5.1.2 Water

Only the Auckland logistics and retail and Christchurch healthcare organisations have any mitigation in place for a water outage. However, all organisations expressed their assumed ability to obtain bottled water and potentially portable toilets rapidly, either through their own efforts or through the assumed provision by local body authorities. The Christchurch logistics organisation who have a thorough business continuity plan suggested they will change this as a result of this interview.

The current business behaviours model is based on an event where water was provided by government. In the Christchurch earthquake, portable toilets and water tanks were rapidly deployed within the most impact areas. This should be noted as a limitation of the current model. Future development of MERIT may include a counter-factual case where no external aid is provided.

The data on use and effectiveness of mitigation gathered to date is not sufficient to add mitigation as a lever in the current MERIT model. However, a mitigation lever would be a beneficial future addition.

Impacts for MERIT

- Include an on/off variable for availability of mitigation measures: that is if mitigation is in place, there would be no disruption to operability.
- Note the limitation that disruption due to water service disruption is based on the availability of (limited) government supplied water.

Future improvements

- Develop a water disruption function that is based on no water aid from government authorities.

5.2 IMPACT OF REDUCED LEVELS OF SERVICE DISRUPTIONS

Infrastructure disruptions results both from total service loss as well as partial service loss (for example domestic airport services only or reduced water pressure). The original survey and infrastructure disruption functions did not distinguish between full and partial service. To better understand how organisations are disrupted by different levels of service (as compared to total loss of service), respondents were asked to consider the impacts of a rolling power outage, a boil water notice and different types of telecommunications services.

For the rolling power outage (where power was on for three, and off for three, hours), there was no significant change to organisation operability compared to total loss of the service.

For the boil water notice, that is the delivery of non-potable water, organisations were notably more disrupted by no water than non-potable water. Respondents were 'not' or only 'slightly' disrupted by a loss of potable supply compared to the majority of 'mostly' or 'very' disrupted by a total loss of supply. Respondent's main concerns were with water for hygiene and production needs, rather than drinking. This indicates that the current infrastructure disruption function, that is an on/off function, may need to be adjusted for water. The original survey questions used to create the water disruption function did not distinguish levels of

disruption; therefore it is difficult to know what kind of disruption organisations assumed when they responded. Creating a function sensitive to disruption levels is recommended for future MERIT improvement.

For telecommunications services, respondents were asked how long they could operate without any one of mobile phone, fixed line phones or the internet. Responses are summarised in Table 20. The majority of respondents referred to needing at least one or other of the phone services (fixed or mobile). Discussion indicated there was little concern over which phone service was available, provided there was at least one. The growing reliance on internet is evidenced in the high number of responses indicating operability for only minutes or days in the event of internet disruption.

The results do not show an obvious reliance on one service over the other, however, internet services are perhaps the most consistently important for organisations. Again, this is an area worth further investigation for future MERIT improvements.

Table 20 Ability to function without communications infrastructure.

Sector	Location	Mobile Phone	Fixed Line Phone	Internet
Retail	Auckland	Weeks	Weeks	Hours
	Christchurch	Weeks	Days	Days
Professional Services	Auckland	Weeks	Weeks	Hours
	Christchurch	Days	Days	Days
Healthcare	Auckland	Weeks	Weeks	Weeks
	Christchurch	Weeks	Weeks	Weeks
Logistics	Auckland	Weeks	Weeks	Weeks
	Christchurch	Days	Days	Minutes
Manufacturing	Auckland	Weeks	Weeks	Days
	Christchurch	Weeks	Days	Days
Construction (Landscaping)	Auckland	Hours	Weeks	Weeks
	Christchurch	Days	Weeks	Hours
Hospitality	Auckland	Weeks	Weeks	Weeks
	Christchurch	Weeks	Hours	Days

Impacts for MERIT

- The electricity disruption function does not need to be adjusted for rolling vs constant power outages.

Future improvements

- Improve the water disruption function so that it is sensitive to potable vs not-potable.
- Include functions for disruption to different kinds of telecommunications services and include for substitutability between these services.

5.3 SUPPLY CHAIN

Case study interviews sought to understand issues associated with disruptions to supply chains, including the reasons or triggers for changing suppliers and potential delays or other penalties from changing suppliers. Results are summarised in Table 21.

Overall, respondents had a high degree of confidence in the ease of which suppliers could be substituted and there appeared to be little loyalty if a supplier was unable to perform. The longest any organisation would wait to source alternative supply was one week with the majority of organisations taking action immediately it was known that a supplier was inoperable. The maximum expected time to be able to locate and agree terms with a new supplier was one week, with 9 organisations expecting this to occur within one day.

There was also a high degree of confidence in the logistics of moving supplies if there was loss of any one airport or port, except for a potential increase in cost of freight movements.

Table 21 Responses to supply chain disruptions.

Sector	Location	Main Supplier Location	Look for alternative supplier after:	Time to agree new supply
Retail	Auckland	Wholesalers – Auckland, Manufacturers – international	If advised 2 week closure would wait, if longer then immediate	Hours
	Christchurch	Wholesalers – Auckland, Manufacturers – International	Days	Days (parallel import)
Professional Services	Auckland	Christchurch	N/A – already have alternative	n/a
	Christchurch	Christchurch	N/A – Multiple suppliers for all	Immediately
Healthcare	Auckland	Rest of New Zealand	Immediately	Unsure
	Christchurch	Christchurch via Auckland head office	Straight away if told, 1–2 weeks if communication void	Within 1 week
Logistics	Auckland	Auckland	Immediately	Immediately
	Christchurch	International and Christchurch	Immediately	4 hours
Manufacturing	Auckland	Auckland, rest of New Zealand and International	Immediately	1 week
	Christchurch	Christchurch with Auckland branches	1 week	1 week
Construction (Landscaping)	Auckland	Auckland, Wellington	Immediately	Less than a day
	Christchurch	Christchurch	After 2nd time they cannot serve	Within 1 day
Hospitality	Auckland	Auckland	Immediately	Immediately
	Christchurch	2 x Auckland, remainder Christchurch	Immediately	1 week

Organisations in this study had a limited understanding of their supply chain: with the majority purchasing through wholesalers, rather than direct from producers. A greater understanding of the vulnerabilities of supply chains may be gained by focusing a future study on supply chain effects. One avenue could be focussing on the impacts of disruptions on wholesalers and their perceptions of downstream impacts. Additionally, given the importance of Auckland as a base for many wholesale and large corporate operations, more work is needed to understand the nationwide impacts of an Auckland disruption.

Impacts for MERIT

- Include a slight delay (3 days) into MERIT for whenever industries need to change suppliers.

Future improvements

- Carry out more in depth modelling of supply chains.

5.4 STAFFING DECISIONS

Organisations were asked on what basis staffing decisions were made in order to understand how far ahead workforce needs are determined. In order to assess the impact on business confidence following a given event, they were also asked if staffing levels would be likely to change as a result of the Port or Alpine fault/volcanic Event.

Table 22 summarises how organisations make staffing decisions, and the likelihood of changes in staffing levels from the scenarios. Unless otherwise stated, numbers refer to months.

Table 22 Staffing level decision making and scenario impacts.

Sector	Location	Increase Staff*	Decrease Staff*	Change staff – Port Outage	Change staff – EQ/Volcano
Retail	Auckland	Prior 6, Forecast 6	Prior 6, Forecast 6	No	No
	Christchurch	Prior 6	Prior 6	No	No
Professional Services	Auckland	Forecast 12	Forecast 12	No	Possibly
	Christchurch	Prior 12, Forecast 6	Prior 6, Forecast 6	No	No
Healthcare	Auckland	Prior 1 (+ manage by flexible contracts)	Prior 1 (+ manage by flexible contracts)	No	Utilise all flexible arrangements
	Christchurch	Prior 12, Forecast 1	Prior 12, Forecast 1	No	Possibly increase
Logistics	Auckland	Experience + Forecast 6	Experience + Forecast 6	No	Possibly but would try hard to retain
	Christchurch	Prior 12, Forecast 6	Prior 12, Forecast 6	No	No

Sector	Location	Increase Staff*	Decrease Staff*	Change staff – Port Outage	Change staff – EQ/Volcano
Manufacturing	Auckland	Forecast 3	Will not – too hard to replace	No	Yes – reduce
	Christchurch	Prior 6, Forecast 1	Prior 6	Possibly	Possibly
Construction (Landscaping)	Auckland	Prior 3 years, Forecast 6	Prior 3 years, Forecast 6	No	Yes – cease
	Christchurch	Forecast 6	Prior 6, Forecast 6	No	No
Hospitality	Auckland	Prior 1 week	Prior 1 week	No	Yes – reduce
	Christchurch	Forecast 1	Forecast 1	No	Possibly
* Times given in months unless noted otherwise					

Clearly, the volcanic scenario has the major impact on staff levels, with the Auckland manufacturer who stated that he would not reduce staff in normal times as good people are too hard to find, suggesting the volcanic scenario may force a reduction.

Hospitality are the most responsive to short term trends with decisions made based on either a week or a month of trading. The difference in approach for a family run business is evident with the Auckland retailer's staff levels remaining unchanged despite their expectation of an enormous drop in demand from the volcanic scenario. Many respondents in both Christchurch and Auckland discussed the difficulty of obtaining good staff as both an incentive to retain where possible, and a disincentive to attempting to increase.

Overall, decisions to change staffing levels are based on both prior and forecast trading. The extent of the assessment appears to be sector and business size specific, as well as dependent on the required skill level of the labour.

The case studies indicate that there is a level of 'stickiness' for staff – staff are not reduced or increased easily. The exception perhaps is in the hospitality industry where staff turnover is high and is significantly impacted by demand. Currently MERIT includes immediate substitutability of labour. We suggest adding a delay function for staff turnover. However, better quantitative data is needed to value this: a sector-specific and possibly business size labour decision factor that accounts for both the length of time that is considered and extent of change of demand over that period.

Impacts for MERIT

- As an initial model for staffing decisions, labour level changes within the economic model should be based on 6 months prior trading (and 6 months forecast) (if possible).

Future improvements

- Currently MERIT includes immediate substitutability of labour. A delay function may be needed for staff turnover with further analysis required using sector and organisation type data.

5.5 RELOCATION

Christchurch organisations were asked about actual relocation and Auckland about hypothetical triggers for relocation, factors affecting the relocation destination and the expected impact on the organisation.

5.5.1 Christchurch

Three of the organisations were forced to relocate their entire premises as a result of earthquake impacts. Decisions on relocation were driven by a severe lack of availability along with the character of the new area and its convenience for travel. Only one organisation stayed in the same locale. Overall, the same features that drive location decision in normal times are evident in these organisations' stories. A balance of neighbourhood characteristics, accessibility and specific locale attachment featured in these organisations journeys.

5.5.2 Auckland

None of the Auckland respondents suggested they would relocate their businesses outside of the Auckland region as a result of the volcanic scenario. For the two organisations within the evacuation zones, relocation choices would be driven by availability of land/premises. It is interesting to reflect on organisation relocation decisions in parallel with a recent survey of evacuation patterns in Auckland. 25.6% of general public surveyed would evacuate the Auckland region if they were advised that an eruption was imminent. Only 23% of respondents indicated they would not or could not move due to their financial situation (Coomer et al., 2015) which could imply they will still be available for work.

Currently MERIT does not specifically model business relocation decisions as a result of a disaster event. With all organisations anticipating being able to relocate within the Auckland region, a better understanding of the feasibility and limitations of this is needed. The perceptions of businesses also needs to be calibrated with perceptions of householders on their relocation plans.

Future improvements

- Detailed analysis of relocation decision-making and feasibility is required to develop a model for relocation. Both organisation and staff perspectives are needed for this analysis.

5.6 CLOSURE

The current Business Behaviours Module focuses on how organisations recover. The model does not, however, predict or model business closure. The case studies sought to understand what factors may contribute to the closure of a business. Interviewee responses are summarised in Table 23.

Table 23 Factors prompting business to stop operating/close.

Sector	Location	Type of reason	Details
Retail	Auckland	Financial	None given
	Christchurch	Financial	Less than 50% normal turnover for 4 weeks
Professional Services	Auckland	n/a	Don't want to close
	Christchurch	n/a	Would not
Healthcare	Auckland	Operability	Unable to meet contractual needs
	Christchurch	Government funding	How sector is organised/funded e.g., government policy change
Logistics	Auckland	Health and safety issues	-
	Christchurch	Financial	12 months reduced turnover
Manufacturing	Auckland	Financial	Less than 50% normal turnover for 3 months
	Christchurch	Financial	Less than 50% of normal turnover for 2–3 months of (dependent on starting position)
Construction (Landscaping)	Auckland	- (respondent not owner)	
	Christchurch	Financial	Insufficient wage for owner/operator after 6 months
Hospitality	Auckland	Financial	Less than 75% turnover for 6 weeks
	Christchurch	Financial	Less than 50% turnover for 3 months

The results show that for essential services and services that rely primarily on non-discretionary spending, such as healthcare, professional services and logistics, reasons for potential closure are non-financial. For other sectors which are more dependent on discretionary spending and more fluctuating customer demands, a decision to close is based a reduction of turnover by 25–50% over 4–24 weeks.

The results show that for the sectors dependent on discretionary, there are clearly operational limits. The data here is too limited to make sector specific estimates for the average closure point. However, this could potentially be a lever in the model. The authors believe that the respondents were overly 'optimistic' in how quick they would make a decision to close. Also, they answered this question in a business as usual context – not a disrupted post-disaster environment with the availability of insurance etc. The authors suggest a starting point of a 50% reduction in turn over for 6 months as being a potential trigger for business closure rates to rise. The lever could be adjusted to determine the sensitivity of the model to this change and can be updated as more sector specific data becomes available.

Impacts for MERIT

- Include a lever in the business behaviour module that closes businesses after their turnover has reduced by an average of 50% for 6 months.

Future improvements

- Detailed analysis of typical tipping points for business closure by sector.

6.0 WHAT WOULD HELP ORGANISATIONS

All respondents were asked to comment on what the greatest challenge and greatest help would be in each of the scenarios. Overall themes included communication, cooperation and coordination.

The majority of organisations suggested that accurate communication of information would be the most helpful aspect to manage disruption. For the shorter infrastructure disruptions, communication of duration and keeping to the promised timing enables organisations to make the most effective decisions to mitigate any loss in terms of both productivity and stock. For the natural hazard scenarios, organisations looked to local authority and government as the key provider of accurate situational assessment and repair timelines.

Coordination and cooperation was referred to primarily by Christchurch respondents in terms of everyone working together to do what was needed and reflects their perceptions of the importance of this following the earthquakes. Coordination was also mentioned by one Auckland respondent as applicable to working with insurance companies to enable rapid restoration following a volcanic event.

Cooperation rather than compliance was a key issue raised in both cities with regard to the local government response to any disruption with a suggestion that local authorities should be looking for ways to assist business to open, rather than looking to assess compliance.

Finally, the impacts on emotional wellbeing, hope and people's desire to keep going was noted as a key challenge in both cities suggesting that attention to building positivity and assisting with a fighting spirit are very important.

7.0 SUMMARY OF IMPACTS FOR MERIT MODEL

As discussed throughout the report, analysis of case study responses has the following impacts for the MERIT model:

- Supports the transferability of the module to other urban contexts.
- Supports the importance of sector as a key determinant of impacts.
- Supports the variety of potential responses given the different attitudes and approaches to both preparedness and adaptation evident in these case studies.
- Confirms that organisations can operate even when services are unavailable and reinforces the importance of the Business Behaviours Module to ensure that these adaptive responses are included in modelled economic outputs.

Specific amendments to the existing model are summarised below

- Check the model for the influence of relocation and temporary closure on level of reported disruption due to water, sewage and electricity, outages.
- Review the weightings of the disruption levels in the calculation of experienced disruption, in particular the weighting of 'slight'.
- Governmental support programmes need to be included as a lever within MERIT and the initial settings for this should be 'on' to reflect the impact of the ESS in the Canterbury data.
- For the electricity scenario, change the electricity disruption operability curve function to a step function: reduced operability (level is based on sector) for duration of outage and full operability immediately after electricity is restored.
- A step function for the water scenario needs to be defined, including suitable reduced operability levels for the duration of the infrastructure disruption.
- Further explore the dependence of particular sectors on different infrastructure types to see if adjustments to the operability curves are required. Confirm with other analysis that these results are valid for water and check other sectors and infrastructure types using criticality paper.
- The operability model needs to include a threshold, beyond which organisations are assumed to have resumed to full operability. This threshold could be related to a particular value (e.g., >95% operability) or could be relative to the outage duration (e.g., >3x the outage duration).
- The effect of port disruption on businesses should only be modelled within the economic module of MERIT.
- For the earthquake event non-infrastructure disruption function within the Business Behaviours module (which is calculated based on MMI), include a lower bound value below which no non-infrastructure damage is expected.
- Consider removing road disruption from the infrastructure function for volcanic scenario (and possibly others).
- Model disruption due to freight through cost increases in the economic model.

- Update the volcanic non-infrastructure disruption function based on organisation location relative to volcanic cone and evacuation zone.
- Include an on/off variable for availability of mitigation measures: that is if mitigation is in place, there would be no disruption to operability.
- Note the limitation that disruption due to water service disruption is based on the availability of (limited) government supplied water.
- The electricity disruption function does not need to be adjusted for rolling vs constant power outages.
- Include a slight delay (3 days) into MERIT for whenever industries need to change suppliers.
- As an initial model for staffing decisions, labour level changes within the economic model should be based on 6 months prior trading (and 6 months forecast) (if possible).
- Include a lever in the business behaviour module that closes businesses after their turnover has reduced by an average of 50% for 6 months.

