National SCIENCE Challenges

RESILIENCE TO NATURE'S CHALLENGES

Kia manawaroa – Ngā Ākina o Te Ao Tūroa

Data and decision making in the transport system following the Kaikōura earthquake:

Final Report

July 2018

Resilience to Nature's Challenges: Data and decision making in the transport system following the Kaikōura earthquake

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Disclaimer

The findings in this report are those derived from a workshop in November 2017 and subsequent interviews, and do not necessarily reflect official policy or position of any agency. Examples presented within this report relate to situations that occurred following the Kaikōura earthquake only, and different events (with different spatial, and temporal characteristics and of different magnitude) will likely reveal different results and examples of information availability, use and exchanges.

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Executive Summary

Large amounts of information and data relating to the transport system were produced, managed, analysed, and communicated following the 14 November 2016 Kaikōura earthquake. This report summarises the key findings of a stakeholder workshop and series of interviews, outlining what information was available and useful, where it came from, how it was transferred between organisations, and how data might be managed and used in transport system monitoring to improve resilience in the future. This report captures common themes of participants' experiences rather than prescribed formal response and recovery structures. The results capture insights into how the system *did* function, rather than the system as it was *intended* to function. The workshop and interviews were designed to include as many participants from across the transport system as possible, from those responsible for transport policy to organisations and industries affected by transport disruptions caused by the Kaikōura earthquake. The report is not intended as a comprehensive review of New Zealand's crisis management system or incident command procedures, and we acknowledge that there are extensive efforts elsewhere to ensure that New Zealand lifeline utilities manage information to facilitate post-disaster outcomes.

Information flows that supported transport system response and recovery following the Kaikōura earthquake were shaped by several factors, including inter-organisational relationships, process informed by prior disasters, and existing and evolving data management and sharing practices. Existing partnerships across both government and private sectory organsiations assisted with the effective communication of information following the earthquake. Additionally, response and recovery efforts seemed to be substantially improved by having industry sector coordinators working with ministries and government agencies, inter-agency engagement, agency collaboration with intra-industry groups, and rapid access to technical expertise. Processes established following the 2010/2011 Canterbury earthquake sequence were useful in the aftermath of the Kaikōura earthquake. For example, some staff transitioned from the Stronger Christchurch Infrastructure Rebuild Team (SCIRT) – established following the 2011 Christchurch earthquake – to the newly formed North Canterbury Transport Infrastructure Recovery (NCTIR) alliance.

New relationships and 'super-organisations' were developed following the Kaikōura earthquake such as NCTIR, the Kaikōura Earthquake Tourism Action Group (KE-TAG), and the Restoration Liaison Group. New modes and patterns of information exchange also occurred, including between the NZ Police and NZ Transport Agency, and port companies and New Zealand Customs.

Organisations responding to transport disruptions drew on existing data sources in new ways, collected novel datasets, and maximised both existing and new relationships to manage the exchanges of critical information. For example, new geospatial data was created to reflect the massive land movements and to capture changes in harbour bathymetry both of which were important for assessing land and sea transport in the response and recovery.

There were also areas where information flows were sub-optimal, and areas where improvements can be integrated for future events. Some necessary information and data were not easy for organisations to obtain, and if obtained, were not available in an appropriate format or a timely manner. Where communication channels were inadequate or non-existent, participants experienced delays in response planning, and some organisations reported dealing with a burdensome number of requests for information and data.

Some other barriers to optimal information exchange and data usage were experienced in the aftermath of the Kaikōura earthquake, including the communication of tsunami warnings to some transport organisations, patchy dissemination of initial damage assessment data, and commercial sensitivities. Some organisations and personnel had an incomplete understanding of relevant organisational structures and were unfamiliar with the transport system set-up including alternative transport modes. Additionally, the auto-generation of false navigation information, and data uncertainties including on the extent and time of transport disruption, added strain on transport system resources.

Resilience-enhancing activities across the transport system continue to face several challenges at both a strategic investment and operational level. These include the potential loss of momentum for resilience investment once crises are over and difficulty maintaining long-term resilience strategies that incorporate all transport modes and critically assess alternative routes. Managing differing expectations for resilienceenhancement responsibilities and forecasting future requirements, such as from technological transformations, present challenges but also provide exciting opportunities.

Based on the lessons identified in this report and acknowledging the challenges above, the following recommendations for organsiations across the transport system target areas to improve data and decision making in the transport system prior to future shock and stress events:

- Work to further develop relationships between different transport sector stakeholders, including tourism organisations. Additionally, responsibilities and expectations of each group should be clarified and communicated, and commercial sensitivities should be considered.
- Explore and enhance processes for communicating relevant information to necessary parties, including the efficacy of coordinating with sector and sub-sector coordinators, and sector representative bodies.
- Discuss and develop guidelines for how to communicate and account for uncertain information and acceptable data accuracy ranges during response and recovery phases.
- Proactively consider communication and information needs for international markets, to facilitate better risk assessment and communication with New Zealand based firms affected by transport disruptions.
- Assess resilience capacities and make necessary improvements. These should include multiple stakeholders within the transport system and across into other infrastructure networks where possible.

The report concludes with an assessment of the types of information used to measure and monitor the progress of the transport system following the Kaikōura earthquake and the way information flowed to different actors across the transport system. This analysis is conducted with the aim of understanding how transport system monitoring around severe events can be optimised for users, from those responsible for managing and repairing the transport system to those whose livelihoods are impacted when there are system disruptions. An approach based on the Kickstart to Measurement (K2M) heuristic decision making tool (Ivory & Stevenson, 2017) was applied as the first step toward the future development of an indicator-based monitoring system, which tracks the progress of response and recovery across the transport system. Using the K2M, users are guided through a process that allows them to:

- Determine the monitoring focus - modes, locations (geographic extents), timeframes, and other elements of interest.
- Identify and prioritise indicators for ongoing assessment and monitoring.
- Select metrics and data for priority indicators.
- Identify areas that require additional resources, new data collection strategies, and/or intervention.
- Determine how the transport system elements of interest are performing on a relative scale.

The tool can be used to develop monitoring processes for transport system performance or resilience before or after natural or human-induced disruptions and could be used by the Ministry of Transport (MoT) Joint Analytical Unit (JAU) and other sector leads or decision makers.

In conjunction with the monitoring tool, the report also presents an 'actor map' of the agencies, decision-makers and other actors across the transport system, and the information flows between them. This can be used following an event to ensure that data gets to the actors it needs to in the most efficient way. The actor map identifies gaps in the data and information exchanges that currently exist. For example, organisations acting at the 'Government Policy and Budgeting' level tended to be the most densely connected (i.e., there were lots of information exchanges occurring with these organisation). Conversely, 'downstream' organisations such as technical and operational management actors (contractors), infrastructure operators, and those responsible for on the ground physical processes such as geotechnicians and farmers were much less densely connected. It is important to the network's resilience that information from these lower levels is able to feed back up the system to the decision making level. The indicators produced from the monitoring tool establish more precisely the forms that this information should take.

