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Industry sector recovery following the Canterbury earthquakes

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Abstract

The Canterbury sequence of earthquakes offers an opportunity to study the post-disaster recovery process of organisations and industry sectors. This study uses data collected via a survey of organisations affected by the 22 February 2011 earthquake in Canterbury, New Zealand. The industry sectors in the study are: *construction* for its role in the rebuild, *information and communication technology* which is a regional high-growth industry, *trucking* for logistics, *critical infrastructure*, *fast moving consumer goods* (e.g. supermarkets) and *hospitality* to track recovery through non-discretionary and discretionary spend respectively. When compared to post-earthquake revenue changes, significant factors affecting organisations include customer issues, staff wellbeing and disruption to utilities. Also discussed is the differential effect these factors have on the industry sectors studied. This paper identifies the different factors that disrupted organisations in different sectors; explores the relative impact of these disruptions; and examines the differences in short- to medium-term recovery trends.

Keywords: organizational disaster recovery, earthquakes, recovery, industry sectors, urban centres, New Zealand

1 Introduction

On 4 September 2010, the Canterbury region of New Zealand experienced a M_w 7.1 earthquake. The epicentre was approximately 40km west of Christchurch, New Zealand's second largest city.

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On 22 February 2011, a M_w 6.3 aftershock located 13km south-east of the Christchurch CBD caused vertical ground accelerations that were among the highest ever recorded in an urban environment (DBH, 2011; GNS Science, 2011). The 22 February 2011 earthquake led to the loss of 185 lives. Parts of Christchurch's central business district (CBD) were cordoned off, restricting access for up to almost two years later. Throughout the greater Christchurch area, liquefaction, lateral spread and shaking caused unprecedented levels of damage to structures and utilities.

The estimated cost of recovery and reconstruction was between NZ$30 and 40 billion (New Zealand Department of Treasury, 2013). This figure accounted for approximately 20 per cent of New Zealand's GDP. After 22 February 2011, organisations in Canterbury faced the complex challenge of recovery from the cumulative effects of multiple earthquakes. These organisations operated in an environment of constant uncertainty as the earthquakes caused repeated closures, structural and non-structural damage, utility disruption, and psycho-social stress of employees and customers (see Whitman et al., (2014), Stevenson et al., (2011), Kachali et al., (2012) and Kachali (2013)).

This paper forms part of a longer-term study whose primary objective is to investigate the ongoing impacts and recovery of organisations and sectors after the 4 September 2010 and 22 February 2011 earthquakes, by collecting information at different points in the recovery timeline. The paper identifies important factors organisations and sectors faced in this time period, as well as to what extent these organisations and sectors were affected by these different factors. Some of these factors are disruption to utilities and effects to staff and customers.

The objective of this paper is to add to the information and knowledge base of organisational and sectoral recovery after disaster by documenting results specifically from the 9-to-12 month period after a disaster event. The study also aims to compare how different sectors are affected by and recover from disasters.

For this study, organisations were sampled by industry sector. This gives a better understanding of the effects of disaster on different industry sectors and the organisations within these sectors. This information is useful for both industry sectors and recovery planners, as input for pre- and post-disaster recovery planning.

This paper is laid out as follows: the first part contains a discussion of some of the key studies that have addressed organisational and sectoral disaster recovery, an explanation of the method

and rationale used to gather data as well as a description of the sample set. This is followed by results for organisations that reported being affected by the September 2010 and/or the February 2011 earthquakes and details the use of post-disaster trends in organisational revenue as a measure of recovery. Thereafter, the direct and indirect effects reported by sectors are discussed. These effects include organisational closure, factors that disrupted organisational operations, staffing adjustments and revenue changes are presented by sector. The effects are then compared to each other using the Kruskal-Wallis test. Lastly, there is discussion on the differential effects, of the earthquakes, to the various sectors.

1.1 Research context

Findings from disaster recovery studies detail differential impacts to organisations after disaster. For instance, Alesch et al., (2001) and Nigg and Tierney (1990) write that some organisations do not re-open. For those that do re-open, the length of operation after disaster and the impacts to revenue also differ. Some organisations open for a short while and then close, while others struggle to survive even a few years after a disaster event and then eventually close. Reasons for this include a change in the customer base, the decreased need for goods and services, the inability to access organisational premises, the inability to access materials needed for the business or decreased cash flow (Miller, Paton, & Johnston, 1999; Wasileski, Rodriguez, & Diaz, 2010; Webb, Tierney, & Dahlhamer, 2002).

Furthermore, organisations are affected by both the direct and indirect effects of a disaster that could last for an extended period (S. E. Chang & Falit-Baiamonte, 2002). An example of a direct effect is structural damage to buildings caused by the ground motions of an earthquake (Coburn & Spence, 2002). Indirect effects are those not directly caused by the event itself. For instance, indirect losses such as decreased revenue could result from utilities interruption caused by a disaster (Dubendorfer, Wagner, & Plattner, 2004; Okuyama, 2007; Rose & Lim, 2002). Indirect impacts also include neighbourhood effects (LeSage, Kelley Pace, Lam, Campanella, & Liu, 2011). For example, location of an organisation next to a building that is damaged and cordoned off could lead to that organisation's closure. Organisational disruption, not only affects the economic health of that organisation, but inhibits the recovery of the organisation's employees, employees' families, and the communities that depend on them (Coles & Buckle, 2004; Miles & Chang, 2006; Nigg, 1995). However, there is not a measure for how *individual* effects of a disaster affect different organisations and sectors. Understanding the impacts caused by individual factors is important for hazard mitigation and planning.