8.0 FUTURE IMPROVEMENTS FOR MERIT MODEL

The data analysis and case studies presented here have identified a number of ways in which MERIT could be developed and improved in the future. These ideas are summarised below.

- Further investigate the impact of size on business behaviour and model.
- Develop a recovery module for large scale events so longer term recovery dynamics can be effectively modelled.
- Further investigate the case for including in MERIT sustained productivity adjustment following large scale disruptions.
- Attempt to quantify the effects of the Earthquake Support Subsidy (or similar aid programmes) in order to adjust the government support lever.
- A threshold level for very short infrastructure disruption durations should be established to enable identification of outages that do not create ongoing operability issues.
- Future versions of MERIT would benefit from more in depth analysis and modelling of supply chains.
- Carry out further calibration of the non-infrastructure damage function for earthquake events.
- Determine a tipping point for increased freight times and impacts on businesses (for all scenarios).
- Further refinement of the non-infrastructure disruption function including sector variation, ashfall depth and road travel time disruption.
- Extend the Business Behaviours Module to be applicable to rural contexts
- Develop a water disruption function that is based on no water aid from government authorities.
- Improve the water disruption function so that it is sensitive to potable vs not-potable.
- Include functions for disruption to different kinds of telecommunications services and include for substitutability between these services.
- Carry out more in depth modelling of supply chains
- Detailed analysis of relocation decision-making and feasibility is required to develop a model for relocation. Both organisation and staff perspectives are needed for this analysis.
- Detailed analysis of typical tipping points for business closure by sector.
- Currently MERIT includes immediate substitutability of labour. A delay function may be needed for staff turnover with further analysis required using sector and organisation type data

In addition, we have identified several areas that were not explored in detail in the case studies that appear to have an influence on interviewee responses and their predicted recovery path.

First, both the ERI survey and these case studies touched upon the role of insurance in mitigating the financial impacts of major disruption. While the case studies did not directly ask about insurance status, every Canterbury organisation made specific mention, often at length, as to the role insurance played in their recovery. Further work is needed to tease out the limitations; benefits and negative impacts insurance may have on organisations return to operations.

Second, there is also a need to consider whether particular economies with less economic diversity and/or key organisations whose closure may create a cascading impact. Further work could explore who they may be and whether they have different drivers of operability.

Third, ownership structure appeared to have an influence on responses. Ideally business ownership structure as well as sector should be used to predict business behaviours. Note that this is not currently possible with organisations in the economic model only identified at meshblock level with sector and number of employees

In addition to improvements within the MERIT model, several observations on how to improve subsequent surveys have also been made.

1. Future survey questions need to consider how best to direct respondent's attention to the actual disruption to function, rather than the degree of damage.
2. A number of organisations identified impacts or disruptions that occurred sometime after the earthquake. In particular, a number of organisations were impacted by structural damage identified years after the earthquakes. In future surveys, consider gathering data on these longer term disruptions.
3. The survey question on mitigation was not consistently answered – some answered hypothetically e.g., how important mitigation would have been. In future, this question should be revised. Several revisions are suggested:
 - a. include a question asking if mitigation was in place
 - b. ask the percent reduction in disruption due to mitigation
 - c. ask duration of mitigation effectiveness
 - d. Stipulate mitigation that was in place pre-disaster and by the organisation (as opposed to post-event measures by authorities / aid agencies)
4. Questions within the survey and case study did not help to clarify the level of experienced disruption due loss of telecommunications. With the development of technology and options for VOIP calling as well as mobile and landline phone services, organisations assume that there will be at least one service available with many answering questions with this in mind. Testing the dependencies on these services – both individually and combined – would be valuable.

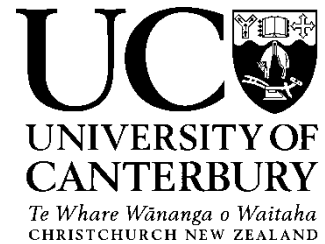
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APPENDICES

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APPENDIX 1: CHRISTCHURCH INTERVIEW GUIDE



Semi Structured Interview Guide

Economics of Resilient Infrastructure – Business Behaviours – Christchurch

Thank you very much for taking the time to talk with me.

SECTION ONE

Firstly, I want to ask about some of your answers to the earlier survey regarding the impacts of the Christchurch earthquakes on your organisation:

1. Can you tell me more about the disruption you experienced and its effect on your ability to operate. Let's start with:
(copy survey responses for each organisation)

What was the disruption, duration and impact?

12c. With reference to the 22 February 2011 earthquake, how was your organisation disrupted by the loss of the following infrastructure services?

	Not disrupted	Slightly disrupted	Moderately disrupted	Very disrupted
Water supply	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Sewage	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Electricity	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Gas	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Phone networks (cell and landline)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Data networks	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Road network	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Rail	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Airport	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Port	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Fuel	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

11. With reference to the 22 February 2011 earthquake, please indicate how disruptive the following factors were

	N/A	Not disruptive	Slightly disruptive	Moderately disruptive	Very disruptive
Difficulty accessing IT data	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Structural damage to building(s) (integrity of building compromised)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Non-structural damage (fittings damaged e.g. windows or light fixtures)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Machinery loss or damage	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Office equipment loss or damage	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Damage to inventory or stock	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Damage to ground surface	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Damage to or closure of adjacent (next door) organisations or buildings	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Damage to local neighbourhood (e.g. other buildings in area, damage to pavements, etc)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Difficulty accessing premises/site	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Health and safety issues for employees	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Supplier issues	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Customer issues	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Availability of staff	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Perceptions of building safety	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Changes in staff emotional wellbeing	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Other	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Other (please specify)					

- Which specific impacts drove the overall effect on your organisation (the game-changing impacts)?
- After the earthquakes, you rated your ability to meet demand initially at %, and then changing after several months to %. Can you tell me more about that journey? (check – what was demand impact)
(copy survey responses for each organisation)

26a. To what extent was your organisation able to meet the demand for your products or services?

	Unable (0– 20%)	Limited (20– 40%)	Partially (40– 60%)	Mostly (60– 80%)	Completely (80– 100%)
Immediately after the earthquakes	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Several months after the earthquakes	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
A year on from the earthquakes	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Two years on from the earthquakes	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

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2013 Organisational Resilience and Recovery Survey

26b. What were the key factors in your ability/inability to meet demand for your products or services?

4. Can you tell me more about the mitigation factors you had in place. You stated that was not important, why was that?
(copy survey responses for each organisation)

12a. With reference to the 22 February earthquake, to what extent have the following factors helped mitigate the impact of the earthquakes on your organisation?

	Not important	Slightly important	Moderately important	Very important
Backup/alternatives to water, sewerage, electricity, communications	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Backup/alternatives to IT	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Relationship with customers	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Relationship with suppliers	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Relationship with businesses in our sector	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Relationship with business advisor/mentor	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Relationship with staff	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Relationship with banks or lenders	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Relationship with our neighbours	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Available cash or credit	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Spare resources (e.g. equipment or extra people)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Insurance	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Business continuity, emergency management or disaster preparedness plan	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Backup or alternative site	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Practiced response to a disaster	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Emergency kit	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Well designed and well built buildings	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Other	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Other (please specify)				

Did inventory levels help with any supplier disruption?

5. Now, I'd like to talk about changes in your productivity after the earthquakes. You stated that productivity had How did productivity increase?

Prompts – duration, nature, extent, why, cause of decline or return to normal.

41b. With the earthquakes in mind, how would you describe your organisation's current productivity? (please tick one)

- ☐ Greatly increased
- ☐ Slightly increased
- ☐ The same
- ☐ Slightly decreased
- ☐ Greatly decreased

ESS Recipients Only

6. (a) How long did you use the Earthquake Wage Subsidy for?
- (b) On a spectrum of nice to have, to a life-saver, where did it fit for your business?

1	2	3	4	5	6	7	8	9	10
Nice to have									Life- saver

- (c) What do you think would have happened if this had not been available?

Re-locators Only

7. Can you tell me about your relocation process?

Prompts – why needed, how long out of action for, how new area chosen, overall impact on organisation of having to relocate.

SECTION TWO

For the rest of the interview, I am going to explain some hypothetical situations to you and then ask you questions about the likely responses of your organisation in this scenario.

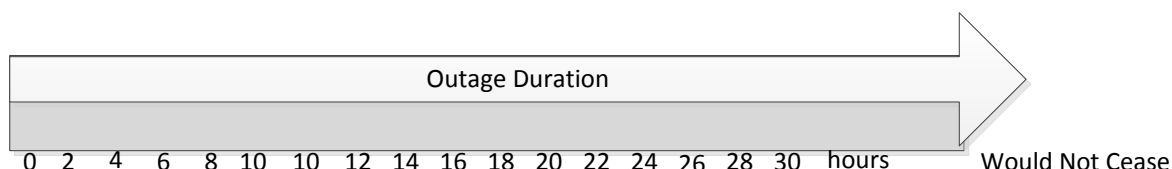
The first scenario is a power outage:

Electricity Disruption Scenario

There is a problem with the region's electricity network. Within two hours of the power cut you are notified that, in order for repairs to be carried out, your organisation's premises will be subject to 3-hourly rolling power outages for 24 hours.

Approximately 20% of the region is affected.

8. What would your business do?
- Stay open or close?
 - If closed – after how long would you close?
 - If open – what % of normal operation could you achieve
 - Impact on demand?
9. After what duration of rolling outage would you cease operation (threshold level for closure)?



10. Do you have anything in place to mitigate power outages – what and how long would it last?
11. Would this scenario impact on demand for your products/services?
12. What would the biggest challenge be for getting through this scenario?
13. What would be the greatest help to you in getting through?
14. What would happen once electricity was restored? (BAU, extra production??)
15. How do you think your answers would change for a complete outage (no power at all for 24 hours)?
16. Have you experienced a major power outage previously? How long was that for? What impact did that have on the organisation?

Water Disruption Scenario

There has been a significant disruption to the water supply to your organisation's premises. Within 6 hours of the damage to the water supply occurring you are notified that you will have no water for 3 weeks. At 3 weeks you receive full water service but the water is non-potable (requires boiling or treatment before consumption). After 5 weeks your water is fully potable.

The rest of the city is also affected. 30% of the city has no water for 3 weeks. It takes 6 weeks for potable water to be supplied to all areas again.

The following table shows how much of the city is affected.

YOUR BUSINESS		REST OF CHRISTCHURCH	
0 hours	No water	0 hours	30% no water, 70% water restrictions e.g., low pressure, restricted use
3 weeks	Full service – non potable	3 weeks	20% no water, 10% (incl CBD) full supply – non potable, 70 full supply potable
5 weeks	Full service – potable	5 weeks	20% full service – non potable, 80% fully supply – potable
		6 weeks	100% potable supply

17. What impact do you think this scenario would have on demand for your products/services?

Percentage up/down no change

18. What impact would this have on the ability of your business to meet demand?

Outage Summary	Production	Unable 0–20%	Limited 20–40%	Partially 40–60%	Mostly 60–80%	Completely 80–100%
100% water restrictions	Day one					
30% of city (incl CBD) no water 70% water restrictions	5 days					
30% of CBD no water 70% water restrictions	2 weeks					
20% of City no water 10% (incl CBD) full service but non-potable 70% full potable service	3 weeks					
20% full service but non-potable 80% full potable service	5 weeks					
100% of City full service potable water	6 weeks					
	3 months					
	6 months					

If applicable:

19. If demand was unchanged from usual patterns, how would you rate your ability to operate?

Outage Summary	Production	Unable 0–20%	Limited 20–40%	Partially 40–60%	Mostly 60–80%	Completely 80–100%
100% water restrictions	Day one					
30% of city (incl CBD) no water 70% water restrictions	5 days					
30% of CBD no water 70% water restrictions	2 weeks					
20% of City no water 10% (incl CBD) full service but non-potable 70% full potable service	3 weeks					
20% full service but non- potable 80% full potable service	5 weeks					
100% of City full service potable water	6 weeks					
	3 months					
	6 months					

20. Do you have anything in place to mitigate water outages – what and how long would it last?

21. How disruptive would impacts on staff be for your business?

	Not Applicable	Not Disruptive	Slightly Disruptive	Moderately Disruptive	Very Disruptive
Availability of Staff					
Changes in staff emotional wellbeing					

22. What would the biggest challenge be in getting through this scenario?

23. What would be the greatest help to you in getting through?

24. What would happen once water services were fully restored? (BAU, extra production??)

25. Have you experienced a major water outage previously? How long was that for? What impact did that have on the organisation?
26. How disruptive would the different types of water disruption be?

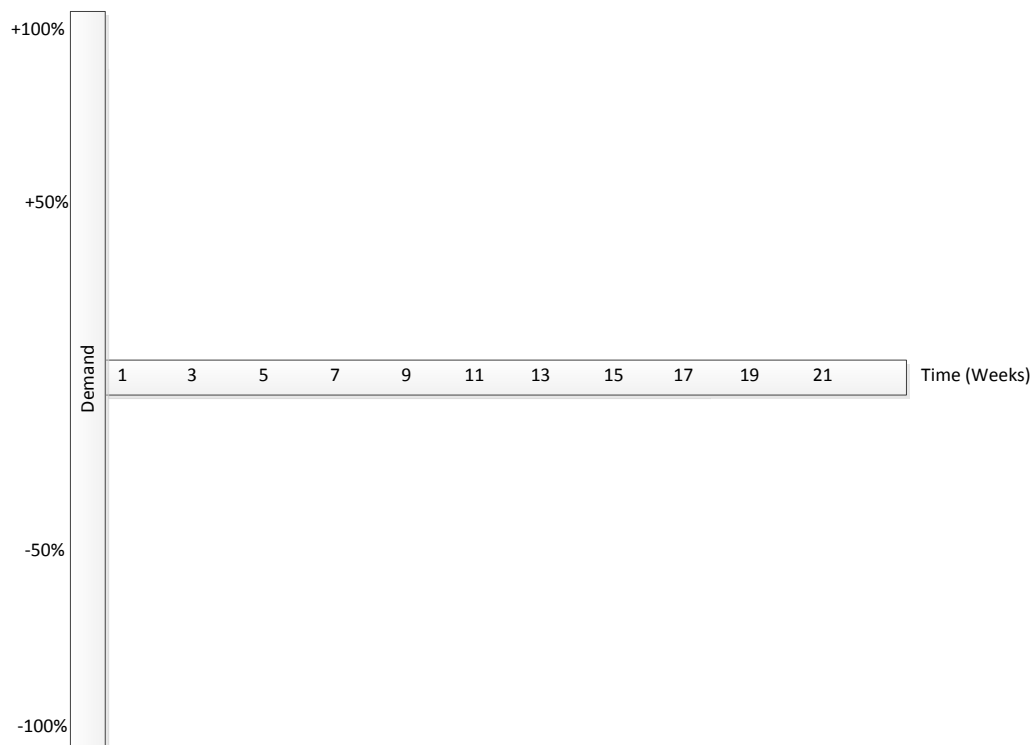
	Not disrupted	Slightly disrupted	Moderately disrupted	Very disrupted
No water				
Water restrictions				
Full non-potable water: Boil water notice				

Port Disruption Scenario

The regional port is inaccessible (both for incoming and outgoing goods) for 6 months. Fuel supplies are unaffected by the disruption.

It takes 2 days for the Port Company to advise the likely duration of the disruption.

27. What impact do you think this scenario would have on demand for your products / services?



28. What impact do you think this would have on the ability of your business to meet demand?

Production	Unable 0–20%	Limited 20–40%	Partially 40–60%	Mostly 60–80%	Completely 80–100%
Week One					
Week Two					
Month 1					
Month 3					
Month 6					
Month 12					

29. Do you have anything in place to mitigate this kind of outage? – how long would it last?

30. Would this impact on decisions regarding staffing levels?

31. How able would your suppliers be to meet your organisation's needs?

Incapable	Somewhat capable	Completely capable	I don't know

32. What would this biggest challenge be in getting through this scenario?

33. What would be the greatest help to you in getting through?

34. What would happen once port services were restored? (BAU, extra production??)

GENERAL

35. Where are your main suppliers located (in Christchurch, rest of NZ or international)?
36. In any of these scenarios, what would you do if a main supplier was unable to operate?
- How long before you look for an alternative?
- How long would you expect it to take to obtain alternative?
37. Which disruptions have the most significant impact on your organisation – the impacts that really guide the fate or actions of the organisation?
- for example: Water, Wastewater, Electricity, Gas, Phone, Internet/Data, Roads, Rail, Port, Airport, Fuel, Damage to premises, Damage to neighbourhood, Staff Impact*
38. What would prompt you to close your business?
- (Reduced revenue – weeks of normal turnover)
- (non-monetary factors)
- Either or both
39. How long could your organisation continue functioning if normal supply to the following infrastructure services were disrupted?

	Minutes	Hours	Days	Weeks
Water				
Power				
Port				
Mobile Phone				
Phone				
Fixed line Internet				
Mobile internet				

40. Based on what information do you make decisions to change staffing levels?

	Increase staff	Decrease staff
Based on prior 12 months trading		
Based on prior 6 months trading		
Based on previous months trading		
Based on forecast trading for following 1 month		
Based on forecast trading for following 6 months		
Based on forecast trading for following 12 months		
Other?		