Abbreviations

API – Application Programming Interface

CAA – Civil Aviation Authority

CDEM – Civil Defence and Emergency Management

CIMS – Coordinated Incident Management System

CRI – Crown Research Institute;

Department of Conservation (DOC)

DPMC – Department of Prime Minister and Cabinet

ECan – Environment Canterbury

EDCIS – Electronic Chart Display Information System

GIS – Geographic Information System

GPS – Global Positioning System

JAU – Joint Analytical Unit

K2M – Kickstart to Measurement

KE-TAG – Kaikōura Tourism Action Group

LiDAR – Light Detection and Ranging

LINZ – Land Information New Zealand

LUC – Lifeline Utility Coordinator

MBIE – Ministry of Business Innovation and Employment

MCDEM – Ministry of Civil Defence and Emergency Management

MERIT – Measuring the Economics of Resilient Infrastructure Tool

MFAT – Ministry of Foreign Affairs and Trade

MNL – Main North Line

MNZ – Maritime New Zealand

MOC – Maritime Operations Centre

MoD – Ministry of Defence

MoH – Ministry of Health

MoT – Ministry of Transport

NCMC – National Crisis Management Centre

NCTIR – North Canterbury Transport Infrastructure Recovery alliance

NIWA – National Institute of Water and Atmospheric Research

NZD – New Zealand Dollars

NZDF – New Zealand Defence Force

NZSF – New Zealand Shipping Federation

ODESC – Officials Committee for Domestic and External Security Coordination

RNZAF – Royal New Zealand Air Force

RTC – Regional Transport Committee

RTF – Road Transport Forum

SCE – Sector Coordinating Entity

SCIRT – Stronger Christchurch Infrastructure Rebuild Team

SH – State Highway

TIA – Tourism Industry Aotearoa

TRT – Transport Response Team

VKT – Vehicle Kilometres Travelled

VSEG – Visitor Sector Emergency Group

WREMO – Wellington Region Emergency Management Office

1 Introduction

1.1 Project Background

'Resilience to Nature's Challenges: Data and decision making in the transport sector following the Kaikōura earthquake' is the result of a collaborative project between the Resilience to Nature's Challenges National Science Challenge (subsequently referred to as the Challenge), QuakeCoRE (New Zealand Centre for Earthquake Resilience), and the Ministry of Transport (MoT). The project has been conducted at the intersection of four of the Challenge's strategic research areas—Governance, Resilience Trajectories, Distributed Infrastructure, and the Rural 'laboratory'—through examination of the transport system in the aftermath of the Kaikōura earthquake.

1.2 Problem statement

New Zealand's transport system was significantly disrupted by the M_w7.8 Kaikōura earthquake, which occurred just after midnight on 14 November 2016. Road, rail, and port infrastructure suffered damage, some substantial, including parts of State Highway 1 (SH1), the Main North Line railway (MNL), Port Marlborough in the upper South Island, and CentrePort Wellington in the North Island. This had substantial implications for transport operators, residents, tourists, and businesses in the Canterbury, Marlborough, and Wellington regions, with cascading consequences elsewhere.

In the immediate aftermath of the event, multiple organisations, both public and private, initiated responses aimed at identifying the level of damage to the transport system and determining how to manage disruption. After the initial response, organisations progressed their focus to identifying and managing longer term recovery strategies.

During both the response and recovery phases[1], large amounts of information and data relating to the transport system was produced, managed, analysed, and communicated within and between organisations to assist decision making. In many cases these information exchanges were effective, enabling the transport system to respond and adapt successfully, allowing continued mobility of users and goods nationwide. In some cases, however, there is scope for improvement.

To improve information and data exchanges, and related decision making for future natural hazard events affecting New Zealand's transport system, it is necessary to learn from the Kaikōura earthquake. This report presents a post-earthquake assessment of what information was available, useful, where it came from, how it was transferred between organisations, and how data might be managed and used to improve resilience across the transport system in the future.

1.3 Aims, Objectives and Deliverables

The project aimed to:

1. Observe and understand the pace at which the transport system, infrastructure, and supply chain adapted to earthquake-related disruptions.
2. Understand how information was used to make decisions about all transport modes (road, rail, air, and coastal shipping) so that lessons can be identified from the event to improve how we manage, plan, and invest in the transport system.

[1] The integrated approach to emergency management in New Zealand is characterised by four phases outlined in the 2002 CDEM Act: readiness, reduction, response, and recovery. The first two phases occur prior to a disruption and refer to actions undertaken to enhance adaptive capacity and reduce hazard exposure. The latter two phases occur following a disruption. Response is concerned mostly with situation assessment and humanitarian relief operations, such as evacuating people who are injured or at-risk. Response also includes immediate 'make-safe' works. This phase transitions into recovery, the focus of which is on repairing damaged system components with the aim of reinstating connectivity or restoring or improving system throughput levels (Faturechi & Miller-Hooks, 2015).

3. Identify short, medium, and long-term measures for ongoing performance monitoring of the transport system. This may include recommendations around how best to manage resilience, recovery, and response related information and developing a case for a centralised data warehouse to share information that currently exists in different sectors and organisations.

To address these aims, three key project tasks were planned and conducted:

1. Stakeholder workshop and workshop summary report.
2. Extended data collection interviews, further developing the workshop outcomes.
3. Data collection and monitoring framework scoping.

The workshop and extended data collection interviews address aims 1 and 2 above. These also inform aim 3 through the development of the proposal for a further project focussing on ongoing post-disruption transport system performance monitoring.

It is important to note that this report is compiled from the views of multiple public and private organisations involved in and affected by transport disruptions caused by the Kaikōura earthquake. It offers a range of perspectives and reflections across the transport sector about information flows and data usage in the transport sector response and recovery. This report is not a comprehensive review of New Zealand's crisis management system or incident command procedures. The authors acknowledge that although the workshop and interviews were designed to capture as many experiences and perspectives as possible across the transport sector, the study is not a comprehensive review of all organisations or views of the transport system.

1.4 Report Structure

This report is the second of two reports for this project and follows the interim Workshop Report (Wotherspoon et al. 2018), which presented the detailed qualitative results from the workshop held with transport agencies and other relevant stakeholders. This report extends the previous work by drawing on interview data and subsequent analysis.

The introduction (this section) describes the rationale, project scope, aims, and key deliverables. Section 2 focuses on insights and lessons, describing key learnings from the Kaikōura earthquake event and remaining challenges. The section also includes recommendations for how to improve resilience of the transport system in future stress/shock cases. In Section 3 we focus on analysis and discussion relevant to the future development of a post-disaster performance monitoring process for transport systems. This section contains an assessment of data sources used by transport sector organisations following the Kaikōura earthquake and proposes a system of an indicator-based monitoring tool and data prioritisation framework. Section 3 also includes an analysis of the information flows relevant to the response and recovery of the transport system following the Kaikōura earthquake. The result of this analysis is an actor map that shows the flow of information through a network of organisations that facilitated decision making in the aftermath of the earthquake. Future research and programme development to develop a post-crisis transport monitoring and information management system may build on the analyses presented. Finally, appendices include detailed descriptions of the workshop (also see Wotherspoon et al. 2018), interviews, and analysis methods (Appendix A), as well as the participants and tabulated summaries from each interview question (Appendix B).

2 Insights and Lessons

This section of the report highlights key insights and consequences of information flows and data usage that have been identified from the workshop and interviews. Focus case boxes provide detailed examples of insights generated through the experiences of organisations navigating post-earthquake transport response and recovery. This section then summarises the enablers of effective flows of information and data and suggests further focus areas for improving transport system resilience. Finally, the report provides recommendations and suggestions for topics that require further investigation and development based on lessons learned from the Kaikōura earthquake.

It is recognised that there are many formal structures for inter-organisational collaboration, transport disruption response, and crisis information management in New Zealand. Examples include the NZ Transport Agency's resilience response framework formed in partnership with KiwiRail and Transpower; Officials Committee for Domestic and External Security Coordination (ODESC) Watch Group structures and the Transport Response Team (TRT) who act as the Sector Coordinating Entity (SCE) under this structure; and the Lifeline Utilities Coordinator (LUC) sub-function which is part of the Operations function in the National Crisis Management Centre[2] (NCMC). The observations and reflections in the following sections are not intended to provide a systematic review of these existing structures. Rather this report draws on the post-disaster observations of a range of organisations involved in and affected by transport disruptions, response, and recovery, exploring the ways they drew on existing information, as well as innovated and adapted to meet emergent needs in a complex and dynamic post-disaster environment.