Studies addressing organisational recovery often include organisations from different industry sectors. However, intentional sampling, in a single study and for comparative analysis, of several industry sectors is rare. Of the few studies that have analysed the recovery of industry sectors after disaster, results show dissimilar recovery trajectories. For instance, Dahlhamer and Tierney (1998) found that a larger proportion of recovered firms were from the manufacturing and construction sectors following the Northridge earthquake while Kroll et al., (1991) write that after the Loma Prieta earthquake, organisations from the retail and service sectors were more likely to suffer greater losses. Other work investigating sectoral recovery has addressed issues such as resilience, crisis management and recovery of individual industry sectors, for example, tourism (Orchiston, 2012; Ritchie, 2004); transport (Chen & Miller-Hooks, 2012); rural (see Whitman et al,. (Forthcoming; 2013)) tertiary education (Seville, Hawker, & Lyttle, 2011); and construction (Y. Chang, Wilkinson, Seville, & Potangaroa, 2011; Wedawatta, Ingirige, & Amaratunga, 2010).

Additionally, there is little agreement on the calculation or quantification of disaster effects to organisations. Some authors (Dietch & Corey, 2011) use a loss of revenue, a measure that is easily understood while others (Committee on Assessing the Costs of Natural Disasters, 1999) use the number of people collecting unemployment insurance in the wake of a disaster. Asgary et al.,(2013) as well as the Business Continuity Management Institute (2008) uses the number of days an organisation is unavailable, that is, closed, as a measure of the effects of disaster. In other work, Zhang, Lindell and Prater (2009) looked at impacts of organisational recovery from a community perspective while Rose et al., (1997) analysed recovery using a regional lens.

1.2 The Canterbury earthquake sequence

Since 4 September 2010, Canterbury had over 10 000 earthquakes of varying magnitudes. At least four events were of M_W 6 or greater. Additionally, each event acted to reset the recovery clock. The earthquake and aftershock sequence can be seen in Figure 1.

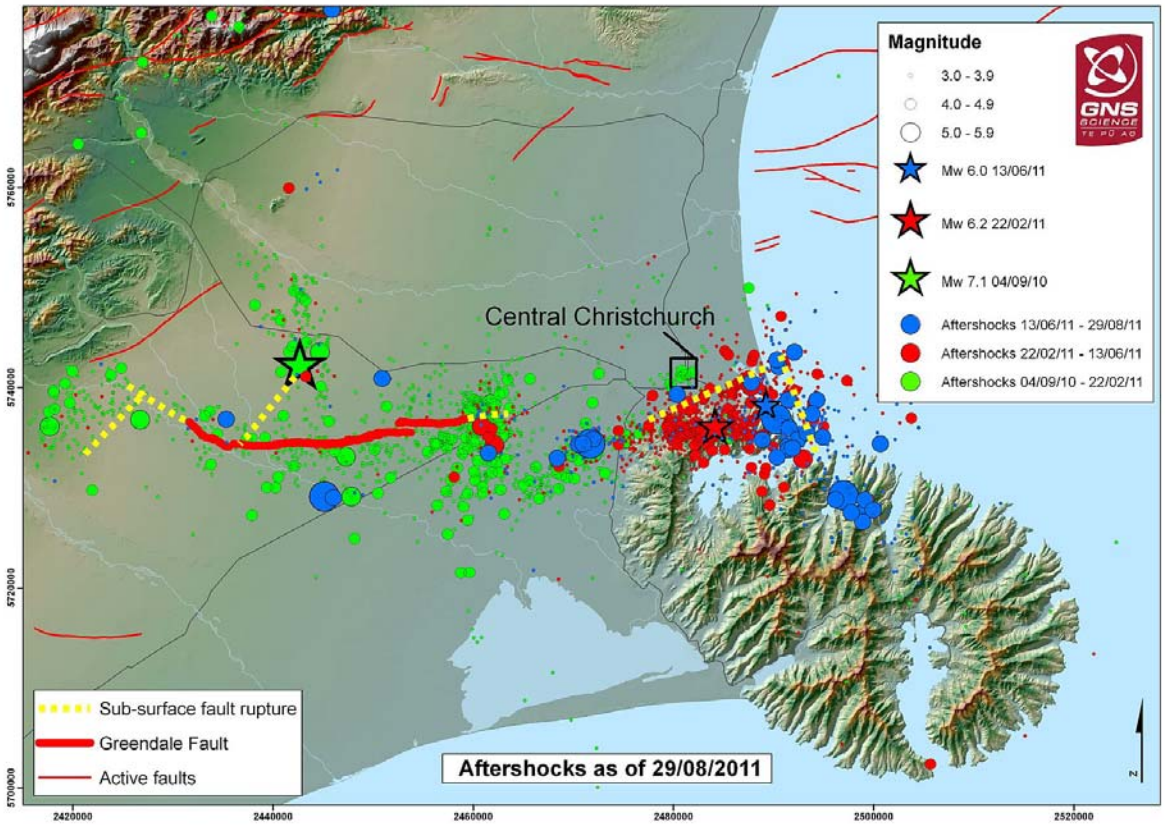

Figure 1: Canterbury earthquake and aftershock sequence from 4 September 2010 (GNS Science)

2 Method

The data utilised in this paper were collected using a questionnaire deployed to selected organisations in the Canterbury region from May to September 2011. The survey was deployed after the 22 February 2011 earthquake. Organisations were selected for the study using a stratified random sampling technique based on industry sector. Data were collected using Dillman's (2007) total design method, adapted to this work. Prior to questionnaire dispatch, all the sample organisations were contacted and asked to verify the physical address the questionnaire should be mailed to. Contact was via fixed and mobile telephone, organisation website, industry association and social media, e.g. Facebook. The multiple means of contact helped to ensure that organisations not operating from their physical address could also be reached. At the time of surveying, some of the organisations that responded were still closed.