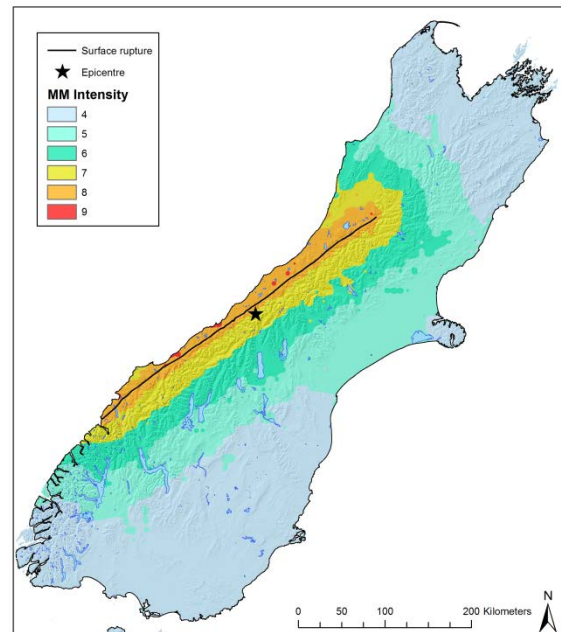
Our last Scenario – the Alpine Fault Scenario

The Alpine Fault has ruptured generating a Magnitude 8 earthquake and causing a ~400 km rupture between Milford Sound and the Ahaura River, east of Greymouth. Shaking is felt in Canterbury but there is only minor damage within the region. The majority of the effects are felt on the west coast of the south island. The major effects on infrastructure are described below.

State highway disruption

Landslides and bridge damage will significantly disrupt the West Coast road network and the roads connecting the West Coast to the East Coast. The features of this disruption are:

- Haast Pass and Arthur's Pass will be closed indefinitely.
- Lewis Pass will be available to vehicles (0 to 6 tonnes) in 14 days.
- Most West Coast towns will be connected to each other (for light vehicles <3.5 tonnes) within 3 days with the exception of:
 - Hokitika and Franz Josef (14 days for light vehicles (<3.5 tonnes) and 90 days for heavy vehicles (3.5–6 tonnes))
 - Milford Sound (30 days for light vehicles and 90 days for heavy vehicles)
- There may still be speed restrictions and possible delays on all routes.



Rail

The time (in days) after the earthquake when rail links are restored are shown below. All east coast routes are unaffected by the earthquake. All west coast routes are operational within 3 days. It takes 58 days to restore the connections between east and west coasts.

Electricity supply

Electricity supply is disrupted on the west coast for 2 days. Franz Josef is without power for 80 days.

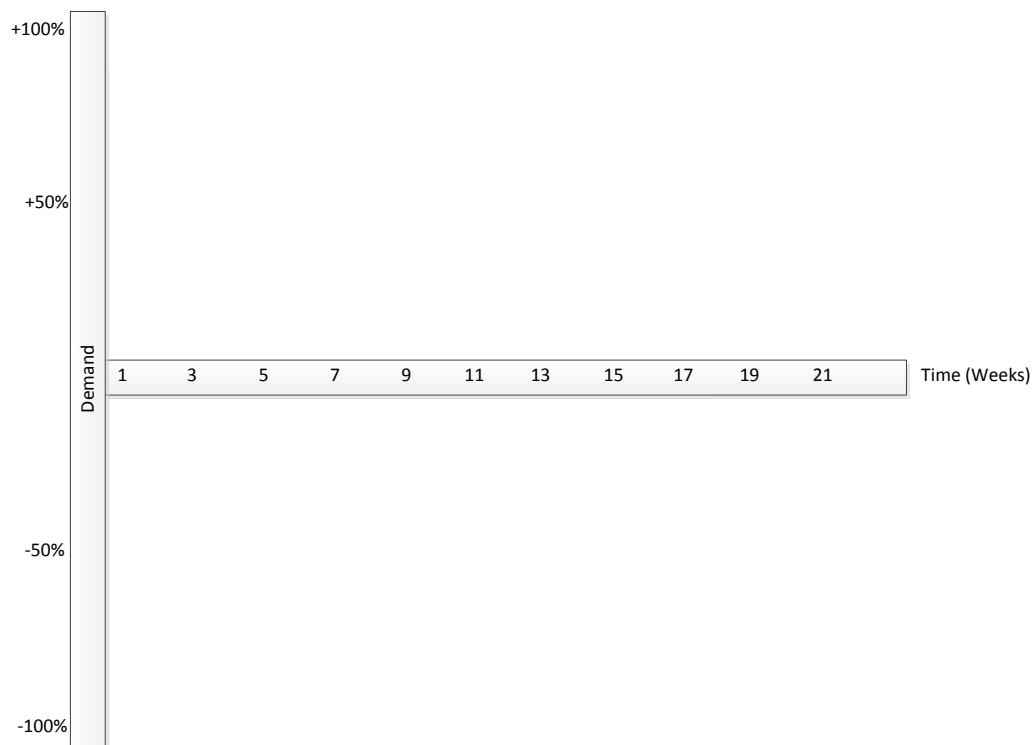
Wastewater

Wastewater networks along the west coast are disrupted for 30 days.

Water networks

Town water supply is affected for 3 weeks. Boil water notices are in place for 6 weeks once water is restored.

41. What impact do you think this scenario would have on demand for your products/services?



42. How disruptive would impacts on staff be for your business?

	Not Applicable	Not Disruptive	Slightly Disruptive	Moderately Disruptive	Very Disruptive
Availability of Staff					
Changes in staff emotional wellbeing					
Perceptions of safety					

Why?

43. What impact do you think this would have on the ability of your business to meet demand?

Production	Unable 0–20%	Limited 20–40%	Partially 40–60%	Mostly 60–80%	Completely 80–100%
Day One					
Week Two					
1 month					
2 months					
3 months					
5 months					

44. Would you change staffing levels in response to this disruption?
45. How able would your suppliers be to meet your organisation's needs?

Incapable	Somewhat capable	Completely capable	I don't know

46. What would you do to cope with supply chain disruptions? (e.g., *high inventory levels, long lead times*)
47. Does your business discharge trade waste to the wastewater system? What would you do if you could not discharge your trade waste to the wastewater system? (e.g., Store onsite, dispose elsewhere, cease operation).
48. What would the biggest challenge be in this scenario?
49. What would be the greatest help to get you through?

Thank you so much for your time. I will email you the write-up for your organisation within the next 6 weeks for your information and review. If you any queries at all, just give me a call. Many thanks.

APPENDIX 2: AUCKLAND INTERVIEW GUIDE



Semi Structured Interview Guide

Economics of Resilient Infrastructure – Business Behaviours – Auckland

Thank you very much for taking the time to talk with me.

Firstly, I just need to check some demographic information:

Organisation:			
Address:			
Sector:			
Size: (No. of employees)	FT:	PT:	Casual:
Organisation Age:			
Ownership:			

For the rest of the interview, I am going to explain some hypothetical situations to you and then ask you questions about the likely responses of your organisation in this scenario.

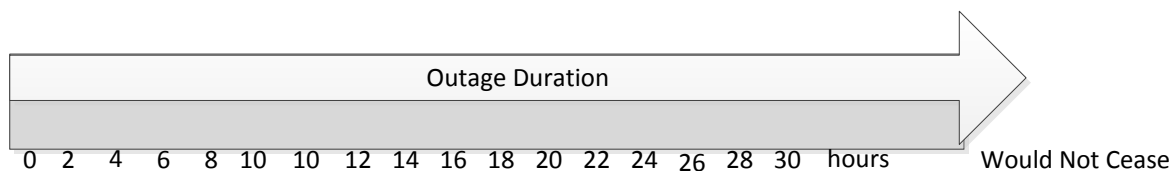
The first scenario is a power outage:

Electricity Disruption Scenario

There is a problem with the region's electricity network. Within two hours of the power cut you are notified that, in order for repairs to be carried out, your organisation's premises will be subject to 3-hourly rolling power outages for 24 hours.

Approximately 20% of the region is affected.

1. What would your business do?
 - Stay open or close?
 - If closed – after how long would you close?
 - If open – what % of normal operation could you achieve
 - Impact on demand?
2. After what duration of rolling outage would you cease operation (threshold level for closure)?



3. Do you have anything in place to mitigate power outages – what and how long would it last?
4. Would this scenario impact on demand for your products/services?
5. What would the biggest challenge be for getting through this scenario?
6. What would be the greatest help to you in getting through?
7. What would happen once electricity was restored? (BAU, extra production??)
8. How do you think your answers would change for a complete outage (no power at all for 24 hours)?
9. Have you experienced a major power outage previously? How long was that for? What impact did that have on the organisation?

Water Disruption Scenario

There has been a significant disruption to the water supply to your organisation's premises. Within 6 hours of the damage to the water supply occurring you are notified that you will have no water for 3 weeks. At 3 weeks you receive full water service but the water is non-potable (requires boiling or treatment before consumption). After 5 weeks your water is fully potable.

The rest of the city is also affected. 30% of the city has no water for 3 weeks. It takes 6 weeks for potable water to be supplied to all areas again.

The following table shows how much of the city is affected.

YOUR BUSINESS		REST OF AUCKLAND	
0 hours	No water	0 hours	30% no water, 70% water restrictions e.g., low pressure, restricted use
3 weeks	Full service – non potable	3 weeks	20% no water, 10% (incl CBD) full supply – non potable, 70 full supply potable
5 weeks	Full service – potable	5 weeks	20% full service – non potable, 80% fully supply – potable
		6 weeks	100% potable supply

10. What impact do you think this scenario would have on demand for your products/services?

Percentage up/down no change

11. What impact would this have on the ability of your business to meet demand?

Outage Summary	Production	Unable 0–20%	Limited 20–40%	Partially 40–60%	Mostly 60–80%	Completely 80–100%
100% water restrictions	Day one					
30% of city (incl CBD) no water 70% water restrictions	5 days					
30% of CBD no water 70% water restrictions	2 weeks					
20% of City no water 10% (incl CBD) full service but non-potable 70% full potable service	3 weeks					
20% full service but non-potable 80% full potable service	5 weeks					
100% of City full service potable water	6 weeks					
	3 months					
	6 months					

If applicable:

12. If demand was unchanged from usual patterns, how would you rate your ability to operate?

Outage Summary	Production	Unable 0–20%	Limited 20–40%	Partially 40–60%	Mostly 60–80%	Completely 80–100%
100% water restrictions	Day one					
30% of city (incl CBD) no water 70% water restrictions	5 days					
30% of CBD no water 70% water restrictions	2 weeks					
20% of City no water 10% (incl CBD) full service but non-potable 70% full potable service	3 weeks					
20% full service but non- potable 80% full potable service	5 weeks					
100% of City full service potable water	6 weeks					
	3 months					
	6 months					

13. Do you have anything in place to mitigate water outages – what and how long would it last?

14. How disruptive would impacts on staff be for your business?

	Not Applicable	Not Disruptive	Slightly Disruptive	Moderately Disruptive	Very Disruptive
Availability of Staff					
Changes in staff emotional wellbeing					

15. What would the biggest challenge be in getting through this scenario?

16. What would be the greatest help to you in getting through?

17. What would happen once water services were fully restored? (BAU, extra production??)

18. Have you experienced a major water outage previously? How long was that for? What impact did that have on the organisation?

19. How disruptive would the different types of water disruption be?

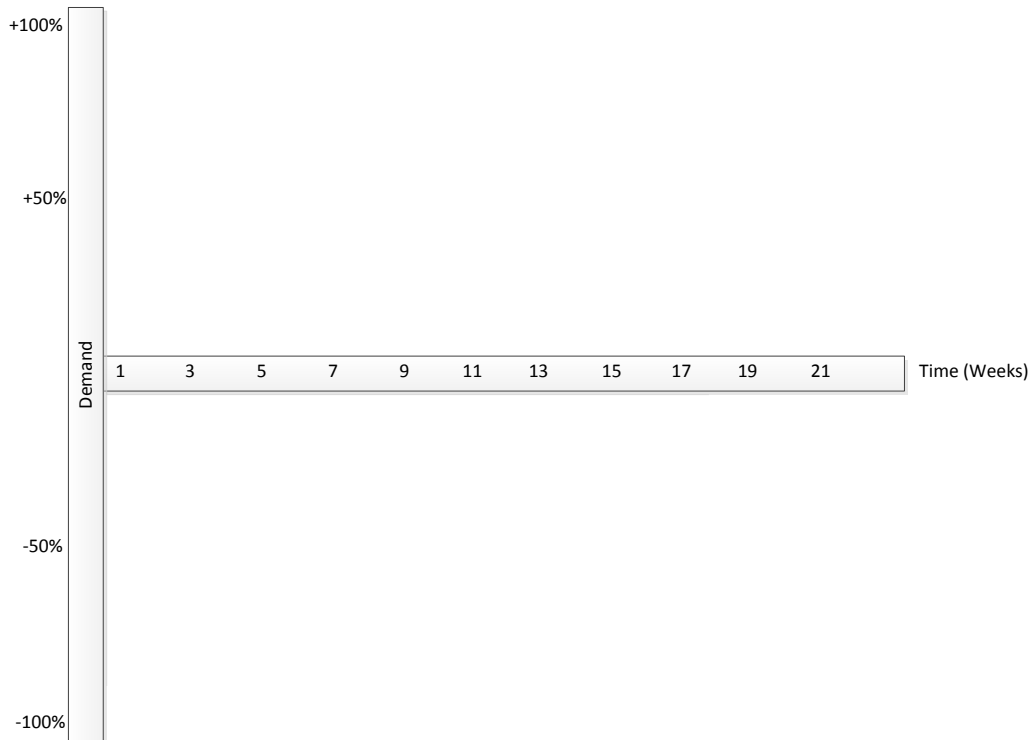
	Not disrupted	Slightly disrupted	Moderately disrupted	Very disrupted
No water				
Water restrictions				
Full non-potable water: Boil water notice				

Port Disruption Scenario

The regional port is inaccessible (both for incoming and outgoing goods) for 6 months. Fuel supplies are unaffected by the disruption.

It takes 2 days for the Port Company to advise the likely duration of the disruption.

20. What impact do you think this scenario would have on demand for your products/services?



21. What impact do you think this would have on the ability of your business to meet demand?

Production	Unable 0–20%	Limited 20–40%	Partially 40–60%	Mostly 60–80%	Completely 80–100%
Week One					
Week Two					
Month 1					
Month 3					
Month 6					
Month 12					

22. Do you have anything in place to mitigate this kind of outage? – how long would it last?
23. Would this impact on decisions regarding staffing levels?
24. How able would your suppliers be to meet your organisation's needs?

Incapable	Somewhat capable	Completely capable	I don't know

25. What would this biggest challenge be in getting through this scenario?
26. What would be the greatest help to you in getting through?
27. What would happen once port services were restored? (BAU, extra production??)

GENERAL

28. Where are your main suppliers located (in Auckland, rest of NZ or international)?

29. In any of these scenarios, what would you do if a main supplier was unable to operate?

How long before you look for an alternative?

How long would you expect it to take to obtain alternative?

30. Which disruptions have the most significant impact on your organisation – the impacts that really guide the fate or actions of the organisation?

for example: Water, Wastewater, Electricity, Gas, Phone, Internet/Data, Roads, Rail, Port, Airport, Fuel, Damage to premises, Damage to neighbourhood, Staff Impact

31. What would prompt you to close your business?

(Reduced revenue – weeks of normal turnover)

(non-monetary factors)

Either or both

32. How long could your organisation continue functioning if normal supply to the following infrastructure services were disrupted?

	Minutes	Hours	Days	Weeks
Water				
Power				
Port				
Mobile Phone				
Phone				
Fixed line Internet				
Mobile internet				

33. Based on what information do you make decisions to change staffing levels?

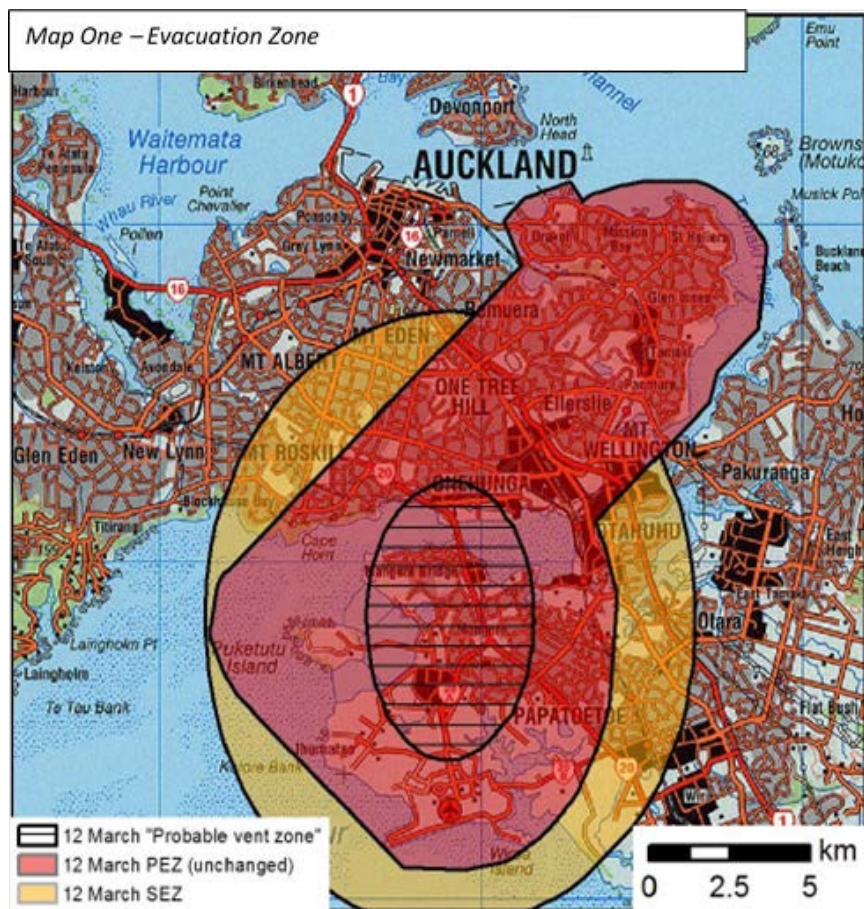
	Increase staff	Decrease staff
Based on prior 12 months trading		
Based on prior 6 months trading		
Based on previous months trading		
Based on forecast trading for following 1 month		
Based on forecast trading for following 6 months		
Based on forecast trading for following 12 months		
Other?		