While many organisations participating in this research were directly involved in formal response and recovery initiatives, others represent perspectives of businesses and communities affected by transport system disruptions. Capturing the experiences of private road freight transport companies and the primary production and tourism sector businesses, for example, allows this review to incorporate the experiences and lessons learned by organisations 'downstream' of official government structures but also critical to New Zealand's economic and social recovery following shock and stress events.

2.1 Information flow and data usage identification

Following significant crises there is always an increased demand for information and pressure to make critical decisions in short timeframes. Organisations responding to the transport disruptions caused by the Kaikōura earthquake used the best information available to enable progress under demanding circumstances. To do this, they drew on existing data sources in new ways, collected novel datasets, and maximised both existing and new relationships to manage the flow and distribution of critical information. These factors are detailed in this section of the report.

2.1.1 New information and data sources

The following information and data sources were generated following the Kaikōura earthquake or repurposed to assist response and recovery, but many could also assist readiness and reduction activities before future events. It does not include existing data that actors were already accessing for business as usual transport management prior to the Kaikōura earthquake.

New geospatial data was created in various forms, including:

- LiDAR and aerial photography techniques, which were employed to rapidly assess ground movement and infrastructure damage.
- Seismic ground motion intensity, which was assessed through the installation of additional instrumentation and monitored through the GeoNet programme.
- Harbour and shipping channel bathymetry surveys, which were conducted for Maritime New Zealand (MNZ).

[2] The National Crisis Management Centre (NCMC) is a multi-agency facility where all agencies work under the control of a lead agency. The lead agency was MCDEM in the case of the Kaikōura earthquake.

- New road user GPS data, which were captured through systems such as Google Maps, and ultimately affected response and recovery activities, including in the police and tourism industries (see section 2.3.2).
- Telematics and engine management data from road freight vehicles, which informed police enforcement activities. This data source also provided new information on current road conditions in the upper South Island.
- 'Hazard exposure heat maps' generated by the North Canterbury Transport Infrastructure Recovery (NCTIR) alliance, which were used to assess long term effects of the earthquake on the transport corridor.

Transport infrastructure damage assessments were conducted rapidly following the event for all transport modes, creating new information that was vital to immediate response activities. Port infrastructure surveys at Port Marlborough and CentrePort Wellington included damage and capacity assessments of berths, buildings, and harbours.

Damage and level of service classification systems and staff Health and Safety monitoring systems were developed by the NZ Transport Agency and KiwiRail following the event.

Web portals, which integrate diverse information sources into a consistent management interface, were used to manage daily information about road risks, incidents, and conditions, and to assist with information exchanges between port companies and transport operators (e.g. see focus case 'Port and Customs Data Exchange' in Section 2.1.3). The MoT Joint Analytical Unit (JAU) also assisted in the regular transfer of new information and data sources (see section 2.1.2 and focus case 'Transport Response Team and Joint Analytical Unit'). The JAU also commissioned external work including the application of the MERIT model to understand wider economic impacts[3].

<u>Focus Case – new information and data sources</u>

TRANSPORT RESPONSE TEAM & JOINT ANALYTICAL UNIT

Ministry of Transport
TE MANATŪ WAKA

The Ministry of Transport (MoT) provides a communication channel to assist in the collation and provision of information to transport organisations. The MOT-led Transport Response Team (TRT) provides transport system co-ordinated advice in the whole of government response to a national emergency.

- Within two hours of the earthquake, the TRT activated.
- In early Decemer 2016, the Joint Analytical Unit (JAU) was set up between the Ministry of Business, Innovation and Employment (MBIE), MoT, NZ Transport Agency, and Treasury and sought to provide a single source of information on impacts and recovery efforts associated with transport and infrastructure systems, tourism, and the local, regional, and national economy.
- The JAU was responsible for providing specific analysis (i.e. impact of port closures), briefings and regular reporting in the form of weekly update reports for Ministers and official groups. The unit operated through to the end of April 2017.

Recommendations for future:

- Ensure all transport organisations are aware of the JAU.
- Practice and refine activities during business-as-usual to ensure that they are as effective as possible for all organisations, and communicate the value to stakeholders before the next event.
- Maintain caution that some groups have strong commercial interests and ensure that these aspects do not become the primary focus of discussions.

[3] The Measuring the Economics of Resilient Infrastructure Tool (MERIT) is a dynamic, multi-sectoral model designed to estimate the indirect economic losses that transpire as a result of infrastructure outages.

2.1.2 Key existing partnerships and communication channels

The communication channels described here represent the partnerships that were already in existence prior to the Kaikōura earthquake that proved especially useful for obtaining crucial information during the response and recovery phases of the event. Several inter-organisational relationships existed between national-level organisations, while others were enacted regionally and locally.

Additionally, pre-existing partnerships between the MoT and other government agencies for security and emergency management purposes came to the fore during the event. For example, MoT is on the ODESC, which is chaired by the Chief Executive of the Department of the Prime Minister and Cabinet (DPMC) and for the Kaikōura earthquake response included representation from the State Services Commission, Treasury, Ministry of Foreign Affairs and Trade (MFAT), New Zealand Defence Force (NZDF), Ministry of Health (MoH), Ministry of Defence (MoD), Ministry for Primary Industries (MPI), New Zealand Police, Crown Law and the NZ Transport Agency. Roles in the Coordinated Incident Management System (CIMS)[4] often make use of the Emergency Management Information System (EMIS) – a system that records response decisions, along with the information upon which each decision was based (at the time it was made), and assisting communications in the NCMC.

Partnerships between government agencies and transport organisations included that between the MPI and Rural Support Trusts for people, animal welfare, infrastructure, and insurance related assistance in rural areas. There were also clear existing partnerships of the Ministry of Civil Defence and Emergency Management (MCDEM) and Regional Civil Defence and Emergency Management (CDEM) groups with the NZ Transport Agency and KiwiRail. However, some potential opportunities for improvement also exist here, for example the effective communication of tsunami warnings to some ports.

Intra-organisational relationships included those between shipping companies, freight and trucking companies, NZ Police, regulators, and sector representative bodies. For example, the recruitment of NZ Police staff from nationwide teams assisted with Police response and recovery activities, which was continuing at the time of writing. Additionally, Airways NZ air traffic controllers that are usually based at Royal New Zealand Air Force (RNZAF) bases were involved in the provision of an aviation information service during the response phase (see section 2.1.4).

At a regional level, The South Island Regional Transport Committee (SIRTC) was established in 2016 prior to the Kaikōura earthquake to provide oversight on land transport decisions and outcomes that could affect the South Island. The SIRTC is composed of representatives from all South Island Regional Transport Committees (RTCs).

There were frequent collaborations between the NZ Transport Agency, MoT, and KiwiRail to the freight sector for road and rail conditions at a regional scale. The NZ Transport Agency and KiwiRail (and their contractors) readily shared information about each other's transport network. This was enhanced further through NCTIR, which was assisted by lessons and staff transitions from the Stronger Christchurch Infrastructure Rebuild Team (SCIRT), established following the Canterbury 2010-11 earthquakes.

At a local level, there were clear existing relationships between engineers and infrastructure owners. For example, good relationships between local engineers / surveyors and infrastructure managers in the top of the South Island assisted with the response and recovery at ports.

2.1.3 New relationships and communication channels

To obtain the information and data required following the Kaikōura earthquake, some agencies developed new relationships, some of which were on-going at the time of writing. These new connections enhanced the adaptive capacity of the transport system and may enable improved efficiencies during future events. For

[4] The Coordinated Incident Management System (CIMS) is an incident management structure established to assist with how roles are assigned, which supports the management of emergency information and decision making.

example, ‘CDEM Air’ was temporarily established, formed as a collaboration between Airways NZ and RNZAF Air Traffic Controllers. These organisations assisted each other with aviation management, particularly through the provision of an information service after airspace was restricted (also see section 2.1.4). Similarly, the establishment of the NCTIR alliance was highly beneficial in assisting collaborations between the NZ Transport Agency and KiwiRail. The alliance allowed access to large amounts of geotechnical and engineering data and facilitated joint operations, decisions and planning. It was reported that NCTIR’s daily information releases filtered through to staff at various organisations very quickly.