Questionnaires were mailed to the address given by the organisation. This was followed by a telephone call where organisations were given the option of completing the survey by phone or in a personal visit with a member of the research team, completing the survey online or returning it by post or e-mail. The multi-format approach was designed to cater for those organisations

that might have relocated, closed or were too busy to complete the telephone survey during work hours. The flexible format approach to data collection helped to improve the response rate.

The survey was used to collect information regarding the direct and indirect impacts of the Canterbury earthquake sequence on organisations, as well as strategies organisations employed to recover. The survey also asked about organisational factors, supply chain issues, the types and extent of disruption, revenue changes, staffing changes, relocation and cash flow.

Similar to other disaster studies, e.g. Dietch and Corey (2011), one aspect of this research is that the organisations followed were those that could be reached during the course of this study. Consequently, there is a possibility of survivor bias as there are no data from possible permanently closed organisations that were on the initial sample list, or that could not be reached by the authors. Information on why organisations may have closed permanently would be helpful to disaster researchers and policymakers.

However, data analysed by Statistics New Zealand (2012e) showed no significant (2.5%) business closure in Christchurch between February 2011 and February 2012. Furthermore, it should be noted that not all the organisations surveyed were foreordained to recover. For instance, Alesch (2005) and Alesch et al., (2001) detailed how some organisations failed 4-7 years after disaster events.

Industry sectors included in the study were selected in consultation with a panel of six experts and key players in recovery, resilience and the economies of Christchurch and Canterbury. One of the factors in selecting the sample was that we wanted to obtain a breadth of information about industry sectors that represented different aspects of the Canterbury economy. Although not all sectors were included, see Table 1 for sectors in the study, we tried to capture diverse perspectives on how different parts of the economy were affected by the earthquakes. In addition, the study was targeted at organisational recovery in an urban setting and with the resources available for the research; only a limited number of sectors could be examined in detail.

For this reason, manufacturing and business services, even though they are high growth sectors, were excluded. However, it was identified that some of the sectors selected, e.g. ICT, had organisations that were involved with aspects of manufacturing or business services. Also, the manufacturing sector is closely linked to some of the other sectors selected such as trucking and retail. Analysing the trucking and retail sectors should provide some insights into some of the factors that might affect the manufacturing industry. Again, while this survey has not sampled all

the industry sectors in Canterbury, the aim was to sample a breadth of sectors that could reflect impacts on the wider economy of Canterbury due to sector inter-dependencies.

Critical infrastructure and building suppliers were identified as sectors that would likely assist in response and recovery efforts, while the trucking was selected because it is a vital link in the supply chains of many other industry sectors. Hospitality and Fast Moving Consumer Goods (FMCG) are sectors that capture customer discretionary and non-discretionary spending respectively. In other work on organisational recovery, Tierney (2007), Zhigalova (2011) and Kachali (2013) point to how consumer behaviour is affected by disaster and that this has a bearing on organisational recovery.

Table 1: Industry sectors included in the study of recovery after the Canterbury earthquakes

Sector	Description
Building Suppliers	Wholesale and retail (includes manufacturers and suppliers for the construction sector)
Critical Infrastructure	Lifeline utilities (for example electricity, water)
Fast Moving Consumer Goods (FMCG)	Includes dairies (the New Zealand equivalent of the corner or convenience store), secondary producers and supermarkets.
Hospitality	Specifically restaurants, bars and cafes
Information and Communication Technology (ICT)	Web based services, computer software and hardware manufacture, sales and repairs, and IT consulting
Trucking	Road transport, including long-haul, pickup and delivery, and specialised trucking

3 Response rate and descriptive characteristics

Two hundred and thirty-five organisations from different sectors were invited to take part in the survey, 102 returned valid responses, giving a response rate of 43%. Organisations were asked to state whether the 4 September 2010 and/or 22 February 2011 earthquakes had had an impact on their organisation. The term "impact" was not defined in order to include the broadest range of answers to a subjective term and to enable the respondents' evaluation and judgement. However, subsequent questions in the survey asked respondents to describe how they had been affected by either event. This was done in 2 ways; through pre-set survey questions which asked about specific impacts and by asking the respondents to describe effects in free-form, open-ended answers. This approach is in line with findings from other disasters. For instance, Freedy et al., (1992) write that disasters should not be seen as events that affect people similarly. They go on to note that some people are affected more than others and that people's capacity to cope also varies.

Eighty-six per cent of organisations reported being affected by the 4 September 2010 earthquake while 92% were affected by the 22 February 2011 event. A complete breakdown of the percentage of affected organisations, by sector, is in Table 2. The responses shown for the rest of the paper are for organisations that reported having been affected by either earthquake.

Table 2 – Per cent of organisations, by sector, affected by 4 September 2010 or 22 February 2011 earthquakes

Sector	N	Sectoral FTE prior to 22 February 2011		Own or Rent organisation's premises		Organisational formal written crisis/emergency or business continuity plan			Affected 4 September 2010 earthquake (%)	Affected 22 February 2011 earthquake (%)
		Sectoral FTE range	Average sectoral FTE	Own (%)	Rent (%)	Yes (%)	No (%)	Don't Know (%)		
Building Suppliers	13	2-80	16	31	69	33	67	0	92	100
Critical Infrastructure	16	1-1000	195	42	56	94	6	0	94	100
Fast Moving Consumer Goods (FMCG)	18	1-1200	151	31	69	63	31	6	94	89
Hospitality	14	1-28	7	21	79	8	75	17	93	86
Information and Communication Technology (ICT)	27	1-138	19	15	85	22	74	4	59	89
Trucking	14	1-500	63	64	36	33	58	8	86	86
Total	102	1-1200	74	32	68	43	52	5	86	92

The sectors with the highest number of organisations affected by both earthquakes were critical infrastructure and building suppliers. The ICT sector had the largest increase in number of organisations affected by the February event (89%) compared to that of September (59%).