SCENARIO FOUR: Auckland Volcanic Field Event

There has been a volcanic eruption in Auckland City. Mandatory evacuations commence on 8 March with Map One indicating the maximum extent of evacuations reached on 15 March. Evacuation areas reduce from 16 March to 1 May when a permanent exclusion zone (Map 3) is created.

You can assume there was a warning and sufficient time to evacuate people prior to significant damage occurring (but not physical material such as documents, equipment, or stock)

By 1 May – 8 weeks later, the volcanic activity has settled.



IMPACTS –from damage and ashfall

WATER – all of Auckland restricted to 50% of usual supply for 15 months.

WASTEWATER – available across city, but NO treatment for all sewage for 2 years with discharge direct into Manakau and Waitamata Harbours.

ELECTRICITY – unavailable within evacuation zones, with rest of Auckland (and Northland) on rolling outages for 7 weeks

INTERNET – extremely unreliable for 2 weeks in 40% of the city. Unreliable across the region for a further 3 weeks

ROAD TRAVEL – slow and difficult for 9 months – worse for first 8 weeks (while evacuation zones in place), then some improvement until SH20 reconnected (Mangere Bridge lost in the scenario)

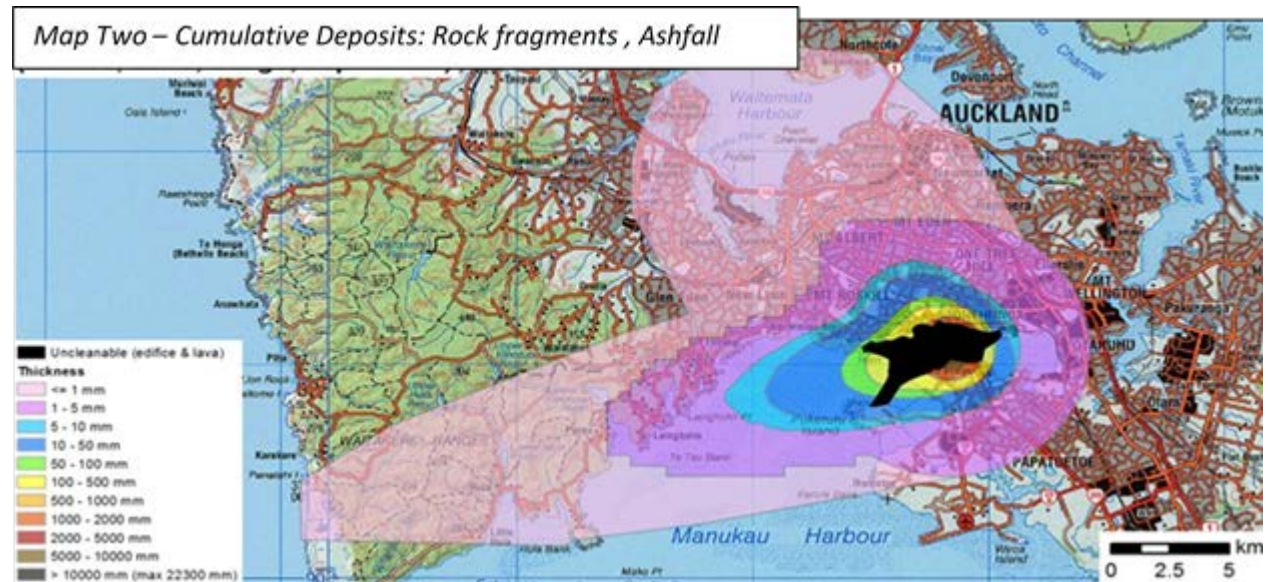
RAIL – southern commuter services (Papatoetoe to Newmarket) out or restricted for 8 weeks. Freight out for 5 days and restricted for 7 weeks.

AIRPORT – Closed for 1 month. Upon opening there is 80% domestic capacity and 10% international capacity. Full services resume after 9 weeks.

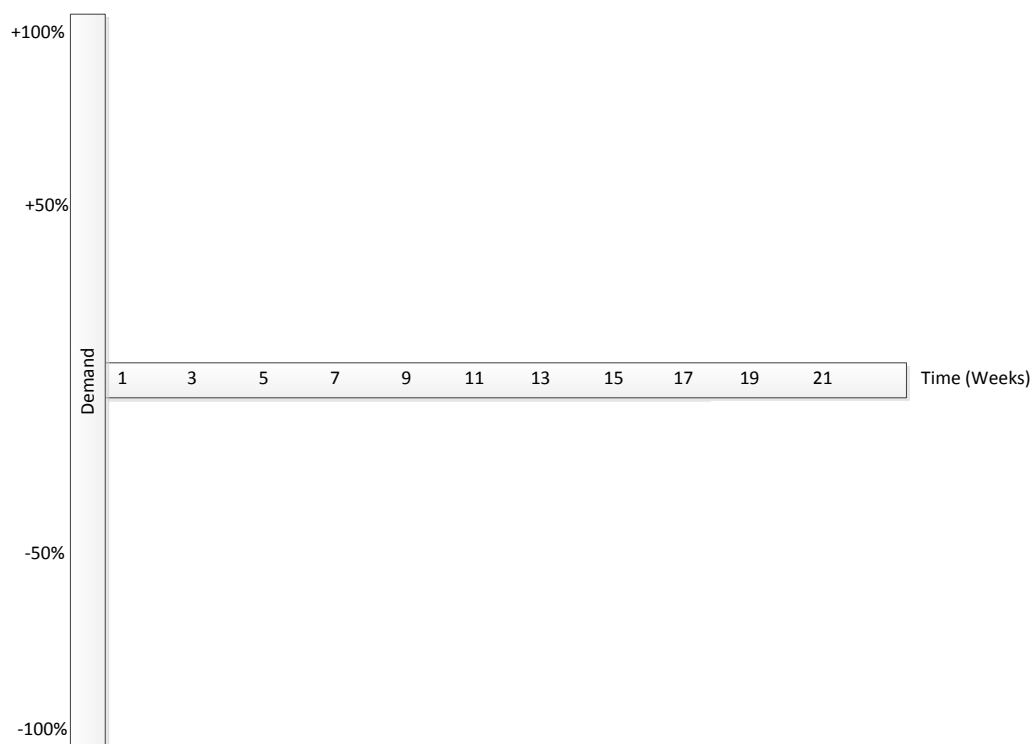
PORT – Onehunga facilities destroyed.

Map 2 summarises the deposits of rocks and ash following the event. Map 3 shows the permanent built environment exclusion zone after volcanic activity ceases. There will be significant structural damage to buildings around the volcano – that is, in suburbs such as Mangere, Mt Roskill, Onehunga, One Tree Hill, Papatoetoe, and Otahuhu

There will be notable ashfall (more than 1mm) across approximately 30% of the city.



34. What impact do you think this scenario would have on demand for your products / services?



35. How disruptive would impacts on staff be for your business?

	Not Applicable	Not Disruptive	Slightly Disruptive	Moderately Disruptive	Very Disruptive
Availability of Staff					
Changes in staff emotional wellbeing					
Perceptions of safety					

Why?

36. What impact do you think this would have on the ability of your business to meet demand?

Outside / Inside Evacuation Zone (circle one)

Outage Summary	Production	Unable 0–20%	Limited 20–40%	Partially 40–60%	Mostly 60–80%	Completely 80–100%
Water 20% no service, 80% boil, Wastewater 70% no service, Electricity 30% no service, No rail service. Road travel severely disrupted. Airport closed.	Day One					
Unchanged	Week Two					
Electricity: rolling blackouts Water services restored with boil warning. Internet-unreliable Airport closed	1 month					
Boil water. 70% wastewater restored Electricity restored Internet restored Roads severely disrupted Airport 25% capacity	2 months					
Boil water. Wastewater, electricity & internet services fully restored. Airport 95% domestic (including local international) and 80% international services restored	3 months					
All services at full capacity, boil warning removed. Road traffic still moderately disrupted.	5 months					
How long do you think it will take to return to full Operation?						

37. Would you change staffing levels in response to this disruption?

38. How able would your suppliers be to meet your organisation's needs?

Incapable	Somewhat capable	Completely capable	I don't know

39. Think about your most critical supplies. How long would it take you to re-establish new suppliers (and supply chain) if your suppliers were not able to meet your needs?

<1 week	1–2 weeks	2–4 weeks	4–8 weeks	>8 weeks

40. What would you do to cope with supply chain disruptions? (e.g., high inventory levels, long lead times)

41. What would prompt you to consider relocating? – What would the key considerations be in deciding a new location?

42. Does your business discharge trade waste to the wastewater system? What would you do if you could not discharge your trade waste to the wastewater system? (e.g., Store onsite, dispose elsewhere, cease operation).

43. What would the biggest challenge be in this scenario?

44. What would be the greatest help to get you through?

45. Once all of the services are restored, would your organisation do anything to recapture lost income or production? What would you do (BAU, extra production?)

Finally – What are the most disruptive impacts for your organisations operability?

46. Airport?

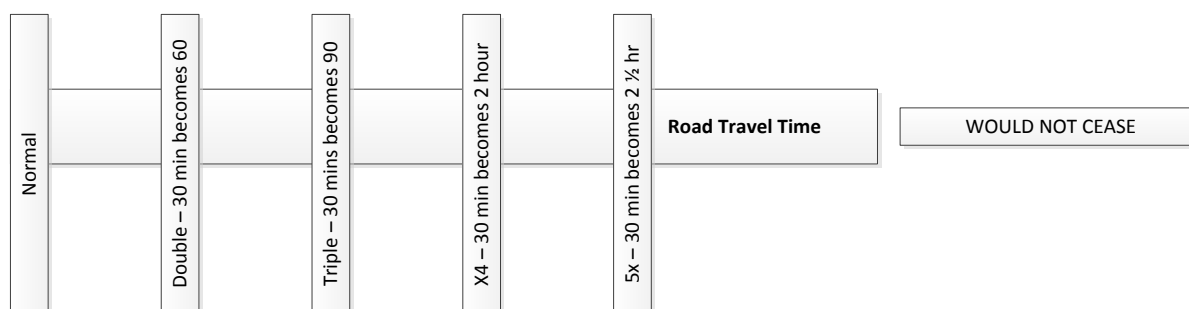
	Not disrupted	Slightly disrupted	Moderately disrupted	Very disrupted
International airport closure for 10 weeks				
Local international (Australia) for 10 weeks				
Domestic for 10 weeks				

47. Rail

	Not disrupted	Slightly disrupted	Moderately disrupted	Very disrupted
Commuter				
Freight				

48. Road (local and motorway) Travel Times for FREIGHT,

At what level of increased travel time would you cease operation?



49. Road (local and motorway) Travel Times for PEOPLE

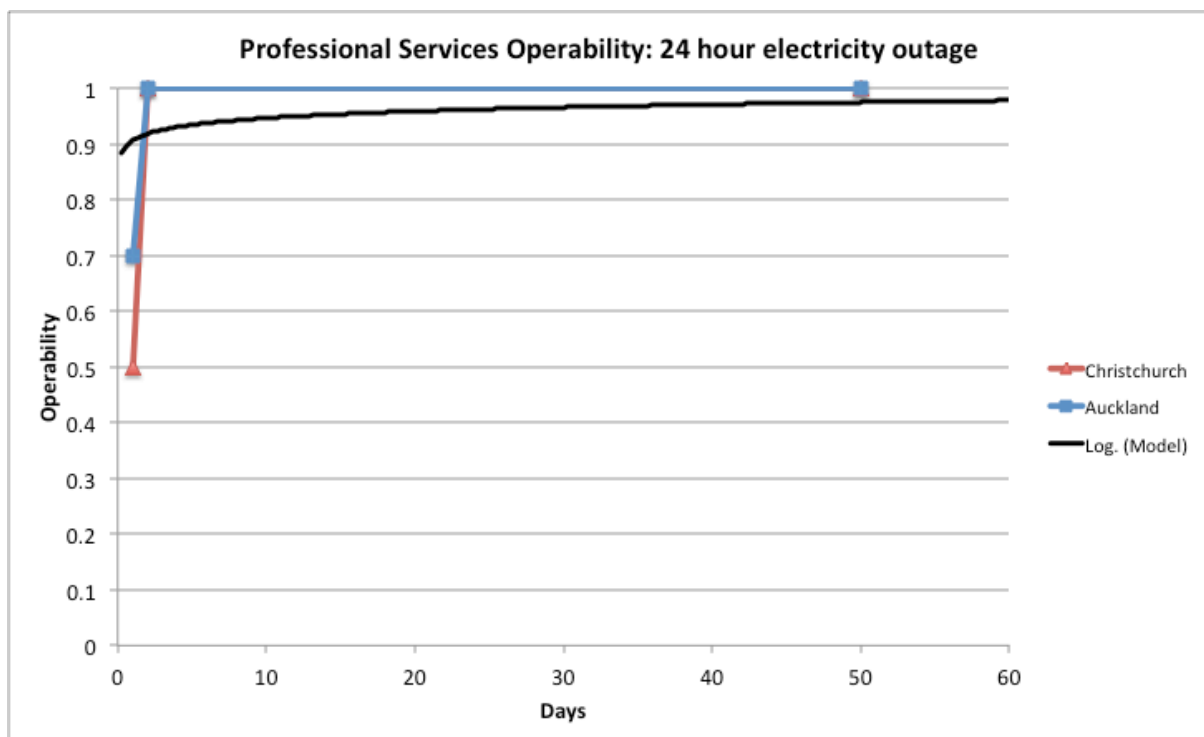
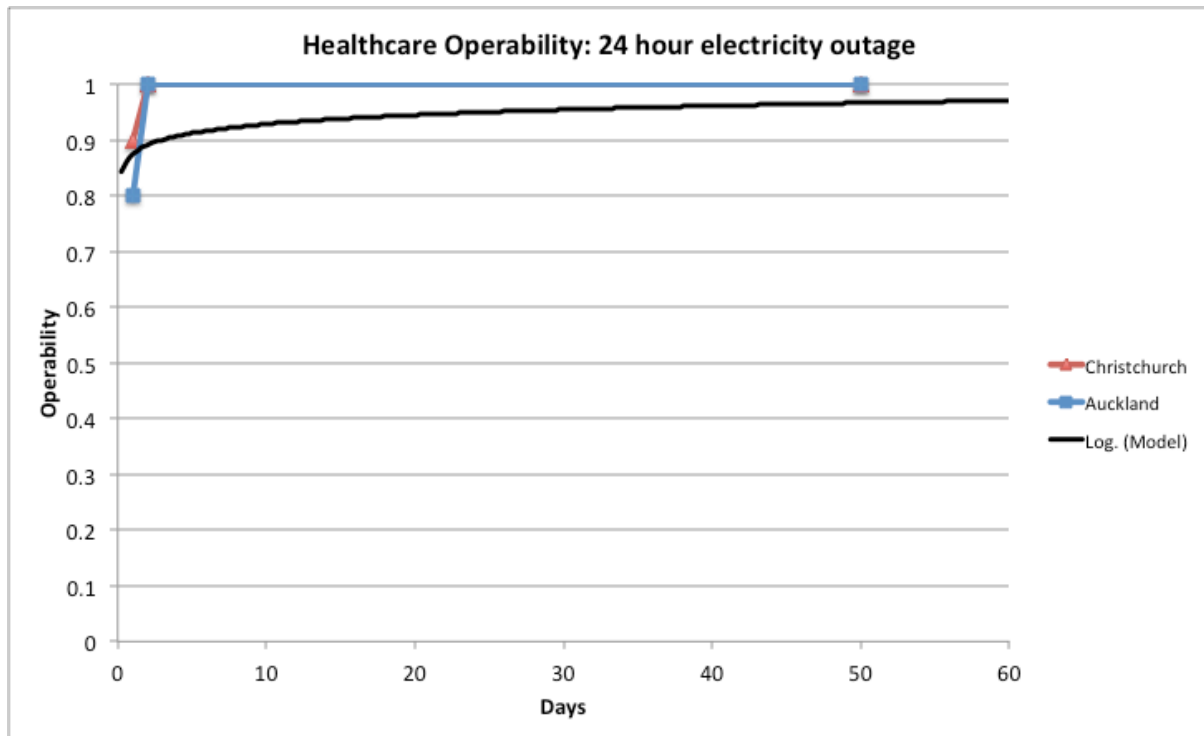
How disruptive for your business would the impact of these increased travel times on people be?