The tourism sector was necessarily involved in the response to the Kaikōura Earthquakes as well, needing to facilitate visitor movement and assist businesses affected by the transport disruptions. The Kaikōura Earthquake Tourism Action Group (KE-TAG) formed as the public-private interface of the tourism sector and provided the ‘single source of truth’ for tourism information. Like the national level Visitor Sector Emergency Advisory Group (VSEAG), established in the aftermath of the September 2010 Darfield Earthquake and also active in an advisory role following the Kaikōura earthquake, KE-TAG is composed of industry bodies and government agencies – Tourism Industry Aotearoa, Tourism Export Council, Regional Tourism Organisations NZ, Rental Vehicle Association, Hospitality NZ, Restaurant Association, Local Government NZ, Automobile Association, MBiE, NZ Transport Agency, Tourism NZ, and the Department of Conservation. KE-TAG was originally established to have a finite life.

The Restoration Liaison Group was developed to formally facilitate stakeholder engagement with NCTIR and involved groups such as Environment Canterbury (ECan), the Department of Conservation (DOC) and Iwi in the affected area.

NZ Transport Agency and Police relationships were further enhanced following the event. Specifically, a new bi-directional daily reporting system focused on the alternative Christchurch to Picton route that was established 2-3 days following the earthquake is still being used at the time of writing. For example, the Police report road condition problems (allowing targeted repairs and maintenance), and the NZ Transport Agency assist with risk identification (assisting with the efficient use of Police resources).

Focus Case – new relationship and communication channel

PORT AND CUSTOMS DATA EXCHANGE

Communication and data exchanges between ports in New Zealand is sometimes challenging due to commercial sensitivities and competition.

The Kaikōura earthquake presented challenges at several ports. One challenge was the rapid fluctuations in the quantity of imports and exports from diverted cargo ships and ground-based freight and other supply chain changes.
Ports urgently required information on how much cargo would be diverted, the timing and duration of new arrivals, and whose containers were involved to arrange appropriate operational and business response activities.

At Napier Port new data was successfully obtained from the New Zealand Customs Service, which assisted their information needs.

- Existing relationships contributed to this new data exchange.
- A new web portal was developed at the port to allow information flow on to transport operators.
- Other communication channels were modified (e.g. import advice vehicle booking system).
- The communication channel and new Customs data continues to be used on a daily basis.

2.1.4 Limitations to information exchange and data usage

Necessary information and data were not always easy for organisations to obtain, and if obtained, were not always available in an appropriate format or timely manner. The following describes limitations that prevented or hindered access to information and data.

Barriers to information exchange were often caused by limitations in understanding of organisational structures and transport system set-up, including:

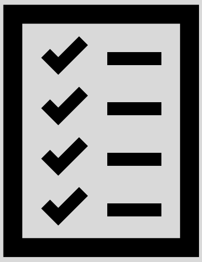
- The organisational structure of those involved in response and recovery actions, especially concerning information coordination. Several interviewees expressed that they were unsure who to approach to obtain information or with whom they should be sharing information.
- Leadership structures and clarity about the balance of responsibility between regional and national level actors. Difficulties arising from this unclear accountability structure flowed through to government agencies in some cases, with actors attempting to obtain a clear working understanding of the structure, delegations, and internal approval chains.
- Awareness of local organisational structures by new staff coming into the area. For example, there may be different processes and regulations in rural areas and unfamiliarity of jurisdictions for different courts. Additional resources are required for training and staff cross-overs as a result.
- The value and data that tourism bodies such as Tourism Industry Aotearoa (TIA) can provide. For example, how their data could help prioritise work to minimise the economic impact of tourism disruptions and how these groups could help tourists plan their travel around disruptions (see the Focus Case 'Tourism Industry Value' below).
- Availability of alternative transport modes. For example, there was limited understanding on coastal shipping capabilities between different ports in some instances.
- The sequencing of port repairs and road repairs, which could have been better coordinated with ferry arrivals and peak traffic flows, especially early in the recovery process.

Business and research interests occasionally took precedence over the sharing of initial damage assessment and other survey data and images. For example, many organisations were involved in the initial surveys and assessments conducted along the SH1 and MNL transport corridor but not all of this information was readily shared or accessible. Similarly, competition and commercial sensitivities hindered communication and data exchanges in some situations. For example, there were communication challenges between ports and freight companies, with a relative shortage of data on the Cook Strait, including passenger and freight movements. This data gap has also been identified in R3.9 of the recommended initiatives in the Transport Domain Plan (along with R3.12 and R1.12) (Transport Knowledge Hub, 2016). Commercial sensitivity also meant that KiwiRail struggled to get information from some engineering and assessing consultants and were not always involved in the coordination of work planning on-site.

Some transport organisations found that they were outside of direct MCDEM and regional CDEM communication channels for tsunami warnings (i.e. they would hear about warnings indirectly from other organisations such as local fire services). There was also limited information available about approved personnel and organisations that could operate in the 'restricted' airspace (see focus case 'Air Traffic Management').

In addition to these information sources, which could have enhanced the response to the Kaikōura earthquake, several workshop participants noted possible issues with the types of data currently being used for future transport resilience planning. Participants raised concerns about whether current cost-benefit calculation approaches and assessment criteria are adequate to inform transport investment priorities and resilience improvement strategies.

Focus Case – limitations to information exchange and data usage
'NEEDS TO BE THE RIGHT MINDSET'



To develop and coordinate effective responses to the Kaikōura earthquake, decision makers in the National Crisis Management Centre needed to rapidly obtain as much information as possible.
During the initial response, obtaining data rapidly was more important than its accuracy or quality, if its limitations were accounted for.

A key limitation to obtaining information with the rapidity decision-makers required was the desire for agencies and analysts to hold on to data until they were certain that it was highly accurate – a business as usual approach.

- MoT emphasised that in the response phase there was not time to spend developing the 'right' solution to apply, rather that it was necessary to start with some information early, then to iterate toward a solution as more data became available. This maintains the agility of the solutions in a constantly changing situation.
- Any information was considered better than no information.
- This focus on speed over quality in the response phase is different from business as usual for many data providers and requires a mindset change.
- This could be prompted by MoT and other high-level decision-makers articulating their data expectations during this phase including what accuracy is needed, potentially through acceptable accuracy ranges based on intelligent industry judgement, and how limitations/uncertainties can effectively be expressed.

Focus Case – limitations to information exchange and data usage
TOURISM INDUSTRY VALUE

Following the Kaikōura earthquake, over 1000 tourists were trapped in Kaikōura and had to be evacuated by air or sea, with many leaving rental vehicles behind. These tourists had to re-plan the remainder of their trips. Tourists in other parts of the South Island also had to re-plan their travel destinations and routes using the alternate route between Christchurch and Picton.

Members of the tourism industry felt they were positioned to provide useful assistance, but **several limitations to information exchange reduced this potential:**

- Relationships between tourism industry bodies and MCDEM could be stronger. In the Kaikōura response those coordinating evacuations did not have a clear plan for integrating the help of tourism agencies and there was a lack of clarity about how the sector could be impacted.
    - Tourism agencies understand what information tourists will need and have the connections to manage bookings and rental vehicles. However, other agencies may be unaware of their connections and capabilities.
    - Coordination of the removal of abandoned rental vehicles was slow and had a knock-on effect to the tourism industry across the country as the vehicles had further bookings.
- The amount of time and effort required to manage tourists appeared to be underestimated.
    - Non-English-speaking tourists travelled past closure and detour signs and distributed information had translation issues.
    - Tourists relied heavily on online map services which were not able to distinguish closed roads due to their use by work vehicles.