4 Sectoral Impacts

The following section details the impacts to the different sectors sampled. Effects are to organisational operating hours, disruption to utilities (water, sewage, electricity, communications and roads) as well as disruption to non-utilities (resulting from damage to building and other organisational assets, staff wellbeing and supply chain issues).

4.1 Operational hours and closure after the earthquakes

Organisations were asked if they closed or had different operating hours than normal because of the earthquakes, with results shown in Table 3. Thirty per cent of organisations from the

hospitality sector indicated that they were still closed 3-7 months after the 22 February 2011 earthquake. Owners and managers indicated that the nature of the equipment and regulations (e.g. food handling) in the sector made it difficult for them to operate from alternative premises. The reasons for closure illustrate that organisational unavailability and interruption are also caused by factors other than direct damage to the organisation's physical assets. Additionally, these are contributing factors to recovery as organisations do not always have the financial means, e.g. insurance, to cover non-structural and business interruption losses (Wasileski et al., 2010).

*Table 3 - Sectoral operational hours and closure after the 4 September 2010 and 22 February 2011 earthquakes**

	Closed temporarily		Closed permanently		Remain open as usual		Remain open fewer hours		Remain open longer hours	
	4 September earthquake	22 February earthquake	4 September earthquake	22 February earthquake	4 September earthquake	22 February earthquake	4 September earthquake	22 February earthquake	4 September earthquake	22 February earthquake
Building Suppliers	62%	54%	0%	15%	31%	15%	8%	15%	0%	0%
Critical Infrastructure	50%	50%	0%	0%	19%	13%	13%	13%	19%	25%
Fast Moving Consumer Goods (FMCG)	73%	60%	0%	13%	20%	20%	7%	0%	0%	7%
Hospitality	62%	50%	15%	25%	15%	17%	8%	0%	0%	8%
Information and Communication Technology (ICT)	52%	64%	0%	0%	35%	28%	9%	4%	4%	4%
Trucking	33%	17%	0%	0%	25%	42%	17%	8%	25%	33%
Total	55%	52%	2%	8%	25%	23%	10%	6%	8%	12%

**For this and subsequent tables, results are reported as percentage of organisations per sector.*

More organisations from the critical infrastructure (25%) and trucking (33%) sectors reported operating for longer hours after the February earthquake than from other sectors. A trucking industry representative reported that one reason for this was the increased demand for trucking services, such as the need for debris removal after the earthquakes and, in some cases, household removal to enable relocation. For both earthquakes, temporary closure was cited more often than permanent closure for the entire sample. For organisations that did close temporarily or permanently, the three most frequently cited reasons across all sectors were: *needed to clear up damage to the interior* (73%), *building waiting to be structurally assessed* (57%) and *stock loss or damage* (53%). In the survey, organisations were also asked to give the reasons that led to closure. A tally

of all the elements that led to closure was used to calculate each organisation's closure impact factor.

4.2 Utility and non-utility factors of disruption

Showing the effects of utilities and non-utilities separately helps to resolve how each set affected organisations in each sector. Results for utility factors of disruption are presented in Table 4 while those for non-utility factors of disruption are in Table 5. For ease of presentation, the disruptive factors are grouped and presented as *utility* and *non-utility*.

Organisations were asked to classify on a 4 point scale, from *not at all* (0) to *very* (3), the level of effect for each disruptive factor. Results were computed so as to obtain an aggregated *degree of effect* for each organisation for all disruptive factors. This is referred to as the organisational degree of effect, ODE, and is calculated using Equation 1;

$$\text{Organisational Degree of Effect } (ODE) = \frac{1}{n}\sum_{i=1}^{n}\left(\frac{Si}{3}\right) * 100$$

Equation 1: Calculation for overall Organisational Degree of Effect (ODE) for factors of disruption, for a single organisation

where *i* is the disruptive factor, *s* is the level of intensity for each factor and is assigned a value from 0 (not at all) to 3 (very) for each disruptive factor (hence S_i) and n is the total number of disruptive factors. For example, each organisation assigns a score (from 0 to 3) for each disruptive factor. Σ is the summation of the disruptive factors. The organisational individual disruptive factor scores are totalled, averaged and then divided by 3 (the maximum possible score for each disruptive factor). This is then multiplied by 100 to give a score out of 100.

Further, to obtain the degree of effect for the sector, the ODE values for all organisations in that sector were averaged. The sectoral degree of effect (SDE) ranges from 100, the highest severity disruption to 0, no disruption.

4.2.1 Sectoral utility factors of disruption

Organisations in each sector were asked which of the utility factors of disruption they were affected by and to what degree. Results are broken down by sectors and shown in Table 4. The three disruptive utility factors sectors were more *frequently* affected by are shown in **bold highlighted cells** and reported as a percentage of organisations per sector**.** In addition, the three factors, or SDE, affecting each sector more *severely* are also shown in **bold highlighted cells**.