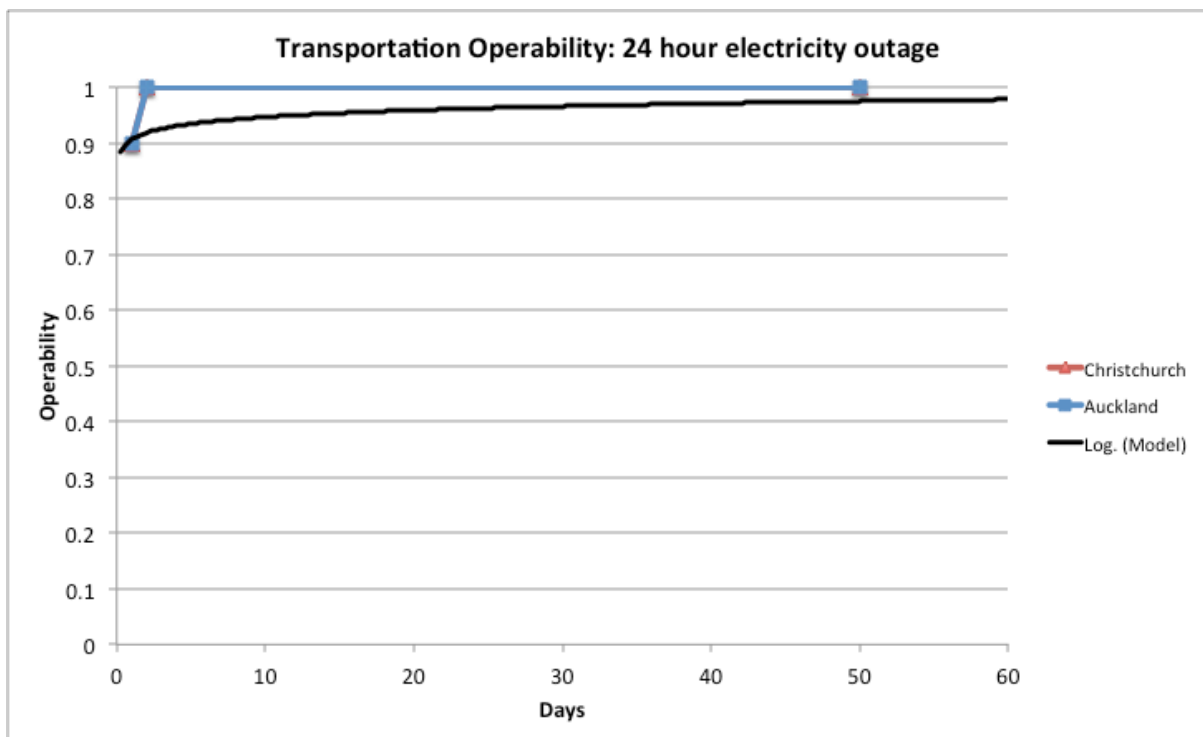
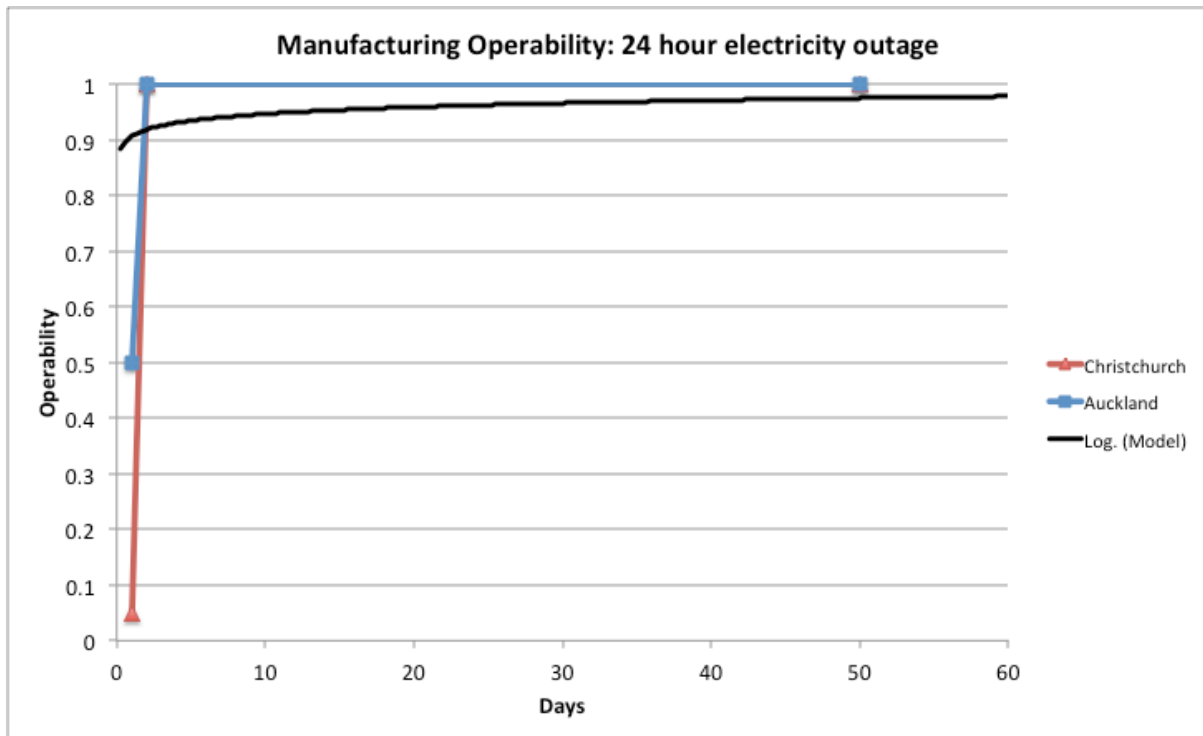
Increase in travel time	Not disrupted	Slightly disrupted	Moderately disrupted	Very disrupted
x 2				
x 3				
x 4				
x 5				
State Highway – no travel possible				

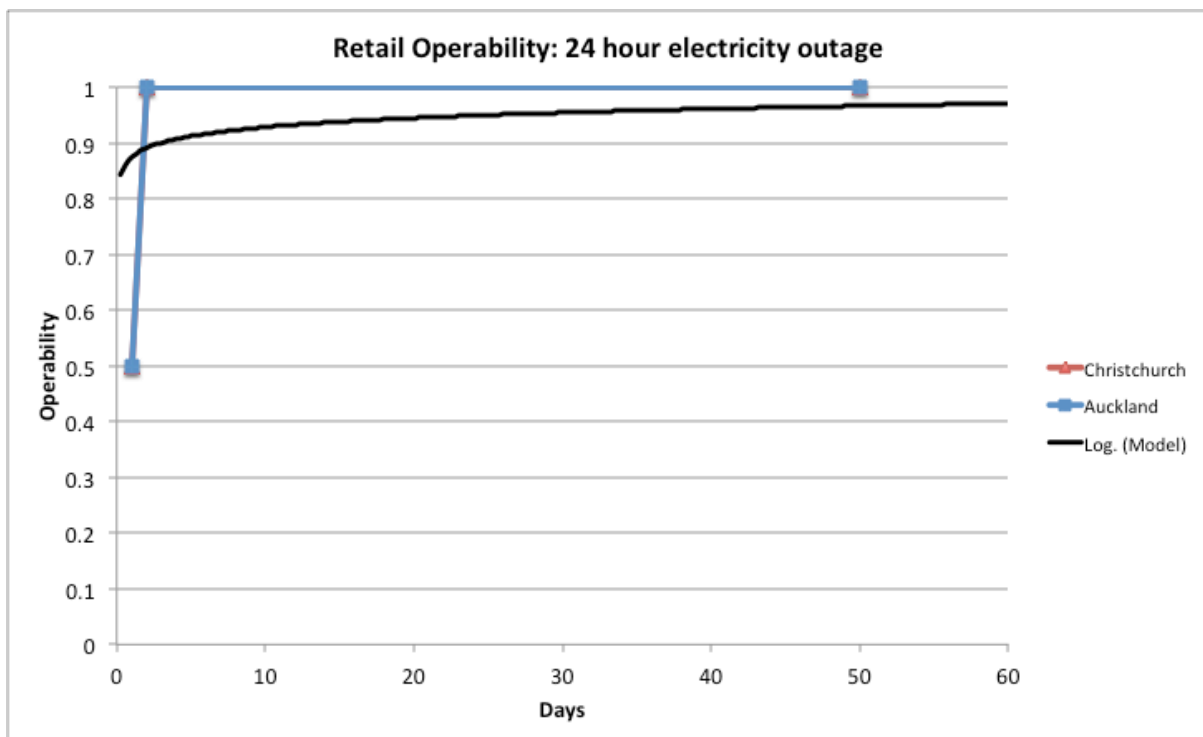
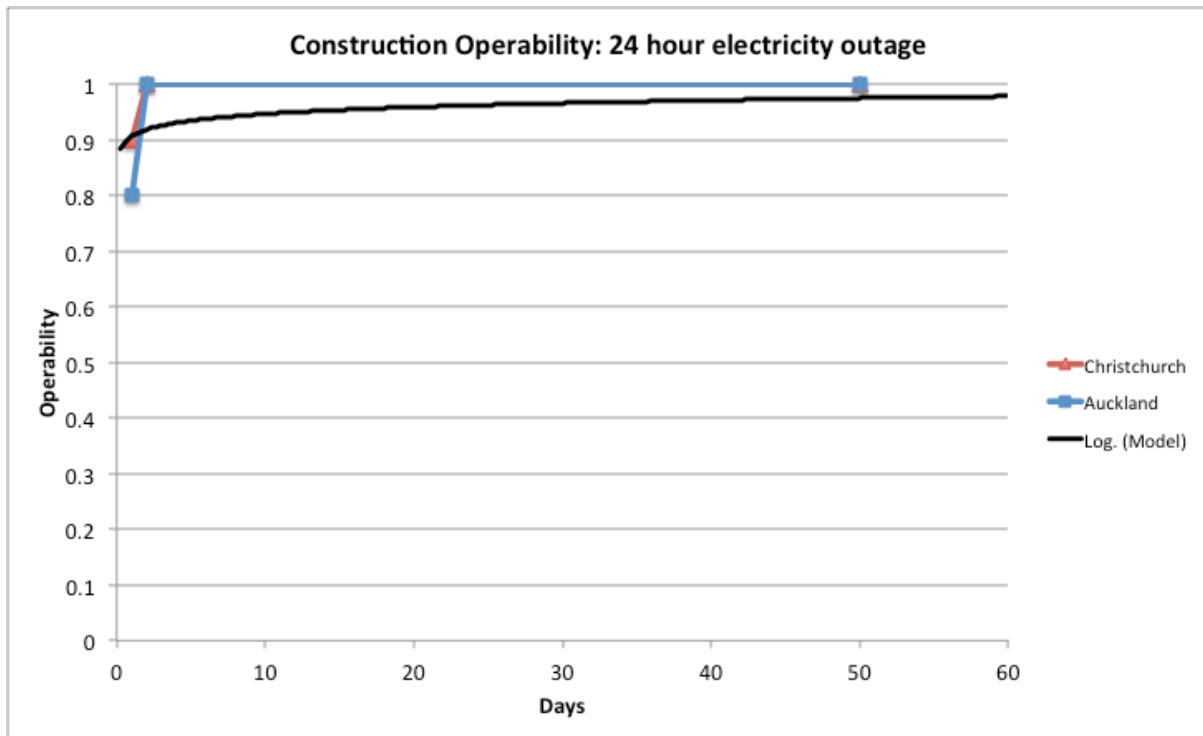
Thank you so much for your time. I will email you the write-up for your organisation within the next 6 weeks for your information and review. If you any queries at all, just give me a call. Many thanks.

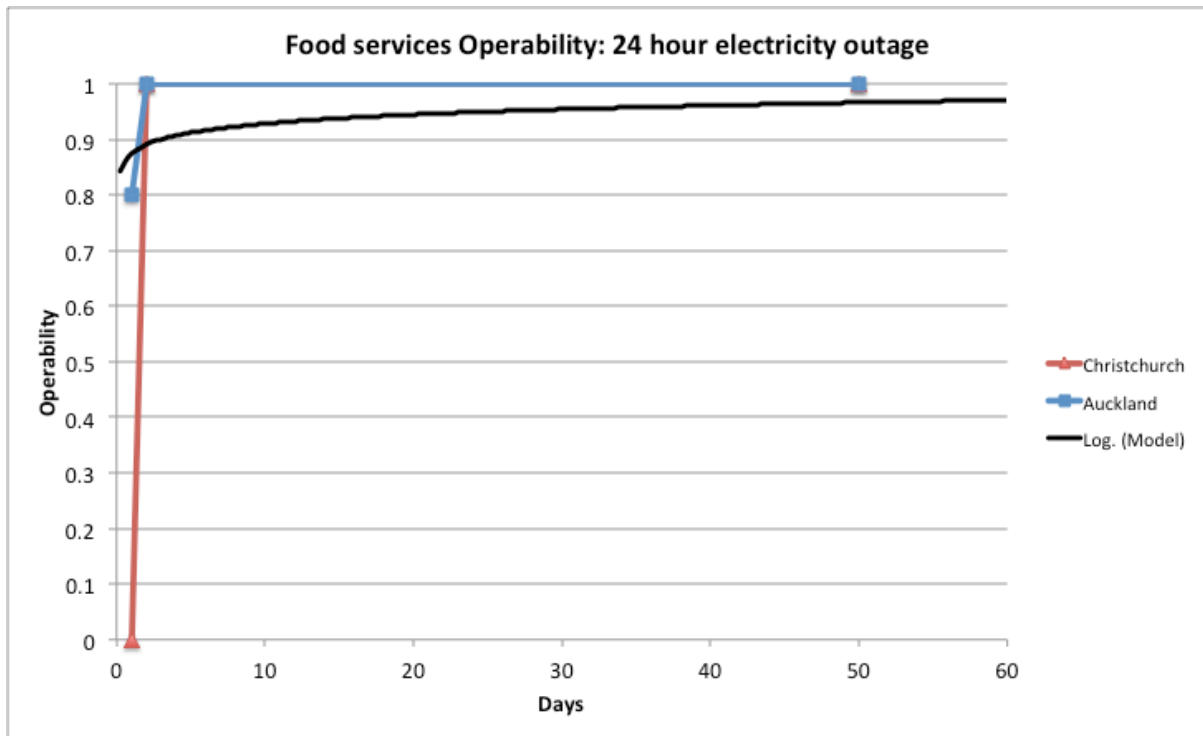
APPENDIX 3: MODEL OPERABILITY COMPARED TO OPERABILITY PREDICTED BY CASE STUDY ORGANISATIONS

Electricity Disruption

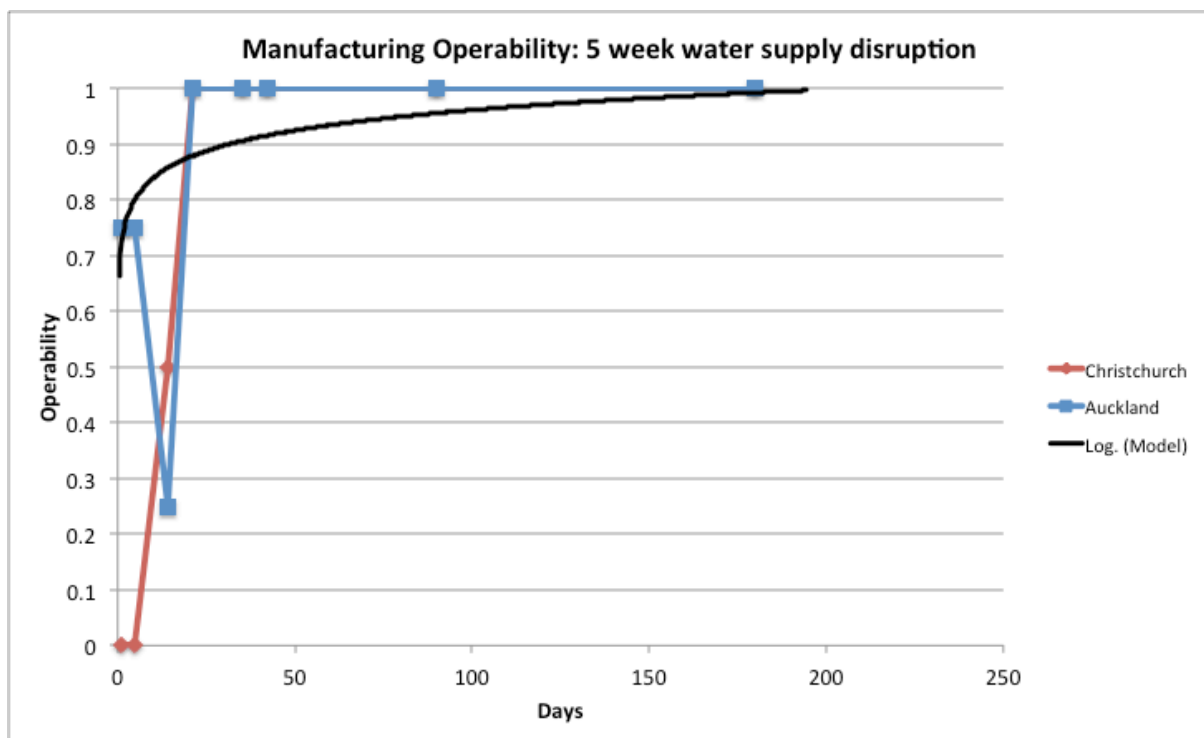
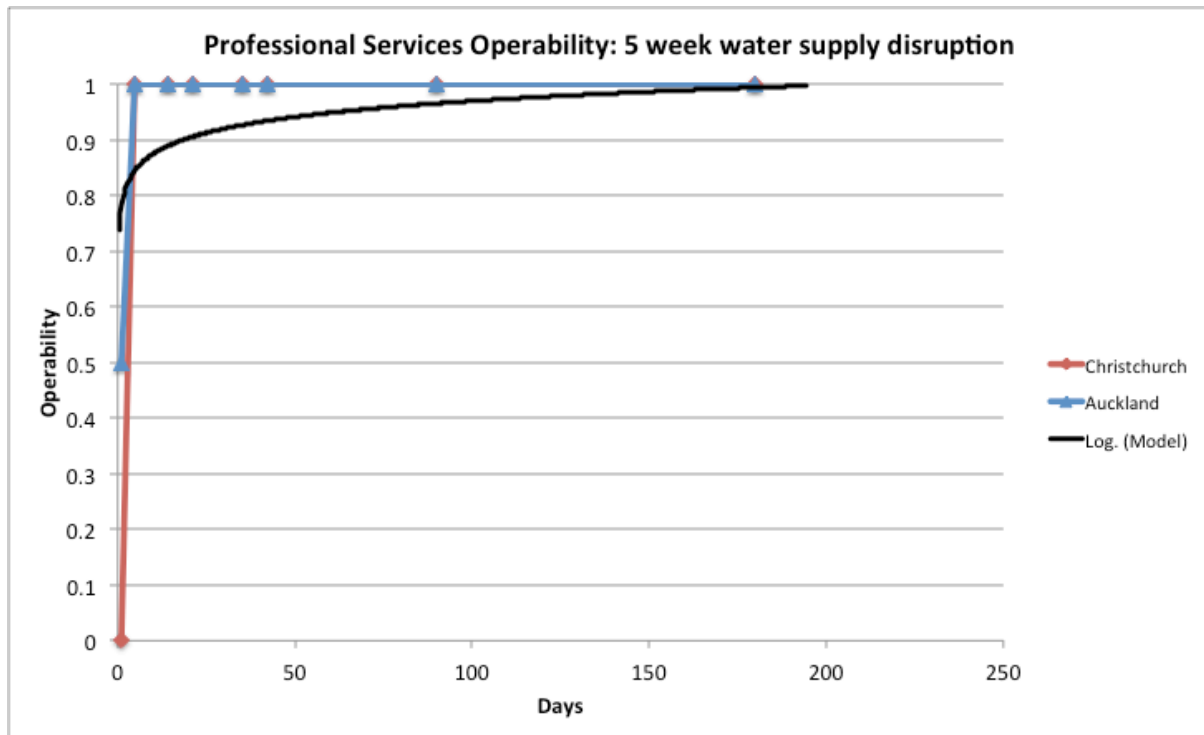