Focus Case – limitations to information exchange and data usage
AIR TRAFFIC MANAGEMENT

A temporary restricted airspace was established in the Kaikōura area two days after the earthquake to facilitate disaster relief operations following concerns about increased air traffic in the area.
RNZAF air traffic controllers for Airways NZ subsequently provided a mobile information service, operated from Kaikōura and assisted by frequent liaison with Civil Defence and Emergency Management.

The new information service was deemed successful; however, no air traffic control service was provided during the response, leading to some issues. **Several potential gaps and limitations to information flows have been identified:**

- Although personnel with appropriate skills and knowledge were available at the time, the newly established radio installation for communications did not have standard certification.
- Notices to Airmen (NOTAMs) were quite vague (e.g. “rubber-necking not permitted”).
- Many information exchanges were on an ad hoc basis over radio or cell phone with few established procedures.
- There was no complete schedule of air traffic in the area and no available list of approved operators that could operate in the restricted airspace – a lot of trust was required.
- Officials on the ground had no ‘visibility’ on aircraft into the area.

Note that air traffic management activities vary between events. E.g. during the 2017 Port Hills Fires in Christchurch, only approved operators were permitted within the restricted airspace.

2.2 Enablers of effective communication, and information and data flows

Overall, there were many positives about the response to the Kaikōura earthquake and it is important to capture what worked well to ensure that these practices can be shared in advance of the next major event. Practices that assisted the effective communication of information and data are described here, in addition to the examples provided in some of the previous sections.

Relationships with key partners that were established prior to the event meant that actors knew who to contact for advice or data. This improved the efficiency with which actors could develop their responses and enhanced their ability to coordinate with others. For example, organisations such as the port companies, KiwiRail, and NZ Transport Agency needed rapid access to technical experts to conduct assessments. Having relationships and agreements in place prior to the event allowed them to be identified and pulled from their regular roles as soon as possible. Similarly, the establishment of NCTIR was assisted by staff directly transitioning from SCIRT.

Having clear sector coordinators with ministries and government agencies meant that information requests to agencies could be filtered to avoid duplication. This ensured consistency in the messages being conveyed to sector organisations. Coordinators also ensured consistency in communications when operational staff were not available to take part in decision making discussions. This process was in place for some sectors, but not all at the time of the event. Inter-agency engagement, thorough sector representation, and collaborative and efficient decision making should be enabled by organisational structures such as the JAU, TRT and ODESC, and multi-agency space sharing that occurred in the NCMC.

Public and private industry groups facilitated intra-industry support and helped information to flow easily while taking commercial needs into account. KE-TAG is an example of such a group. This was formed immediately after the Kaikōura earthquake due to the success of a similar group following the Christchurch earthquake (VSEAG).

In the initial hours after the event, when little information is known, a number of agencies found that the media were their primary source of information online and having contacts in the media helped them get a clearer picture of the situation. However, caution is required when using this secondary information source.

2.3 Consequences of communication channel set-ups

The efficacy of communications between different stakeholders had consequences for the efficiency and effectiveness of responses to the Kaikōura earthquake. The following outlines key consequences of both effective and inadequate or absent communication management.

2.3.1 Consequences of effective communication channels

Data for specific attributes of the transport system allowed improved response and recovery for other attributes. For example, transport scheduling information was used to manage reconstruction processes in ways that reduced disruption to the flow of people and goods, such as ferry timetables allowing peak traffic flows to be predicted in advance and resources to be prioritised. Although a success, there is room for better and earlier coordination of this kind of information in future events.

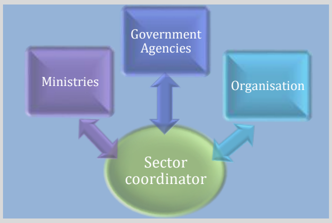
An existing culture of collective responsibility within the shipping industry, as well as the Maritime Operations Centre (MOC) and Harbourmaster, meant that ship captains had contact information for peers readily available. Information about the state of CentrePort Wellington, harbour bathymetry and other maritime information was therefore disseminated effectively.

The NZ Shipping Federation (NZSF) and the Road Transport Forum (RTF) as sector representative bodies acted as conduits of information to and from decision-makers providing consistent communications to their member organisations and from their members to decision-makers. Similarly, when established, NCTIR acted as a conduit of information about the status of repairs, emerging issues, position and coordination of workers on the route and novel datasets and observations produced while managing the infrastructure recovery to relevant stakeholders. For example, the NCTIR Resilience Study (Brabhaharan et al., 2017) provided a wider understanding of the long-term effects of the earthquake on the transport corridor.

Focus Case – consequences of effective communication channels

'SECTOR COORDINATORS'

Following the Kaikōura earthquake high level decision-makers, including Ministries and government agencies, required a great deal of data from impacted organisations from across the transport system. Coordinating these requests effectively was (and still is) necessary to ensure the efficient flow of communications and data.



Having a sector or sub-sector coordinator to act as single point of contact for a sector was identified as an effective way of managing these requests. For example, the Road Transport Forum acted as a conduit of information between road freight companies and the agencies coordinating response and recovery, ensuring that businesses had a clear voice and were also receiving the information they needed.

Benefits of having a sector coordinator:

- Preventing organisations from having to provide the same data multiple times to different agencies, saving time and frustration (e.g. MoT representative coordinating government requests for Centreport in later response stages)
- Providing consistency in communications by ensuring the same messages are getting to everyone in a sector and likewise, ensuring consistent representation of the sector to the decision makers (e.g. sector coordinator representatives on the JAU teleconferences).
- Ensuring representation of organisations even when operational staff were busy with response and recovery duties.

2.3.2 Consequences of less effective or absent communication channels

Early on in the response and recovery process, there was inadequate communication from some groups conducting the initial geological hazard and damage assessments, including some CRIs and consultants, which led to challenges and delays with transport system response planning. Additionally, some transport operators expressed frustration that they did not have sufficient information on possible timeframes of disruption, which meant significant delays (2-3 months) on purchasing new assets such as truck and trailer units and extra journeys required as a result of prolonged route disruption.

Conversely, a burdensome number of requests for data by government agencies was frustrating and resource intensive for some stakeholders. This included requests for different data for one or more agencies as well as multiple requests for the same data for different agencies. The latter gave the impression to stakeholders that there was a lack of coordination between different agencies. The authors also note that LUCs and the information coordinating role that they provide was not very prominent during workshop or interview discussions.

The NZ Police was one organisation that managed the consequences of misleading auto-generated information about the SH1 status being provided to tourists (e.g. generated from construction sector vehicles' GPS data making it look like the road was open for public use on the Google Maps platform). Increased police resources were required to manage drivers unexpectedly entering areas that were undergoing works.

Focus Case – consequences of less effective communication channels

ROAD CLOSURES / RESTRICTIONS AND ROAD USERS

State Highway 1 in the upper South Island is heavily used by both tourist and freight vehicles – both were disrupted by the Kaikōura earthquake due to SH1 road closures and restrictions.
Effective communication was (and still is) required to minimise disruption to road users resulting from road closures, diversions and restrictions.

Several issues associated with communication channels following the event were identified:

- Appropriate communication to tourists (particularly non-English speakers) and correct translation of information to other languages.
- Real-time GPS navigation equipment provided false information on current road conditions.
- Provision of sufficient information and enforcement in affected areas and on alternate route.

Consequences of these less effective communication channels included:

- Vehicles continuing along roads unaware of road closures and restrictions ahead, or upcoming planned closures / restrictions.
- Motorists on the alternate route unfamiliar with roads, journey durations, and available amenities.
- Breaches of restrictions had knock-on effects for road maintenance teams and residents.
- Increased requirement for enforcement and road safety management resources.

2.4 Remaining challenges

The pace at which the transport system, infrastructure, and supply chain adapted to earthquake-related disruptions is a function of the resilience of the organisations, governance structures, and infrastructure that compose the transport system. Any attempts to enhance the resilience of the transport system will need to be facilitated by concerted efforts to improve the way transport system information is managed, monitored and shared. Additionally, there is a need for adequate cross-sector information sharing to monitor whether spending on system resilience actually achieves the desired outcomes. Resilience-enhancing activities across the transport system continue to face a number challenges, which are outlined in this section.