A larger percentage of critical infrastructure organisations, than any other sector, were affected by disruption to road networks (87%), water (81%) and sewerage (81%). For instance, not only does a break in the road network cause disturbance to an organisation's suppliers or customers, it also impedes how quickly and effectively utility providers can restore essential services. The hospitality sector had a higher sectoral degree of effect, SDE, from disruption to road networks (76 out of 100), electricity (76 out of 100) and sewerage (71 out of 100). The results in Table 4 demonstrate that not only is it important to investigate the factors that cause disruption to organisations but also to what level this disruption occurs and affects recovery. For example, 87% of critical infrastructure and 69% of hospitality organisations reported road network disruption while the SDE for road network disruption was 67 (out of 100) for critical infrastructure and 76 (out of 100) for hospitality. It is evident that utility outages had different degrees of disruption on organisations across the different industry sectors.

Table 4: Per cent of organisations, by sector, citing factors (utility) that caused disruption to organisational operations and sectoral degree of effect (SDE) for affected organisations broken down by disruptive factors (utility)

	Building Suppliers		Critical Infrastructure		Fast Moving Consumer Goods (FMCG)		Hospitality		Information and Communication Technology (ICT)		Trucking		Total	
	% of organisations	Sectoral degree of effect	% of organisations	Sectoral degree of effect	% of organisations	Sectoral degree of effect	% of organisations	Sectoral degree of effect	% of organisations	Sectoral degree of effect	% of organisations	Sectoral degree of effect	% of organisations	Sectoral degree of effect
Water supply disruption	**62%**	**74**	**81%**	**72**	**73%**	**67**	**69%**	70	**60%**	47	33%	**42**	**64%**	**62**
Sewage or effluent disruption	46%	67	**81%**	59	38%	**63**	50%	**71**	44%	**55**	25%	**50**	48%	**61**
Electricity disruption	**62%**	**70**	69%	**69**	56%	40	**69%**	**76**	**52%**	**62**	**42%**	40	**58%**	60
Communications disruption	**75%**	63	69%	63	**63%**	52	58%	70	48%	**51**	**42%**	**50**	**58%**	58
Road network disruption	**67%**	**70**	**87%**	**67**	**81%**	**64**	**69%**	**76**	**60%**	49	**67%**	**71**	**71%**	**66**

4.2.2 Sectoral non-utility factors of disruption

For the non-utility factors of disruption shown in Table 5, within each sector the top three factors (by percentage) cited most frequently as affecting organisations are shown in **bold highlighted cells**.

Table 5: Per cent of organisations, by sector, citing factors (non-utility) that caused disruption to organisational operations and sectoral degree of effect (SDE) for affected organisations broken down by disruptive factors (non-utility)

	Building Suppliers		Critical Infrastructure		Fast Moving Consumer Goods (FMCG)		Hospitality		Information and Communication Technology (ICT)		Trucking		Total	
	% of organisations	Sectoral degree of effect	% of organisations	Sectoral degree of effect	% of organisations	Sectoral degree of effect	% of organisations	Sectoral degree of effect	% of organisations	Sectoral degree of effect	% of organisations	Sectoral degree of effect	% of organisations	Sectoral degree of effect
Structural damage to building(s) (integrity of building compromised)	46%	44	56%	**77**	63%	64	**69%**	**76**	32%	50	33%	33	48%	**57**
Non-structural damage (fittings damaged e.g. windows or light fixtures)	**69%**	47	**75%**	56	75%	40	**67%**	**73**	**64%**	**56**	36%	17	**66%**	48
Damage to equipment (non-computing)	46%	37	63%	60	56%	45	58%	70	56%	48	25%	7	52%	45
Damage to computers	15%	17	50%	58	19%	6	50%	58	38%	**60**	0%	0	31%	33
Damage to inventory or stock	**69%**	42	40%	63	**81%**	**72**	**77%**	70	36%	50	27%	33	54%	55
Damage to ground surface	46%	37	**75%**	47	63%	42	50%	67	28%	52	**45%**	20	49%	44
Damage to or closure of adjacent (next door) organisations or buildings	46%	43	38%	57	25%	47	58%	**74**	36%	29	33%	8	38%	43
Damage to or closure of nearby buildings or organisations	38%	56	44%	50	44%	**79**	**67%**	**73**	40%	30	17%	0	41%	48
Our organisation was located within cordoned-off area	31%	**67**	38%	**76**	31%	**80**	62%	70	28%	**57**	0%	0	32%	**58**
Physical harm to employees	8%	17	13%	25	6%	7	17%	20	8%	7	0%	0	9%	13
Supplier issues	**69%**	**57**	**75%**	53	63%	58	58%	48	40%	42	33%	**39**	55%	49
Customer issues	**85%**	**73**	**75%**	64	**94%**	56	50%	52	**61%**	**58**	**83%**	**67**	**74%**	**62**
Staff temporarily relocated	31%	50	56%	67	44%	41	50%	48	36%	52	17%	17	39%	46
Staff permanently relocated	8%	42	25%	**73**	19%	33	45%	42	21%	33	0%	0	20%	37
Staff did not feel safe returning to building	62%	43	56%	50	56%	39	64%	67	32%	50	0%	0	44%	41
Changes in staff emotional wellbeing	**83%**	50	**94%**	43	**100 %**	54	58%	53	**68%**	46	**92%**	**37**	**82%**	47
Other	20%	17	40%	33	0%	0	20%	42	20%	25	17%	0	21%	19