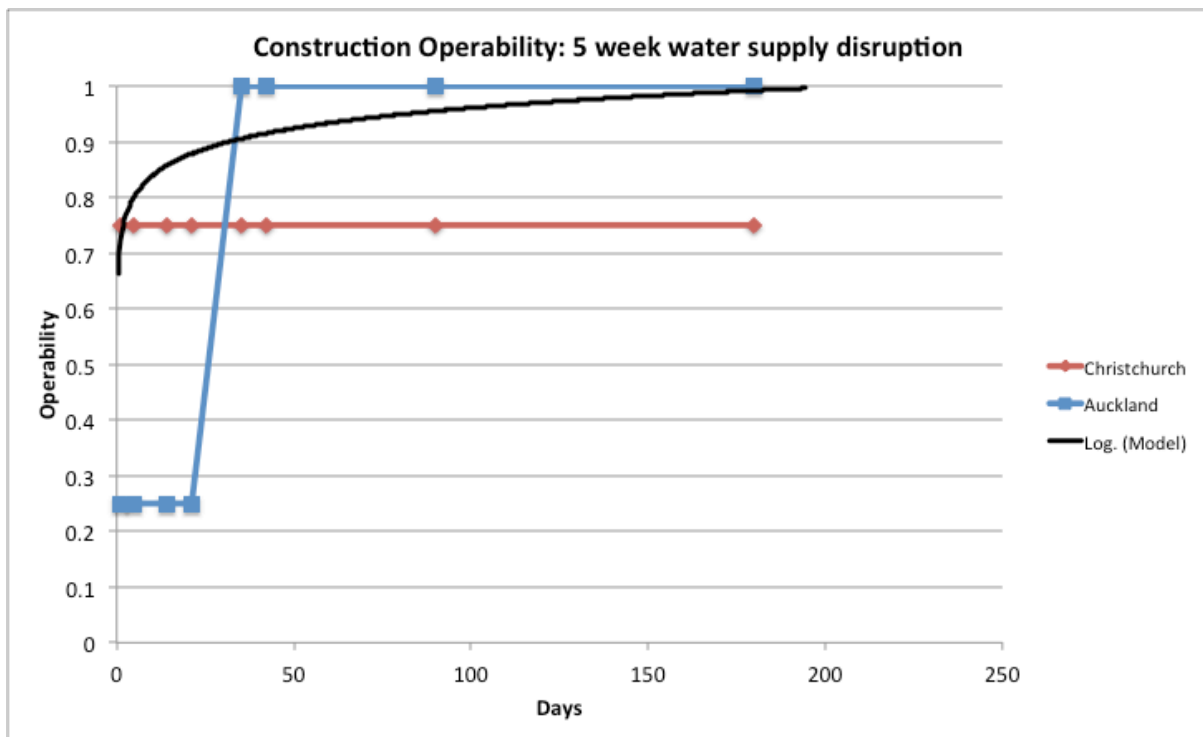
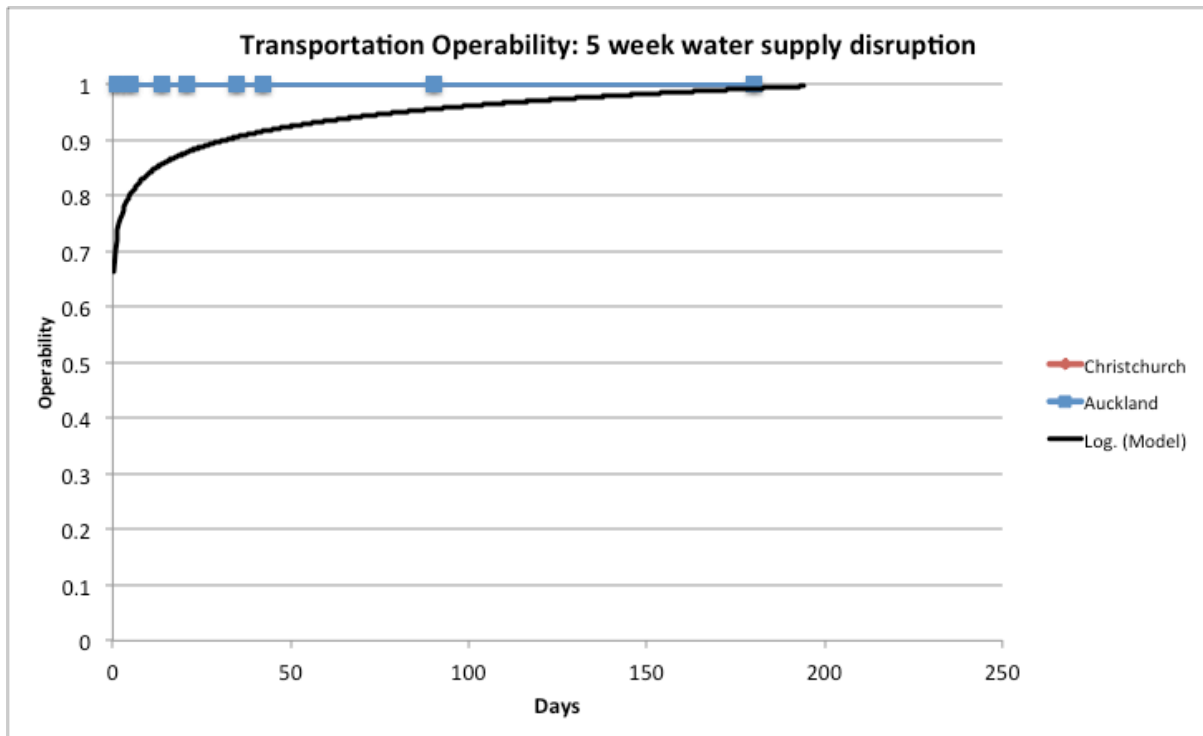


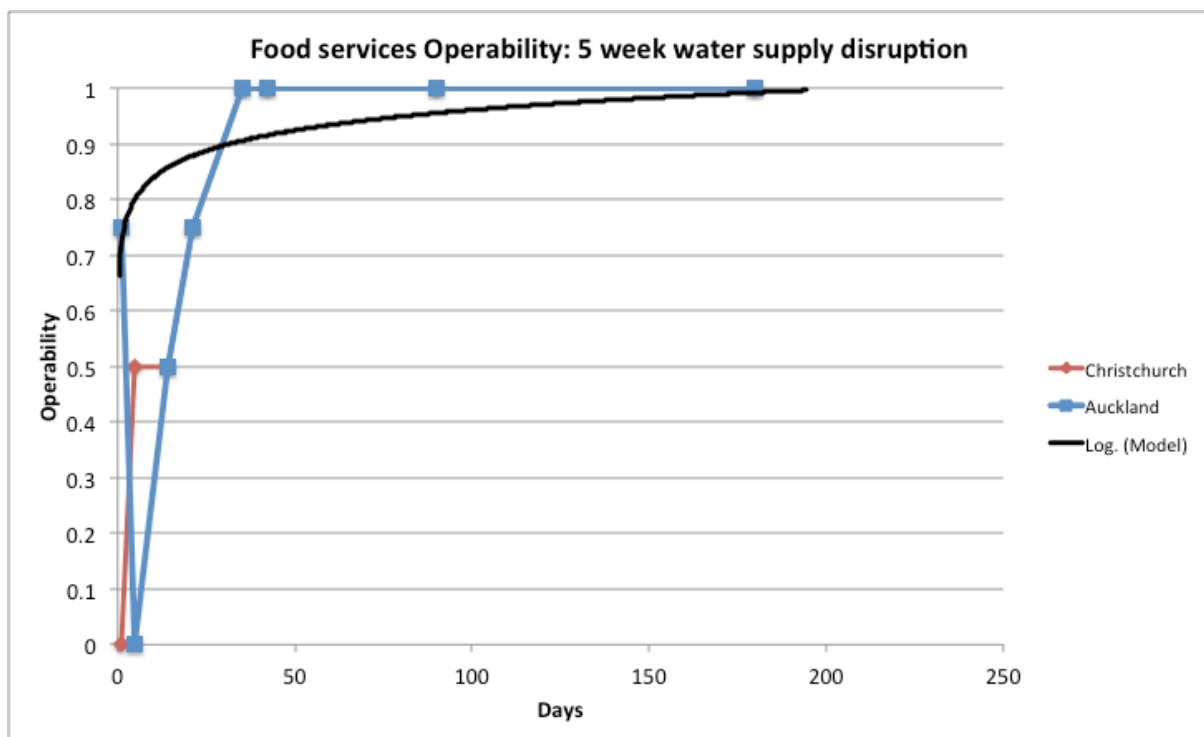
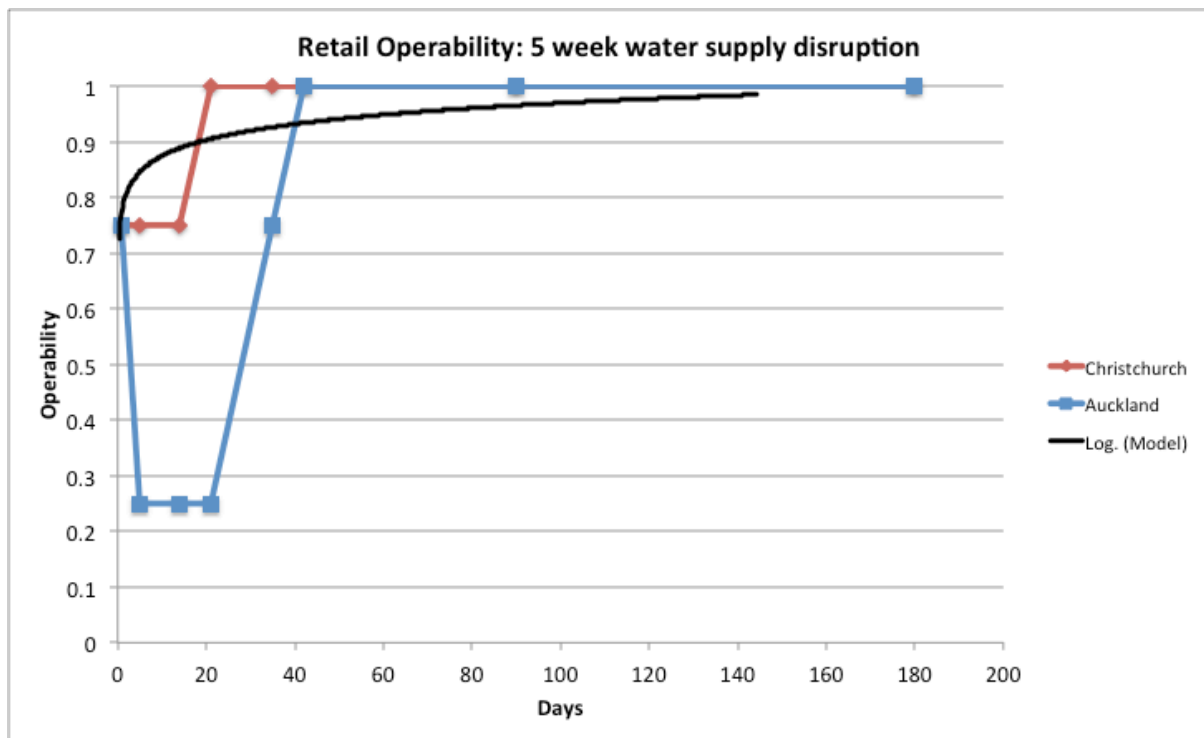




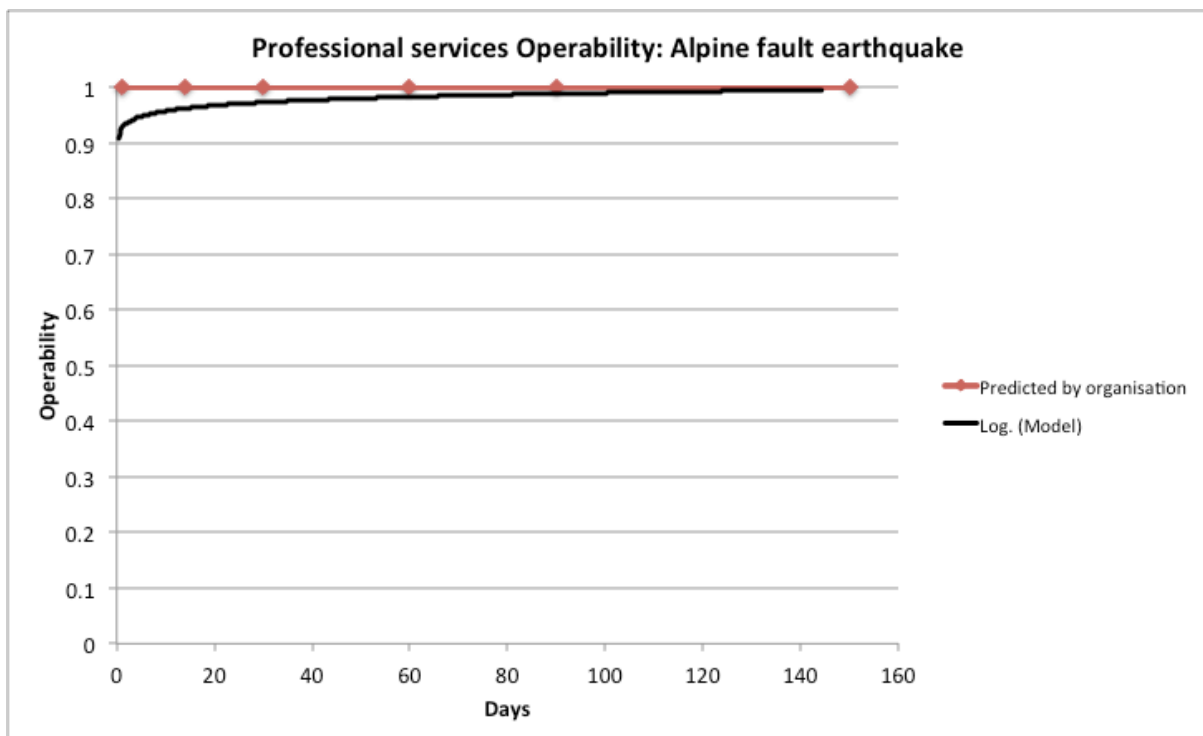
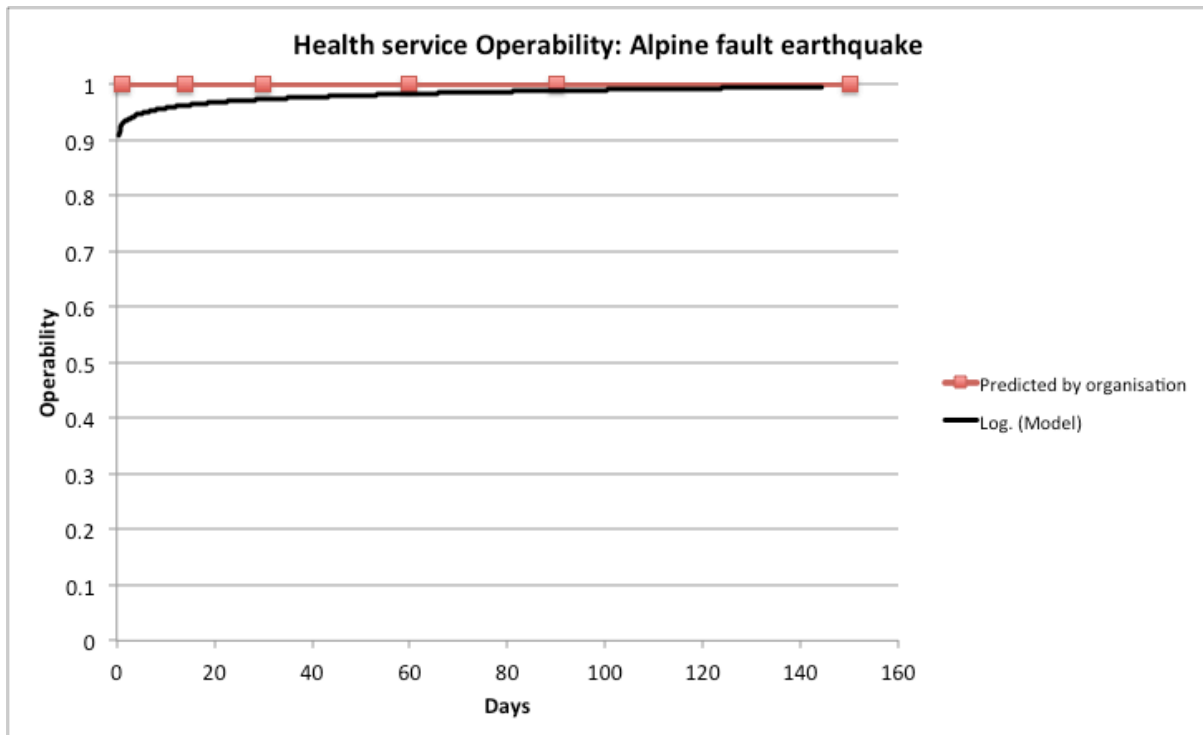
Water Disruption