At a strategic investment level across all sectors:

- Once crises are over, resilience investment decisions are not always highly prioritised by organisations over day-to-day requirements, with resource limitations potentially restricting resilience investment further.
- Long-term national resilience strategies and associated engagement within some sectors are in the early stages of development, and there are challenges with some organisations overlooking the importance of considering a multi-modal transport system perspective.
- Expectations differ between central government and local government about who is responsible financially for resilience enhancements to utilities and infrastructure.
- There are capacity and experience limitations in local councils, particularly those with high staff turnover.
- Parts of the network that might serve as alternative routes when a main route is disabled lack the capacity and amenities to fully absorb additional throughput (e.g. near Wellington and the upper South Island). Enhancements would require significant investment and are difficult to justify where there is high uncertainty around risk exposure.
- Similarly, there is a need for investment in redundancy in energy supply (fuel and electricity). This can be difficult to justify during business-as-usual and in a resource limited environment.

- Defining the most appropriate way for information sharing processes to facilitate relationship development is a strategic challenge, although also presents exciting opportunities.

At an operational level, following the Kaikōura earthquake:

- Continued traffic management is required to support tourist and freight traffic on some routes (e.g. reduction from two roads to one road entering CentrePort).
- Continued resources are required to effectively inform transport users on continuing closures and upgrades to roads and rail, particularly in the upper South Island.
- Road transport and engineering and construction organisations are facing shortages of machinery and vehicles as well as skilled drivers and operators.
- Competition and commercial sensitivities across the private sector make cooperative arrangements (e.g., freight load-sharing or open data policies) more difficult.
- There are slow feedback mechanisms across the sector and within organisations to implement changes based on lessons learned from past events.
- The relationships, communications networks, and other positive lessons that emerged following the earthquakes may be difficult to maintain as people revert back to other day-to-day activities, even though they will inevitably be needed in the next crisis (and will arguably enhance daily operations).
- There can be knock-on consequences on business-as-usual activities for certain organisations if they become involved in response and recovery, with any additional data and assessment reporting activities also requiring additional resources and time. For example, there may be considerations for other commercial activities of the RNZAF and MNZ if they are brought in to assist.

Interestingly, having several disruptive events in close temporal and spatial proximity (including the 2010 Darfield, 2011 Christchurch, 2013 Seddon and 2016 Kaikōura earthquakes) may have had positive implications for the resilience of the transport system. Transport information availability, knowledge, and use often improved in a cumulative fashion following each event. Staff retention and staff remaining in the same or similar roles at organisations following the Christchurch 2011 earthquake appeared to assist with the proactive requests, offers of support, and functional transitions during the Kaikōura response. Additionally, existing asset inventories likely enabled effective data transfer. However, we note that updated and more readily accessible internal asset inventories for buildings, equipment, transport and machinery, would have assisted data transfer processes in some situations.

2.5 Recommendations

Based on the lessons outlined in the previous sections, and acknowledging the challenges above, it is worth considering a number of ways by which the exchanges of information and data could be enhanced in future events. This section outlines practices that can be developed prior to future shock and stress events.

Relationship development work should continue, including between tourism organisations (perhaps assisted by KE-TAG or TIA) and traditional transport sector stakeholders (e.g. MoT, NZ Transport Agency, MCDEM). Activities to develop relationships may include incident and resilience exercises, which include exploring aspects of data sharing. As part of these relationships, the overall data system is an important factor, and should align with the relationship structures that are in place. We suggest that preparedness activities including exercises may also provide an opportunity to further strengthen the role of LUCs if required.

Responsibilities and expectations of each group (particularly ministries and government agencies) should be clarified and communicated with key partners. Indeed, a more thorough review of how well transport sector organisations understand their reporting obligations could be conducted. Such work would aim to reduce any confusion between agencies as to who is responsible for what aspects of the response, communications and data collection and dissemination. However, it should be noted that when an event involves the private sector, there may be commercial sensitivities that prevent the effective exchange of some information. This can be managed by bringing all parties together into one room to identify and address the private companies concerns. This was achieved during the 2017 fuel shortage with rapid, positive effect.

Techniques to get the right level of messaging to the right people should be investigated further. Structures that streamline post-crisis communications (such as the JAU), to provide organisations with a clear, single point of contact either within government, within their sector, or between sectors and subsectors, can be established and tested during business as usual (see focus case 'Sector Coordinators'). It may be necessary to give one level of information to one group, such as to domestic partners and customers, and another to others, such as to the international markets and the general public, but this needs to be clearly distinguished. Data platform options should be explored to host and deliver such information.

Some information during an emergency response phase will contain high uncertainties and the sharing of such information should be discussed. Uncertain information may be better than none in some situations, as long as any limitations, ranges and/or distributions of the data are acknowledged and clearly communicated. Acceptable data accuracy ranges could be established in collaboration with industry experts, based on industry principles. To streamline data sharing during the response phase of future events, organisational assets must be clearly understood in advance. A national inventory for transport assets will assist with this process. Additionally, new technologies should be considered such as the potential for information exchanges from company fleets, including real-time vehicle speed, position and route choices. Much of this data is auto-generated and can be analysed and passed on to the MoT, NZ Transport Agency or another appropriate organisation. In turn, this would assist with transport management and recovery plans such as the provision of accurate travel time information for travellers and determining heavy vehicle usage on alternative routes.

Information for international markets also needs to be considered in the response, including timeliness, travel delays, and delays with purchases and delivery, so that this can be passed on to potential customers, export/importers and tourists, allowing them to assess their risk appropriately and communicate information accurately with their own customers.

Stakeholders, particularly key decision-makers, should consider improving internal resilience capacities in advance of the next crisis. For example, organisations should develop business continuity plans that address regional vulnerabilities and the ability to run operations from multiple locations nationwide. Future resilience improvement strategies should also consider multiple stakeholders within and across transport (and other infrastructure) sectors where possible. For example, the development of new resilience strategies implemented at CentrePort should consider the impacts on and lessons learned by other New Zealand ports in terms of physical infrastructure impacts and transport disruption that they experienced following the Kaikōura earthquake and previous events.

2.6 Looking ahead

A number of the recommendations described above, and the lessons outlined in previous sections, point to the need for further investigation and development, particularly to establish the most effective methods for enhancing resilience from new knowledge on data availability and use. Areas that would benefit from further detailed investigation include:

- 'Brokering' relationships, including between modes (e.g. NZ Transport Agency and KiwiRail), within modes (e.g. between Napier Port and CentrePort) and across system levels (e.g. between central and local government).
- Managing spontaneous support, such as that offered by private pilots, tourism operators and locals.
- Resilience and redundancies of port infrastructure, the freight and trucking industry, and supply chains to future shocks and stresses.
- The capacity of alternative transport modes including coastal shipping to absorb future shocks and stresses to existing networks.
- Identification and prioritisation of criticality and resilience indicators for ongoing assessment and monitoring, and selection of appropriate data sources.
- Developing plans and processes for the strategic cross-organisational management of air space and private aviation fleets (e.g. personal and commercial airplanes and helicopters that are used for response following disruptive events).
- "Collective responsibility" and how this culture can be engendered across the whole transport system.

‘Corridor forums’ have been used in the European Union to address many of the issues identified in this study (Oberg et al., 2016). These are designed to facilitate better communication and strengthen networks before an event, and operate across modes, regions, and between central and local government and public and private organisations. A RNC-funded research study is currently underway to trial corridor forums in the Manawatu-Whanganui-Taranaki regions.