Organisations in all sectors, except hospitality, reported *change in staff emotional well-being* as one of the most disruptive factors after the earthquakes. This was especially so for the FMCG (100%), critical infrastructure (94%) and trucking (92%) sectors. In the case of the critical infrastructure sector, some of the organisations report that this is because their staff worked longer hours (see Table 3) in order to restore essential services as quickly as possible. The other most disruptive factors for the entire sample group were *customer issues* (74%) and *non-structural damage* (66%), e.g. damage to windows or light fixtures. For FMCG (94%), building suppliers (85%) and trucking (83%), *customer issues* was frequently cited as disruptive. Customer issues can be brought about by a number of factors. For FMCG, some customers within Canterbury relocated or closed, customer access was restricted by road network disruption, and damage to premises. Some trucking sector organisations cited problems meeting increased customer demand while others were having difficulty getting work as some of their customers, such as those in manufacturing, were closed. Unlike FMCG and trucking organisations, customer issues in the building supplies sector resulted from the delay in insurance payments due to the prolonged land zoning process as well as from pre-earthquake work that was cancelled or put on hold. In relation to upstream and downstream supply chain disruption after disaster, both FMCG and Trucking had a high number of organisations reporting infrastructure damage – *road network disruption* – as a challenge.

Table 5 also contains the results for the degree to which each sector was affected by the individual non-utility disruptive factors, i.e. the SDE. For the entire sample, the most intense disruptive factor was *customer issues* with a SDE score of 62 out of 100. This was followed by the organisation being located within a cordoned off area (SDE 58 out of 100) and structural damage to buildings (SDE 57 out of 100). Of all the sectors, the trucking sector was the least severely affected by many of the disruptive factors; just over 1/3 of the non-utility disruption factors had a score of 0 (meaning not at all disruptive). Conversely, the hospitality sector had over 2/3 of their non-utility disruptive factors with a SDE score of over 65 out of 100.

4.3 Organisational staffing adjustments

The disaster literature points to organisational staffing changes as one of the consequences of disaster. Overall, following the 22 February earthquake, more organisations took on staff (47%) than made them redundant (14%). Results for all sectors are presented in Table 6. The sector with a higher percentage of organisations reporting staff redundancies and the lowest percentage reporting staff hiring was hospitality. This corresponds to hospitality having more organisations reporting that they were still closed at the time of surveying. Sectors with more organisations reporting hiring staff after the 22 February were trucking (67%), FMCG (60%), critical

infrastructure (56%) and building suppliers (54%). Trucking, FMCG and critical infrastructure respondents reported that this was due to the increased workload after the earthquakes while building suppliers cited preparation for the impending rebuild as the reason for taking on staff.

*Table 6: Organisations, broken down by sector, reporting staffing changes in the aftermath of the 22 February 2011 earthquake**

	Staffing changes after the 22 February 2011 earthquake	
	Redundancies	**Hires**
Building Suppliers	17%	54%
Critical Infrastructure	0%	56%
Fast Moving Consumer Goods (FMCG)	13%	60%
Hospitality	58%	17%
Information and Communication Technology (ICT)	9%	35%
Trucking	0%	67%
Total	14%	47%

**Not all organisations answered this question; results may not add up to 100%*

4.4 Post-earthquake sectoral revenue changes

Organisations were asked how they would measure recovery; the most cited measure was the return to pre-earthquake levels of revenue or better. Respondents reported how their revenue had changed in two time periods: period 1 was from 4 September 2010 to 22 February 2011 and period 2 was after 22 February 2011 to the time of surveying (May to September 2011). Each change in revenue was assigned a value of +1 (increase), -1 (decrease) or 0 (no change). The two values for each organisation were added to come up with a final score for revenue changes. For example, an organisation that had a revenue increase (value +1) in period 1 and a revenue decrease (value -1) in period 2 had a total score of 0 (zero) while an organisation reporting revenue increases in both time periods had the maximum possible score of +2. It should be noted that a limit to these revenue change values, in this case, is that it asks about consecutive time periods in the chaotic short-term period after a disaster. The effects to organisations in this time period may not be a reflection of their ability to recover in the medium- to long-term. However, it is still possible for organisations to use the revenue change information to plan for and mitigate the effects that manifest in the period immediately following a disaster event.

As seen in Table 7, after 22 February 2011 more organisations reported revenue decreases than increases. However, more FMCG and ICT organisations had positive revenue changes after 22 February 2011 compared to negative changes. For ICT, this is likely because some of the ICT

organisations had a customer and revenue base outside Canterbury and New Zealand and could work from alternative locations to deliver goods and services. Other ICT organisations, with customers in the greater Christchurch region, also reported an increased workload after the earthquakes. One reason for this is relocating organisations needing support and new equipment. The critical infrastructure sector reported a decrease in revenue, which can be attributed to some of their customer base not being operational or having moved to outside the region post-earthquakes. In the short- to medium-term there was also increased expenditure on overheads, such as replacing equipment damaged by shaking or liquefaction as well as on overtime pay because of longer working hours. The hospitality sector had twice as many organisations reporting unfavourable revenue changes than those reporting favourable revenue changes. At the time of survey deployment, building suppliers, in continuing trends emerging after September 2010, reported mainly revenue decreases. The building supplier organisations pointed to the slow start of post-earthquake rebuilding work, as well as the cancellation of work ordered pre-earthquake, as some of the reasons for their negative revenue changes. Further delay in restarting the rebuilding process was attributed to the multiple earthquakes and aftershocks experienced in Christchurch. Organisations reported that each earthquake or aftershock acted to reset the recovery clock. From the direction of revenue changes and using the definition of recovery provided by the organisations themselves, it is clear that some sectors performed better after the earthquakes.