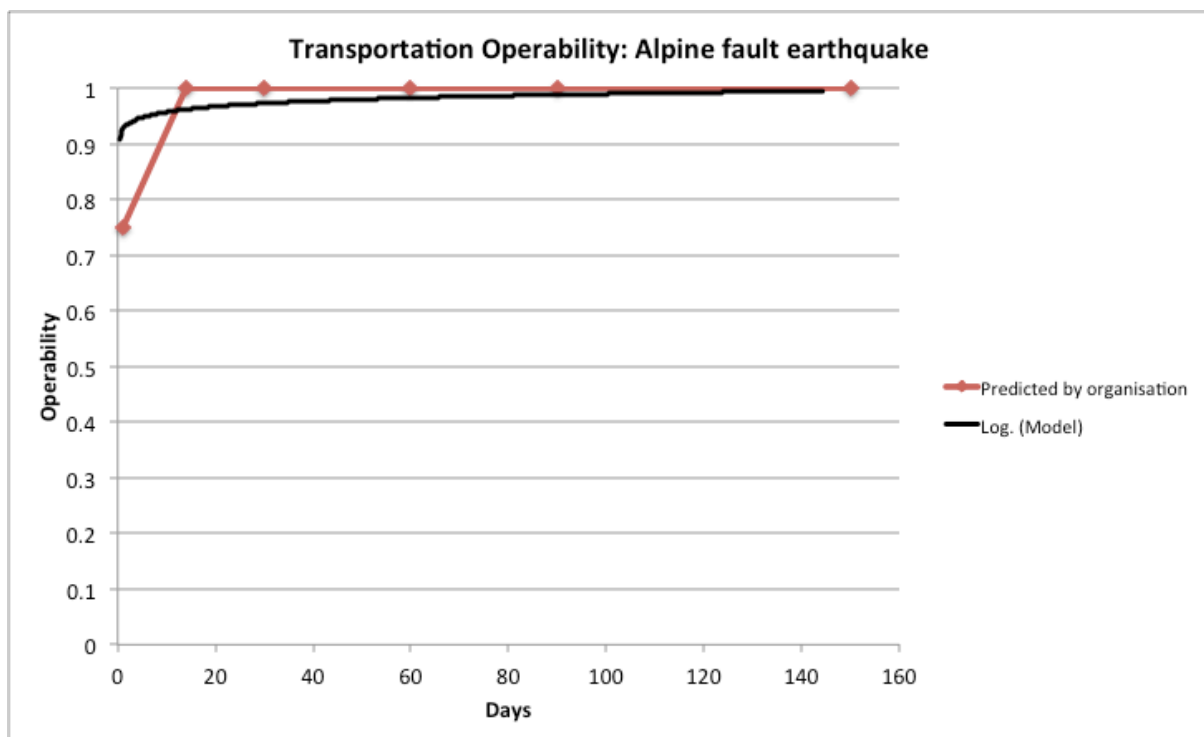
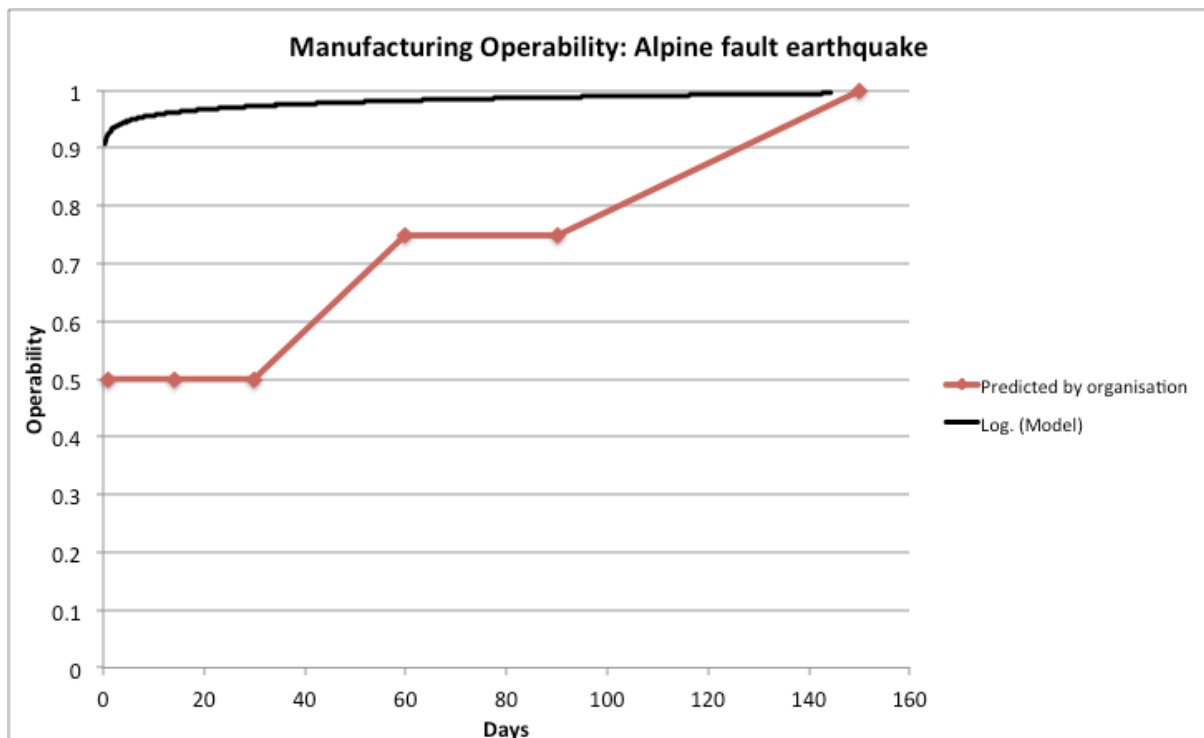


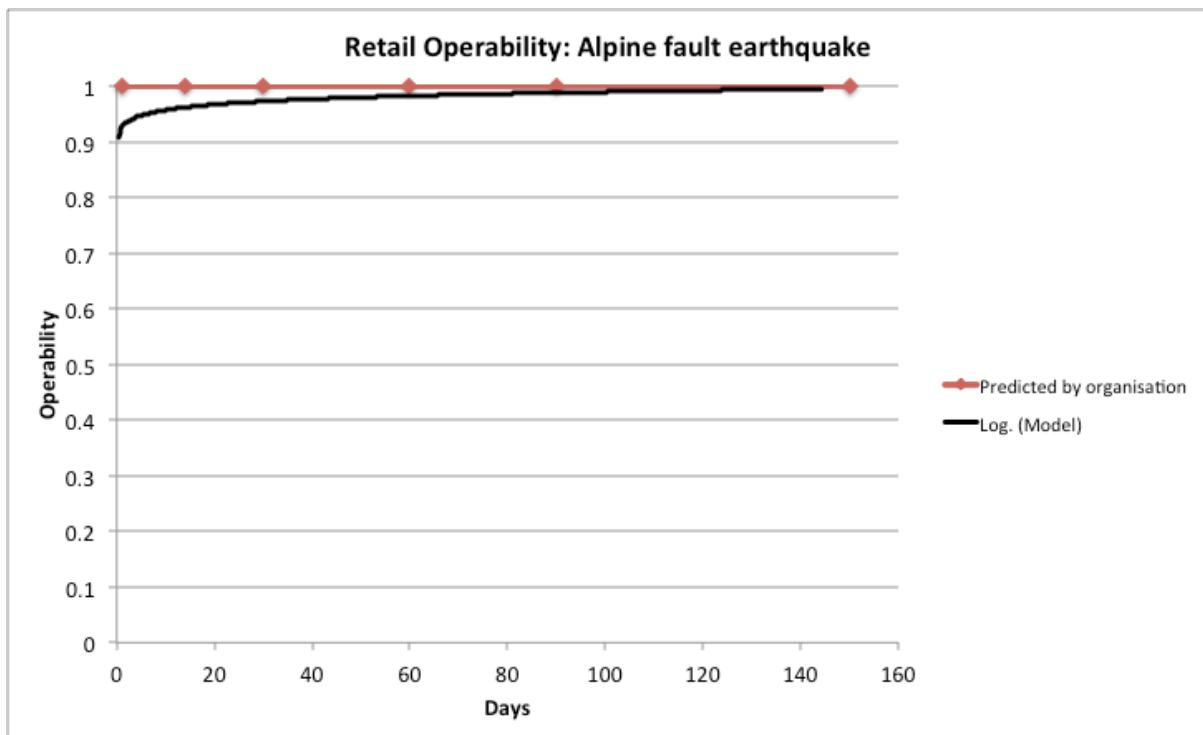
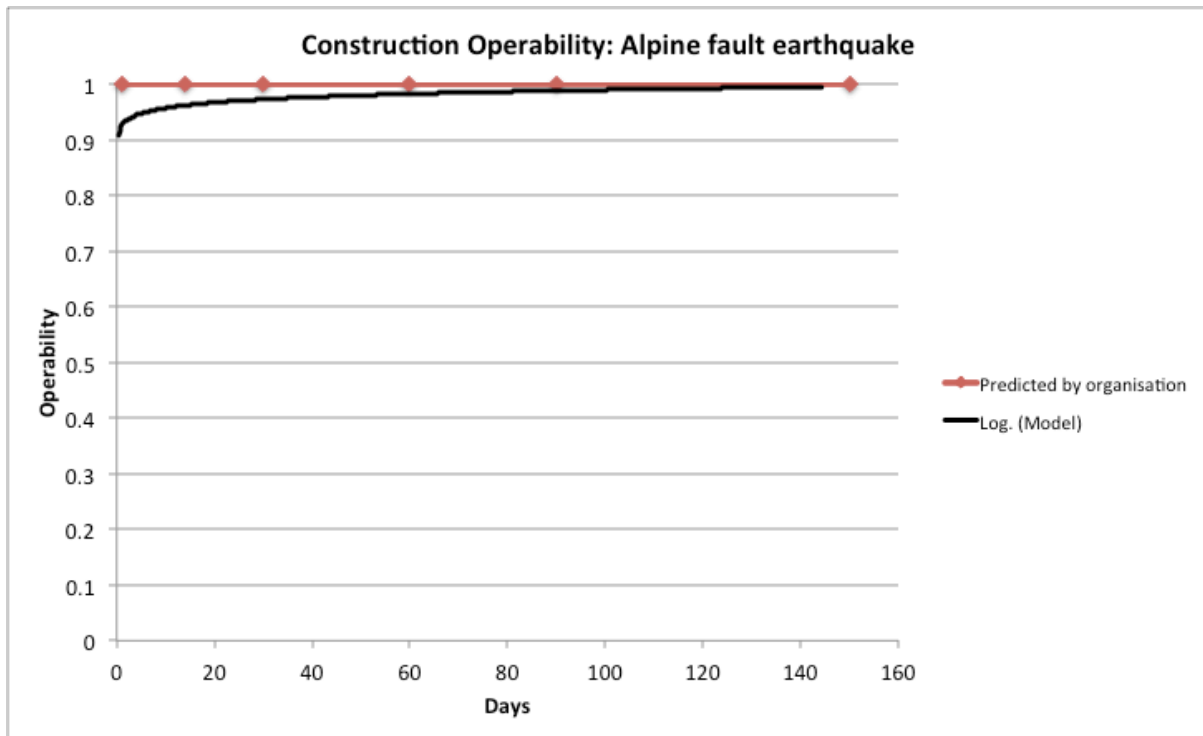