3 Monitoring Transport Systems: Performance Following Disruptive Events

The final stated objective of this research project was to suggest possible short, medium, and long-term measures for ongoing performance monitoring of the transport system around disruptive events. The aim of such a process would be to better manage information in a way that improves response and recovery following crises and enhances system resilience.

In this section we distil and analyse the types of information discussed in sections 1 and 2 in order to measure and monitor the progress of the transport system in response to this significant disruptive event and the way information flowed to different actors across the transport system. This analysis is conducted to understand how monitoring of the transport system for severe events can be optimised for users across the system, from those responsible for management and repair to those whose livelihoods are impacted when there are system disruptions. This section provides further avenues for the Ministry of Transport and other relevant stakeholders to explore as they consider the development of an overarching transport monitoring system. The development and testing of the transport monitoring system and supporting processes will need to be done in subsequent research. Initially, we briefly identify some of the existing systems used for managing data and monitoring both business-as-usual and post-disruption performance of the transport system. We then present an example of an indicator framework for monitoring the performance of the freight transport system to demonstrate some of the decisions and complexities around indicator prioritisation and data management.

Following the freight example, the post-Kaikōura information flows are captured in an actor map. The actor map shows how formal and informal relationships were used to facilitate data exchange and decision making following the Kaikōura earthquake. The actor map can be used following an event, in the readiness phase of the emergency management cycle, in conjunction with the monitoring tool, to ensure that processes can be set up and relationships established that will ensure that in the next event data gets to the actors it needs to in the most efficient way. The actor map can, for example, be used to identify where gaps in the data and information flow currently exist, while the indicators produced for the monitoring tool establish more precisely the forms that the information should take.

3.1 Current Transport Monitoring Systems

There are several existing business-as-usual initiatives to support data collection and management across the New Zealand transport sector. They include the Transport Knowledge Hub and forums, MoT's Transport Indicator Framework, the NZ Transport Agency's Transport Performance Monitoring Initiative, and the MoT's Transport Dashboard.

Following a disruption, the transport sector uses several existing structures to manage communication and information exchange across a broad multi-agency environment. This includes the ability to establish recovery organisations such as NCTIR, which include GIS teams and ODESC Watch Group structures to support information flows for the TRT. They also include technical platforms such as the CIMS which is run through WebEOC, an emergency response information management tool (used by multiple public and private organisations in New Zealand, Australia, and the USA to aid in emergency information management and decision making). WebEOC is used by Maritime NZ, Fonterra, and Air New Zealand as part of their global incident management structures (Critchlow, 2018).

It was outside the scope of this study to systematically evaluate the efficacy or future applicability of existing information management systems; however, evaluations suggest that systems such as WebEOC can be effective for managing information relevant to a significant transport disruption. For example, a report published by the Bay of Plenty Regional Council on Marine Oil Spill Contingency Planning details MNZ's use of WebEOC to host and facilitate collaborative maintenance of critical databases and information including hosting: an equipment database, incident response standard operating procedures, and systems for tracking costs and managing assets during a response. WebEOC can also be applied to national and regional incident response and can be used for exercises and training (BOPRC, 2018). Similarly, MCDEM and the MoH use the SharePoint-based information sharing application Emergency Management Information System (EMIS). The application is intended for use by and coordination between CDEM officials and those who are only temporarily or less directly involved in the response to a crisis, such as volunteers. It would be useful to conduct further assessment of the ability of these and/or other available systems to be integrated into multi-agency response to events affecting the transport sector. It is important to remember, however, that an information management system must be underpinned by expert awareness of the data needs, good data stewardship, and relationships between staff across affected agencies. These and other concepts emerging from the analysis of the Kaikoura earthquake response and recovery are discussed in the following sections.

3.2 Overview of Future Transport Event Monitoring

The analyses that follow in sections 3.3, 3.4 and 3.5 further make the case for the fundamental importance of fostering best-practice data stewardship and data sharing practices across a multi-agency environment, and for establishing, testing, and maintaining systems for communication and coordination that may be relevant in a crisis.

Our analyses have supported the belief that it would be inefficient, and likely impossible, to adequately centralise the collection and management of *all* relevant information for transport monitoring following a disruptive event. There are, however, several areas that may be worth exploring in future research to improve existing formal and informal data and information systems, so they can be used for crisis response and recovery as well as readiness and reduction.

In addition to the recommendations presented previously, ongoing investigations may consider (ordered from short to long-term):

- Running multi-agency disruption simulations that require rapid information exchange for better response and recovery to identify data gaps and communication weak points. Simulations can identify the 'trigger' points for instigating information flows, including scale and complexity of the event and extent of information sharing required.
- Identifying transport monitoring indicators that are likely to be 'high priority' by information users during and following a crisis and establishing pre-event baseline monitoring systems or databases (where relevant) (extending the example discussed below).
- Identifying the key cross-over data sources, indicators, and processes needed for business-as-usual transport monitoring and crisis related monitoring needs.
- Identifying the most effective crisis information management processes needed to improve information flows across the wider transport system (complementing the indicator and technical tools).
- Assessing the MoT's role in getting wider buy-in from the transport sector for better data management, identifying the barriers around data stewardship and data sharing processes (with the aim of increasing sector resilience in the event of a crisis).
- Building on the MOT's Transport Dashboard approach, prototype a decentralised Application Programming Interface (API[5])-based system for federating key post-crisis indicators and other datasets across multiple organisations (including private-sector data).

3.3 Indicator-based Post-Crisis Monitoring System

Here we offer a preliminary scoping exercise and assessment of the types of data and information that may need to be considered in future post-crisis transport performance monitoring systems. During business-as-usual, transport performance and planning is often supported using complex transport models that are data-

[5] An API is a set of protocols that allow one application to 'talk to' another. A web API can be used to set up a request-response system between a server or database and an application, meaning that populating an application with data across a number of sources hosted across different servers is a lot easier. APIs can facilitate real-time data integration across a network and are being used in data analytics for the shipping and road freight industries internationally.

intensive and typically developed with a project or planning process in mind. Following a crisis, complex models are often impractical and inadequate (Chang and Nojima, 2001). Simple summary measures are uniquely suited to making rapid post-disaster assessments and facilitating assessments of progress and resource and information gaps.

An indicators-based approach is well suited to short and medium-term performance monitoring of the transport system, especially when developing monitoring systems that will be useful following a crisis. They should, however, be established prior to a disruption where possible. A thorough analysis of the workshop data and interviews was conducted in which all the sources of information that respondents applied in their decision making and the degree to which they found it timely and useful were identified. Drawing on this information we examined how these data might be applied in an indicator-based framework for monitoring the performance of freight transport.

To advance the development of this example indicator framework we use an approach based on the Kickstart to Measurement (K2M) heuristic decision making tool (Ivory & Stevenson, 2017). Such heuristic techniques are applied in situations where finding a truly optimal solution is impossible or impractical (e.g., collecting data that capture every aspect of transport system performance), but where a logical defensible satisfactory solution is desired. The K2M progresses users through a series of questions and measurement decisions to identify the underlying theory, assumptions, information requirements, and limitations of their monitoring tool.

The K2M takes the user through several steps, which are specified in the process diagram below (Figure 1).

Figure 1: Process diagram for using the proposed monitoring tool

The K2M is composed of a series of key questions about resilience measurement designed to clarify the assumptions, barriers, and opportunities of different types of measurement. It starts with a specification of the purpose, focus, and scale of the desired analysis. There are then scope refinement questions specifically relevant to research involving system disruptions (i.e., the disruption type and temporal phases relative to the disruption that are of interest to the researcher), followed by a series of questions about the data required or desired for the measure (Ivory and Stevenson, 2017). Such questions include:

- What would you like to measure?
- What are you happy to [or what can you] measure?
- What are you struggling to measure?

Implicit in these broad questions about data are numerous practical considerations, including data accessibility (i.e., cost and permissions) and data quality (i.e., completeness, timeliness of collection, consistency, accuracy, and validity). Consideration of data needs often sharpens and constrains the parameters of the assessment framework. Each step of this process is defined generally in Table 1 and illustrated with examples for the Freight Transport Monitoring System in section 3.2.