Table 7: Per cent of organisations, by sector, and trends in revenue changes after the 4 September 2010 and 22 February 2011 Canterbury earthquakes

	Revenue change trends after the 4 September 2010 and 22 February 2011 earthquakes in Canterbury				
	-2	**-1**	**0**	**1**	**2**
Building Suppliers	62%	15%	8%	8%	8%
Critical Infrastructure	13%	25%	44%	0%	19%
Fast Moving Consumer Goods (FMCG)	13%	13%	44%	6%	25%
Hospitality	38%	8%	31%	8%	15%
Information and Communication Technology (ICT)	4%	12%	56%	16%	12%
Trucking	33%	8%	25%	8%	25%
Total	23%	14%	38%	8%	17%

In this paper we focus on differences between sectors. The average size of organisations within each sector varies, and so we tested to see if organisation size influenced recovery. We found no

statistically significant relationship between revenue impacts and organisation size measured using full-time equivalent (FTE) staff numbers.

5 Sectoral differences for effects of the earthquakes

We examined whether organisations across the industry sectors experienced significantly different post-earthquake impacts and recovery trends (see Table 8). We used the Kruskal-Wallis test, a version of the one way analysis of variance (ANOVA) test, but for non-parametric data. The Kruskal-Wallis test allows for the statistical comparison of two or more independent groups. Additionally, the sample sizes being compared do not have to be the same.

*Table 8: Kruskal-Wallis test results for differences in effects, within and between sectors, after the 22 February 2011 earthquake**

		Total for revenue changes	Full-Time Equivalent (FTE) staff	Degree of Effect (non-utilities)	Degree of Effect (utilities)	Degree of Effect Combined (average)	Closure Impact Factor	Full-Time Equivalent (FTE) staff hires	Full-Time Equivalent (FTE) staff redundancies	Organisational operating hours after 4 September earthquake	Organisational operating hours after 22 February earthquake	Does your organisation have a formal written crisis/emergency or business continuity plan?
All Sectors	Chi-Square	11,533	28,050	6,859	5,966	6,904	18,882	11,914	8,386	24,097	9,374	15,912
	Df	5	5	5	5	5	5	5	5	5	5	5
	Asymp. Sig.	**,042**	**,000**	,231	,310	,228	**,002**	**,036**	,136	**,000**	,095	**,007**
Building Suppliers (within sector)	Chi-Square	12	12	11	11	11	12	12	11	12	12	11
	Df	12	12	11	11	11	12	12	11	12	12	11
	Asymp. Sig.	0,446	0,446	0,443	0,443	0,443	0,446	0,446	0,443	0,446	0,446	0,443
Critical Infrastructure (within sector)	Chi-Square	15	15	15	14	14	15	15	0	15	15	15
	Df	15	15	15	14	14	15	15	15	15	15	15
	Asymp. Sig.	0,451	0,451	0,451	0,45	0,45	0,451	0,451	1	0,451	0,451	0,451
FMCG (within sector)	Chi-Square	15	15	15	14	14	15	14	15	14	14	15
	Df	15	15	15	14	14	15	14	15	14	14	15
	Asymp. Sig.	0,451	0,451	0,451	0,45	0,45	0,451	0,45	0,451	0,45	0,45	0,451
Hospitality (within sector)	Chi-Square	12	12	12	11	11	12	11	11	12	11	11
	Df	12	12	12	11	11	12	11	11	12	11	11
	Asymp. Sig.	0,446	0,446	0,446	0,443	0,443	0,446	0,443	0,443	0,446	0,443	0,443
ICT (within	Chi-	24	24	24	19	19	24	22	22	22	24	22

sector)	Square											
	Df	24	24	24	19	19	24	22	22	22	24	22
	Asymp. Sig.	0,462	0,462	0,462	0,457	0,457	0,462	0,46	0,46	0,46	0,462	0,46
Trucking (within sector)	Chi-Square	11	11	10	9	9	11	11	0	11	11	11
	Df	11	11	10	9	9	11	11	11	11	11	11
	Asymp. Sig.	0,443	0,443	0,44	0,437	0,437	0,443	0,443	1	0,443	0,443	0,443

**Statistically significant results are bold and highlighted.*

From Table 8, *Chi-Square* represents the Kruskal-Wallis test *H* value, *Df* is the *degrees of freedom* and Asymp. Sig. is the *p* value which indicates the statistical significance of H.

From the table, there is no statistically significant difference observed when comparison is *within* each sector. This indicates that within sectors, organisations experienced similar trends. However, there are statistically significant differences *between* the sectors for six of the factors of disruption: revenue changes (H (5) = 11.533, p = .042), full-time equivalent (FTE) staff (H (5) = 28.05, p = .000), closure impact factor (H (5) = 18.882, p = .002), FTE hires (H (5) = 11.914, p = .036), organisational operating hours after 4 September 2010 (H (5) = 24.097, p = .000) and the existence of formal organisational emergency/business continuity plans (H (5) = 15.917, p = .007).

6 Discussion

From the results presented, we have identified the factors that contributed to business disruption for the different sectors and the degree to which the factors caused disruption. We related these impacts to post-disaster sectoral revenue changes. These differential effects can be attributed to sectoral differences in: type of goods and services, how goods and services are delivered to customers, the demand for goods and services post-disaster, and location of the organisation's customer base and of the organisation's premises.

For location specific sectors such as hospitality, off-site delivery of goods and services is often not possible if the organisation's premises are inaccessible. This is because of the specific equipment used and industry health and safety regulations that may make it difficult to relocate. Productivity for such organisations is reduced or suspended and has an impact on the affected organisation's revenue. In addition, the nature of goods and services in hospitality is that it is difficult to re-coup losses by making up for production at a later date. For some trucking organisations, it may be possible to make up for lost revenue by increasing the amount of goods transported. For some in the ICT sector, their ability to deliver goods and services remotely, coupled with their customers being located outside the disaster affected region, aided recovery.