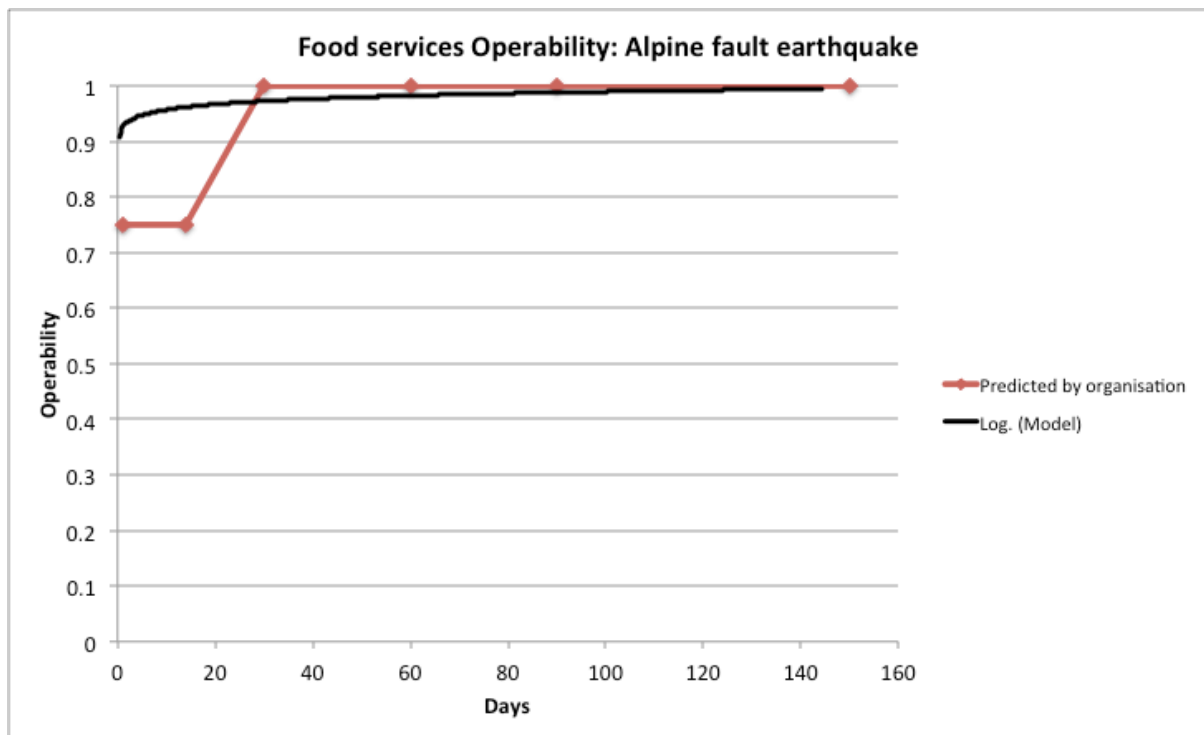


Alpine Fault

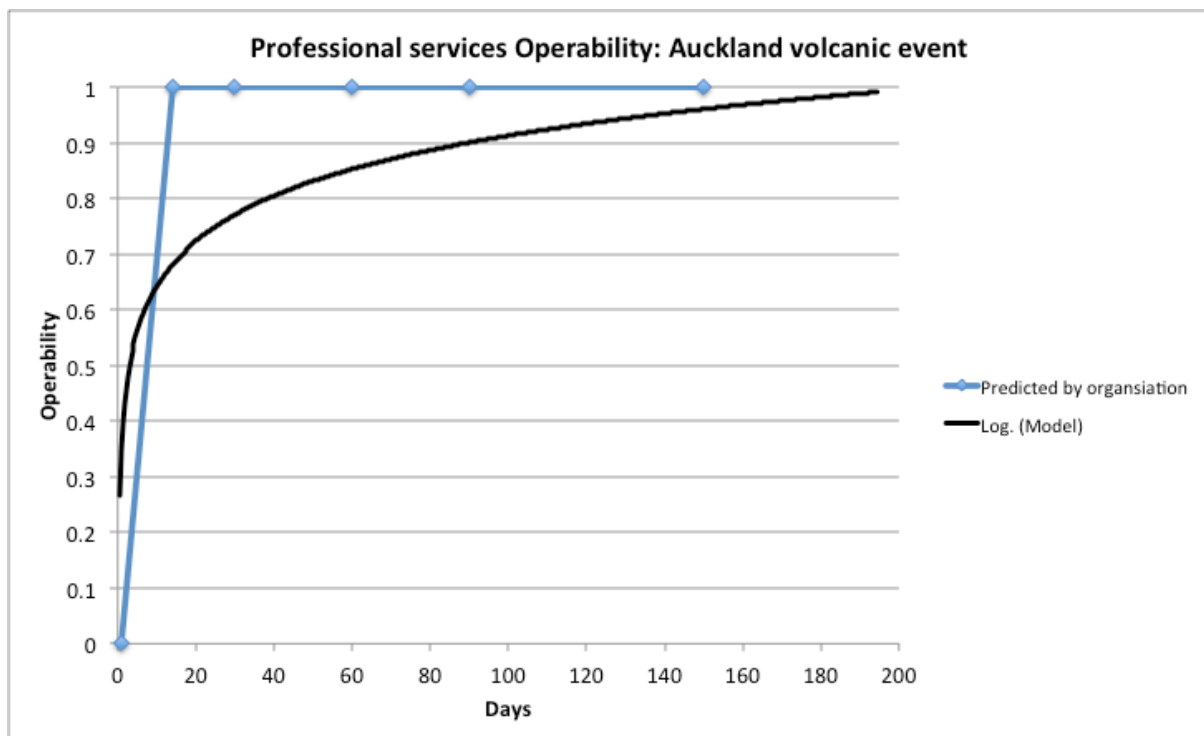
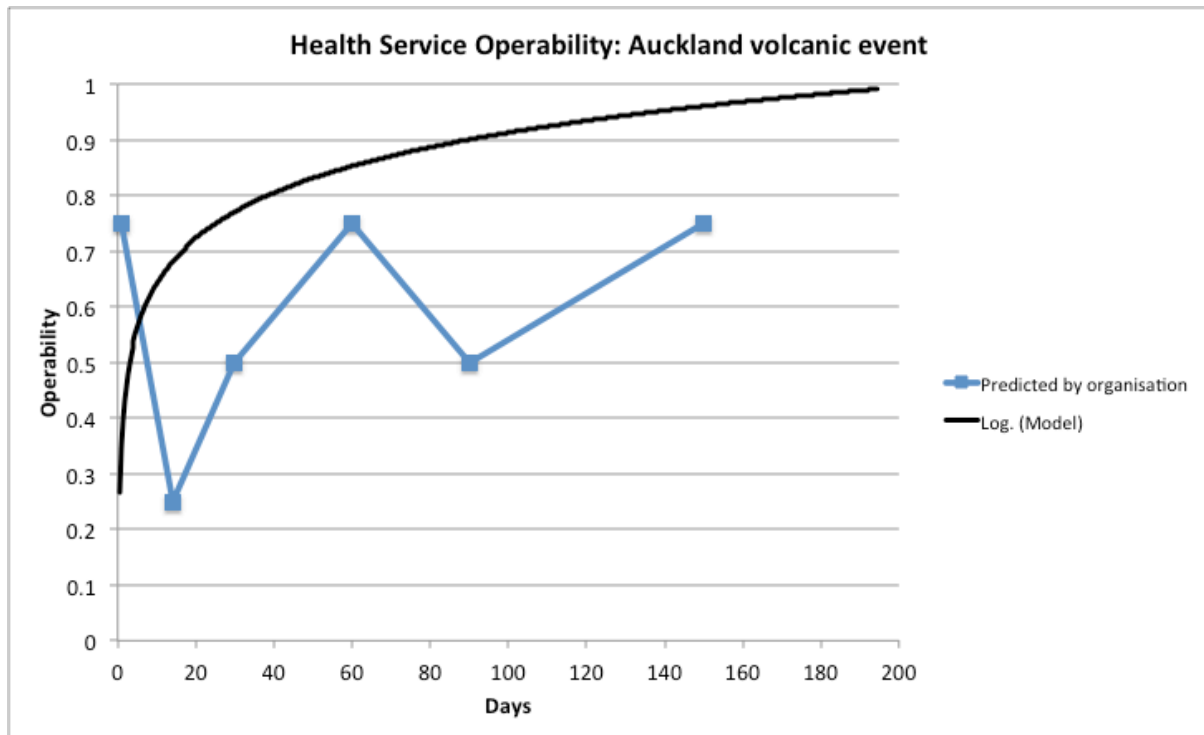


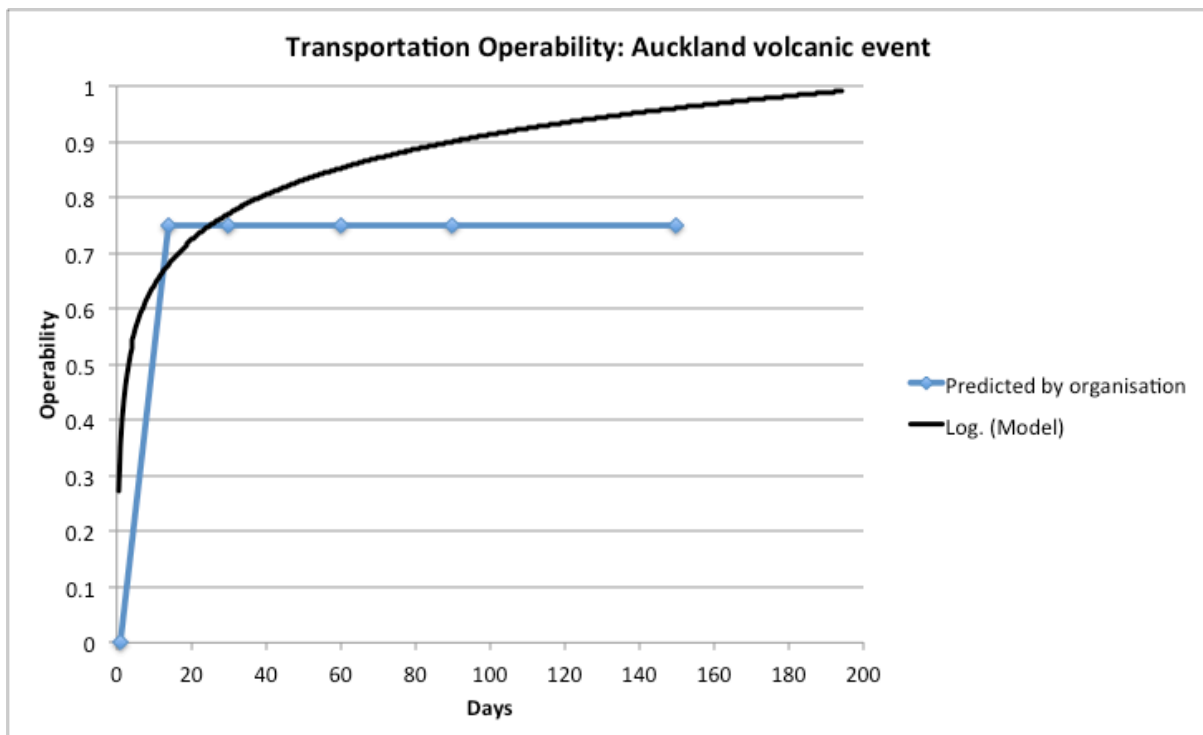
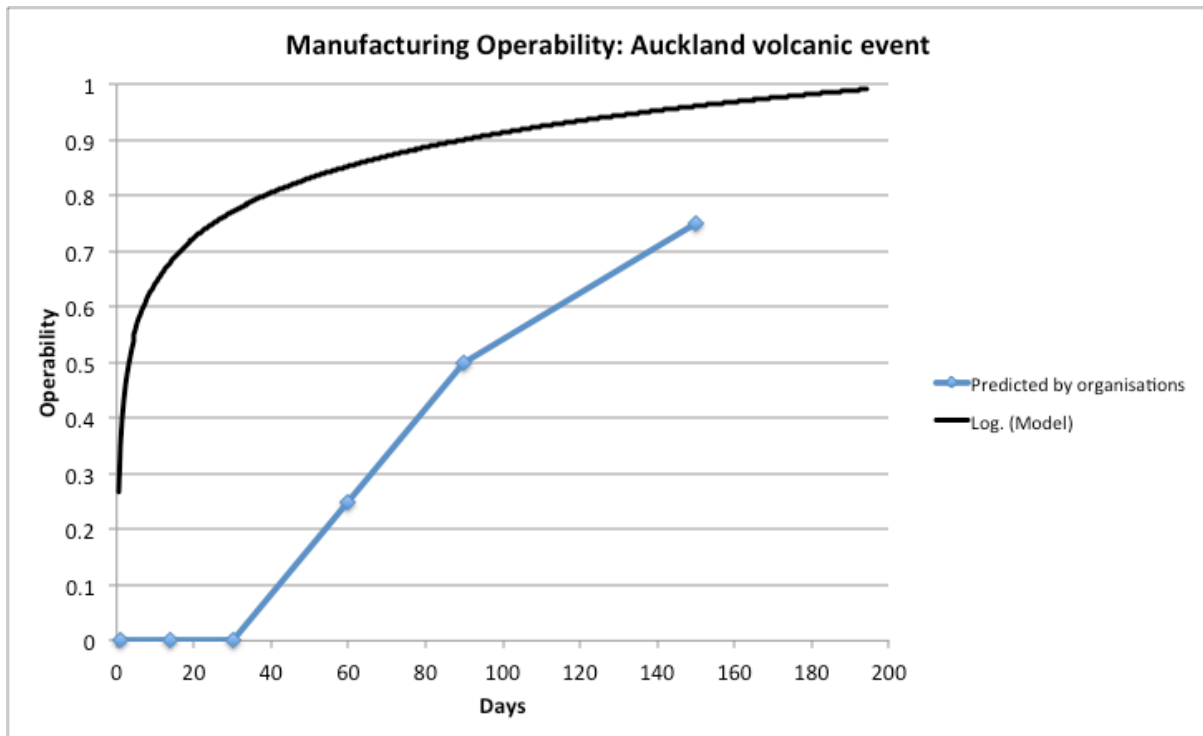


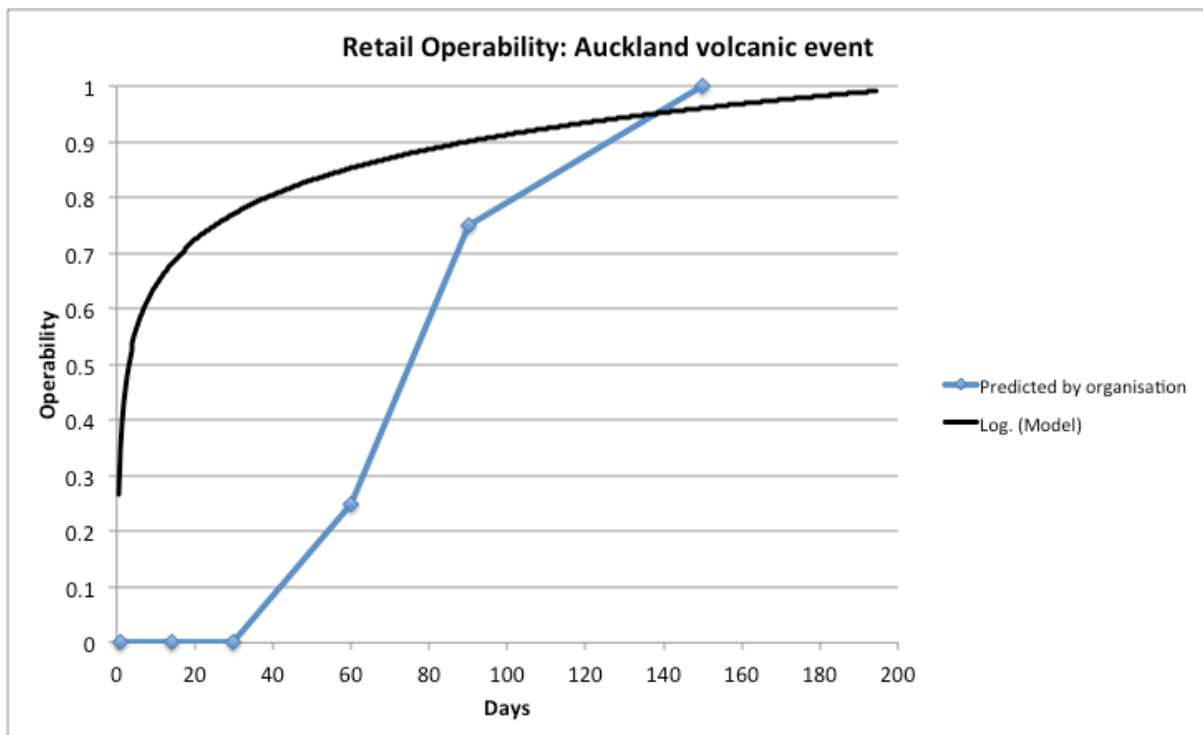
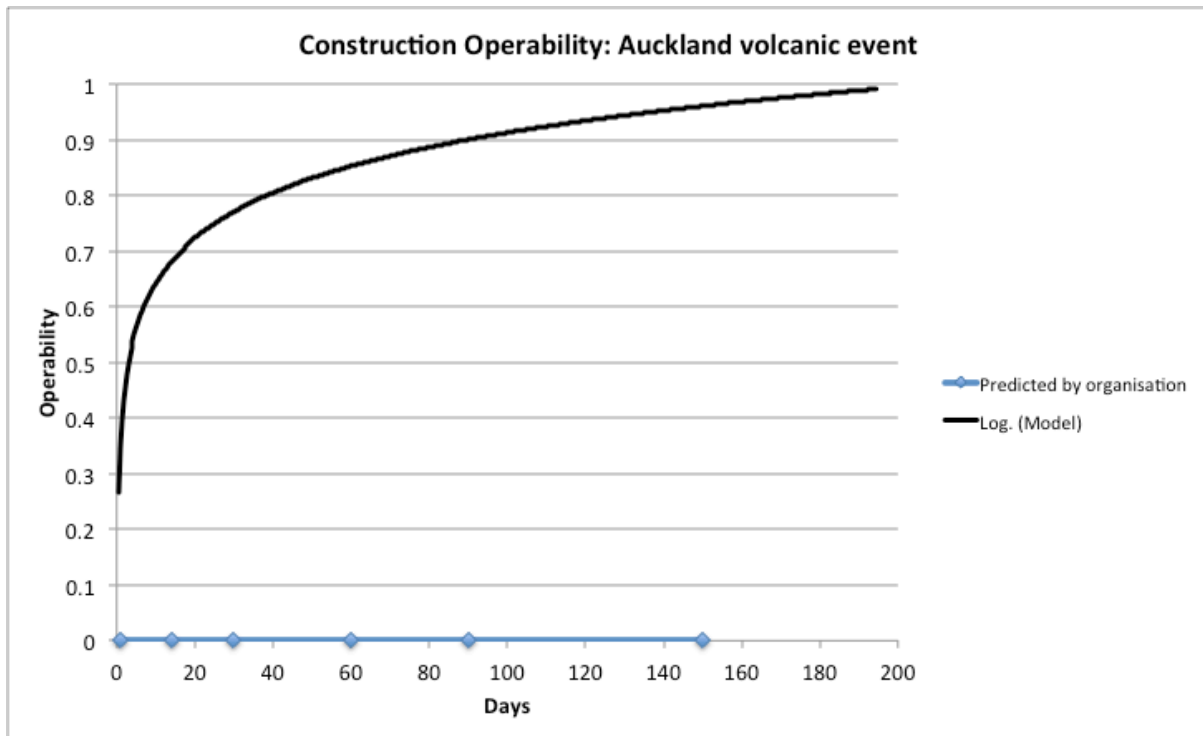


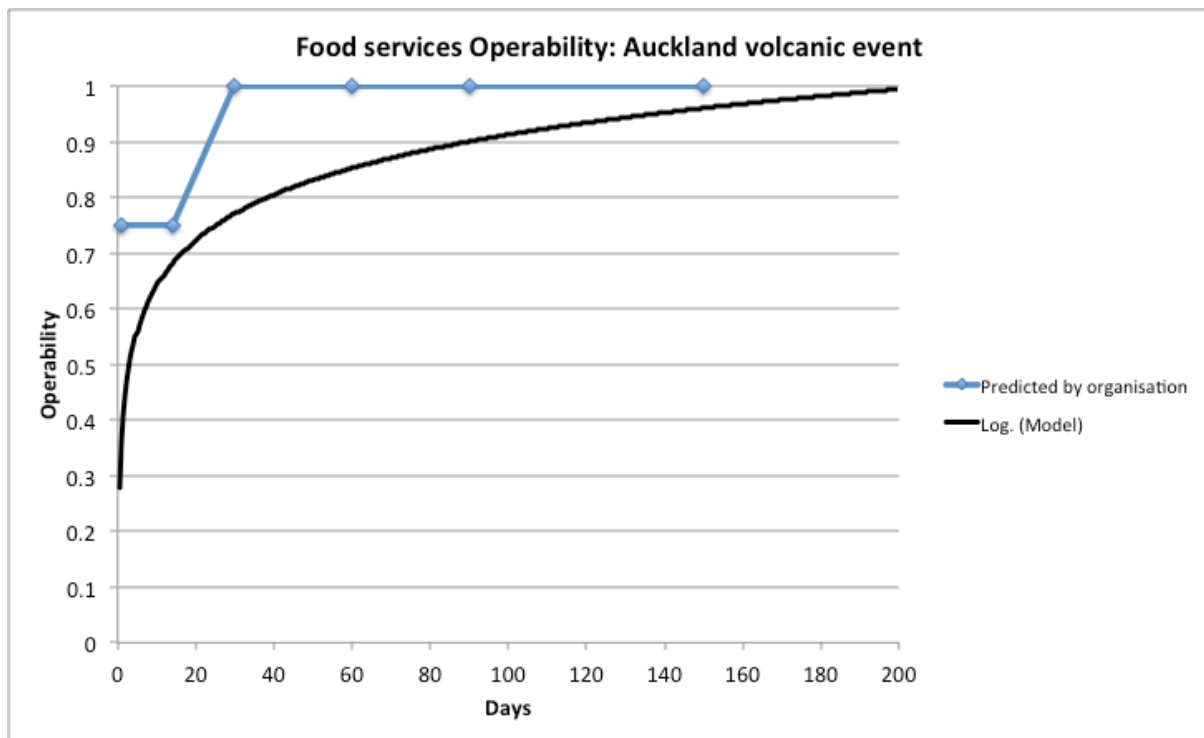


Auckland Volcano











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