Another industry related attribute is the situation and amount of goods required for the organisation to operate. Sectors such as FMCG, hospitality and building suppliers, with large amounts of stock on-site, had more organisations reporting damage to inventory or stock. Apart from stock loss, this leads to the need to clean-up premises before the organisation can operate again as well as the need for re-stocking damaged supplies. Clean-up and re-stocking of premises means that organisations are closed for longer periods, may require more staff to carry out the task and is also dependent on the capability of suppliers. However, closer examination of the closure impact factor and full-time equivalent (FTE) staff redundancies showed that organisations that made staff redundant were more likely to report more reasons leading to closure.

Organisations reporting being open for longer were likely to experience positive revenue changes. However, it is possible to still be open and suffer the same effects as a closed organisation if there is disruption to utilities. Organisations reporting negative revenue changes were also more likely to report being more affected by disruption to utilities. This shows the importance of utilities in both the supply and demand sides of the supply chain. On the supply side, disruption to utilities means that productivity is lowered or halted or that suppliers cannot deliver while on the demand side, customers may not be able to access and purchase goods and services. Across the entire sample, more organisations reported being affected by disruption to road networks than any other utility. Rose and Lim (2002) and Wein and Rose (2011) discuss in more detail the effects that disruption to utilities have had and could have on businesses and the wider economy.

The need for an organisation's goods and services can also affect post-disaster recovery. First, the organisation relies on customer discretionary spending, e.g. in the hospitality sector. Tierney (2007) found that customers were more reluctant to spend money on goods they thought they could do without following the economic uncertainty brought about by disaster. Second, an organisation's goods and services may be important but not needed in the immediate aftermath of an event. For instance, in Canterbury, some ICT organisations reported that there was less demand from some of their customers who were closed after the earthquake. Conversely, critical infrastructure, trucking and others in ICT reported an increase in demand for their goods and services post-earthquake. Organisations whose workload increased were more likely to operate longer hours, which correlated to positive revenue changes.

For building suppliers, environmental factors had an effect on their recovery. Building suppliers, who reported already decreased revenue as a result of the preceding global financial crisis, were

affected by uncertainty of supply and demand after the earthquake. Rebuilding work post-earthquakes was slow to take off partly because of the delay in settlement of insurance claims as well as the prolonged period of seismic activity. Consequently, building suppliers did not know when or which goods and services would be needed.

7 Conclusions and future work

These results are one part of an ongoing study of the impacts of the Canterbury sequence of earthquakes on organisations and industry sectors. This paper details the differential impacts on six industry sectors and highlights factors that contribute to business interruption after disaster. Overall, sectors were more affected by customer issues. The sectors most affected by disruption to road networks were hospitality and trucking. The trucking organisations were affected by the post-earthquake conditions of the roads that are integral to delivery of goods and services. Truckers were also affected by the increased number of road users on roads whose capacity was diminished. Critical infrastructure and hospitality were affected by structural damage to buildings, FMCG were affected by damage to or closure of nearby buildings, ICT were affected by damage to computers while building suppliers and trucking were more affected by customer issues.

Furthermore, from the results, organisations more affected by utility and non-utility disruption were closed for longer periods and were more likely to report revenue losses. This shows that organisations within sectors may experience similar post-disaster impacts and have similar recovery needs. Such information can be utilised by sector representatives in designing support plans for organisations. It is important to note that having a one size fits all approach to recovery may not adequately address specific recovery needs for each industry sector.

This paper outlines how industry sectors have been differentially impacted by the Canterbury earthquakes. Post-disaster revenue trends are used as a measure of organisational and sectoral recovery. We found that organisations and sectors that were more affected by the earthquake experienced negative revenue trends. By identifying differential impacts to sectors, this study begins to highlight sectoral vulnerabilities to disaster, knowledge which could be used to design organisational mitigation plans. It is important for organisations to understand what effects of disaster they could face. Post-disaster revenue change patterns, for example could be used as input in pre-disaster planning. Organisations aware of the possibility of long periods of decreased revenue can plan ahead for how to overcome this.

From the results in this paper, the authors show that in the response and short-term recovery phases after disaster, organisations may experience effects that are counterintuitive when taken in

the context of long-term recovery. For instance, building suppliers showing revenue losses when their products should be in high demand after the physical damage caused by an earthquake. Short-term organisational recovery results are not necessarily an indication of the final organisational recovery trajectory. However, understanding how disaster impacts affect recovery at a sectoral level may inform how we conceptualise and plan for recovery for different organisations and industry sectors. It may be possible to use short-term recovery results and trends as one of the inputs in an overall recovery strategy.

Later work by the authors (see for example Kachali (2013), Whitman et al., (2014) and Stevenson (2014)) shows the progression of recovery, as well as some of the reconstruction efforts, for industry sectors and organisations after the Canterbury earthquakes. It is shown that some of the factors identified as contributing to organisational experiences after the earthquakes were:

- Type of business (e.g. café versus ICT);
- Organisational location (Christchurch CBD was particularly affected by the 22 February 2011 earthquake);
- Decrease in number of customers; and
- Decreased customer spending.

In addition, and subsequent to the survey this paper is based on, the authors conducted contextual and case study interviews with some of the affected organisations from each industry sector. This was in order to supplement and add to information collected via the surveys. This qualitative information allowed for a more in-depth comparison of how the sectors, represented by the case study organisations, were affected after the earthquakes: were they affected differently; were they affected similarly; and the reasons for this.

The third and last survey in the series used information from the contextual and case study interviews as input.

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