Table 1: Defining each step in the monitoring tool development process

Item	Explanation
Purpose	Defines what you would like to monitor and why, including what is out of scope.
Focus	Specifies: modes, locations (geographic extents), timeframes, and other elements of interest.
Outcomes	Specifies 'desired' outcomes or system performance levels or reference points against which the system can be evaluated.
Indicators	Select the indicators and prioritise for monitoring. Indicators refer to the observable variables of system performance that allow users to measure change. Each indicator should have a clearly specified metric that ensures that the indicator will be reported against accurately and reliably over time.
Data	Specify the data sources for indicators and rate the accessibility and quality of data for each metric.

3.4 Freight Transport Performance Case Study

In Table 2 below we have demonstrated an approach to specify the strategic intent (purpose), assessment focus, and monitoring outcomes to monitor freight transport performance and recovery following the 2016 Kaikōura earthquake.

3.4.1 Define purpose and determine focus

Defining the purpose and focus of what is to be monitored is essential for limiting and streamlining what will be examined. This helps users avoid being inundated with irrelevant information by trying to monitor too much or missing critical information because of a poorly designed scope. In the purpose section users set the *strategic intent* for the rest of the process by identifying at a strategic level what will be monitored and for what purpose. In the example in Table 2 the purpose is to monitor freight transport performance following the Kaikōura earthquake. The focus section then further refines the strategic purpose by specifying the monitoring scope.

Table 2: Monitoring tool scoping process for freight transport example

Purpose	
Monitoring the performance of the freight transport system in areas affected by the November 2016 Kaikōura earthquake.	
Focus	
Networks of interest	Freight transport – all modes
Geographic extent	All of New Zealand
Timeframes	Response and early recovery phase November 2016 – November 2017
Outcomes	
Network performance & capability	The freight throughput, cost, and time to transport is the same or better than before the Kaikōura earthquake.
Safety	The rate of transport accidents, injuries, and deaths is the same or lower than before the Kaikōura earthquake.
Community Health & Wellbeing	Freight transport is not hindering the mobility, safety, or wellbeing of the communities through which it passes.
Cost	The costs of repair and recovery are economically justified for the long-term economic health of the affected areas/ New Zealand.

3.4.2 Specify Outcomes

Next, users create outcome statements or performance levels against which the system can be evaluated. Outcome statements make explicit where the user would like the system to be and can be used as a benchmark against which progress can be measured. For the transport system, there are several domains in which outcomes may be specified and that would require different indicator sets, including transport network and capability, safety, community health and wellbeing, and environmental health. There may also be cost or financial outcomes for specific projects that need to be monitored. In this example, we have identified four outcome statements: network performance and capability, safety, community health and wellbeing, and cost (Table 2).

3.4.3 Select and prioritise indicators

Once the monitoring intent is set, the user then identifies a range of potential indicators for monitoring progress towards the desired outcomes. In this example, we identified approximately 60 indicators and 90 metrics (i.e., quantifiable measures) from actual data used, requested, or desired by workshop and interview participants. We also integrated indicators and processes identified as part of the Transport Knowledge Hub's "Stocktake of Data and Information Sources" (2017) and from the NZ Transport Agency's "Framework for Investment Performance Measures for the Transport System" (2017) that are likely to have been relevant post-disaster, but not captured in our qualitative assessments.

Indicators identified from the study are shown in Appendix C along with an assessment of their priority for monitoring post-disaster recovery of the freight transport system. Selecting and prioritising indicators is relevant in a resource limited environment. Gathering and collating data for indicators takes time and resources. Indicator prioritisation allows users to establish the relative priority of the indicators.
In the freight system performance monitoring example provided, we assessed priority as a function of two variables:

- Importance – The importance and practicality of the indicator to the stated purpose of the monitoring tool (How important is this indicator to your ability to say something meaningful about what you are trying to measure?)
- Timeliness - The degree to which the absence of this indicator would delay or hinder key decisions (i.e., decisions that will influence outcomes for the transport system)

The importance factor was rated on a 1-5 scale, with 1 being: "the indicator will not have a significant role in monitoring" and 5 being: "we will be unable to accurately monitor the system without this indicator". Similarly, the timeliness indicator was rated on a 1-5 scale, with 1 being: "the absence of this indicator will have almost no effect on key decisions", 2 – "the absence of this indicator will have a slight effect on key decisions", 3 – "the absence of this indicator have a moderate effect on key decisions", 4 – "the absence of this indicator will have a major effect of key decisions", and 5 being "the absence of this data will severely hinder the ability to make key decisions". Ultimately, each indicator received a prioritisation score between 1 and 10, with indicators that scored closer to 10 being higher priority.

Determining when the indicator will be most relevant is also an important part of prioritisation. Initial damage assessments, evacuation and other life-safety needs are critical immediately following a disruptive event and, depending on the nature of the event, may not be repeated. On the other hand, indicators that provide insights into the network capability and performance, such as the total distance-based accessibility of the road network, will need to be monitored regularly throughout the recovery period. Therefore, we recommend regularly assessing the frequency with which indicators are reported and noting when collecting indicators becomes redundant. The indicator tables in Appendix C note the priority scores as well as the indicator likely to be most relevant when in the post-disaster phase (response or recovery).

The prioritisation process identifies 24 top priority indicators (i.e., those with a priority score of 10). Of these, 20 need to be monitored regularly throughout the response and recovery period. Two indicators are most relevant in the response phase only, and two are most relevant in the recovery phase only.
Once the user identifies the priority indicators, the data needs, sources, and gaps, a process for regularly gathering and processing the indicators against the monitoring outcomes begins.

3.4.4 Link to data

A preliminary data availability assessment for the 24 priority indicators for freight transport system monitoring is available in Appendix C. The analysis shows that many of the priority indicator datasets available following the Kaikōura earthquake were owned or maintained by multiple organisations and agencies and would need to be reported and updated on a daily or weekly basis during the response phase and, in some cases, throughout the recovery phase. Additionally, many of the datasets, such as damage and asset capability assessments and traffic behaviours (e.g., breaching cordons), need to be regularly collected in the field and reported back to a coordinating agency.

3.4.5 Reflections on freight transport performance monitoring example

The assessment of the freight transport performance monitoring needs using data from the post-Kaikōura response was instructive in the consideration of the spread of information needing to be regularly collated to form the basis of a relatively streamlined indicator-based monitoring framework - from geophysical data, to impact and functionality information for transport assets, and information about the needs and behaviours of transport users.

Although most of the information required for critical decision making was available, some indicators that had been identified as 'priority' indicators in this analysis were only captured following the Kaikōura earthquake or emerged following multiple requests for the same data. Many of these indicators were collated on an ad hoc basis. For example, there was no data capture or reporting system available for 'freight transport ability to meet demand', so it was unclear whether and where freight company customers were experiencing delays and losses. It may be possible for freight companies to consider this prior to a disruption and find ways of capturing and processing this information to optimise their response. It is also important to note that indicators will need to be compared against a pre-disaster benchmark to assess progress relative to the strategic intent and desired outcomes of the process. This requires the establishment of more comprehensive pre-disruption (business-as-usual) monitoring as part of an overarching transport monitoring system that specifically includes key indicators that would also be relevant in a crisis response and recovery environment.

Significant work has already been undertaken to assess whether the transport sector has the data and information it needs. The Transport Domain Plan (Transport Knowledge Hub, 2016) identifies transport-related data and information gaps, some of which emerged in our analysis. For example, the shortage of data on the Cook Strait, including passenger and freight movements noted earlier in this report relates to R3.9 of the recommended initiatives in the Transport Domain Plan (along with R3.12 and R1.12). Similarly, the recommendation emerging from the analysis of the post- Kaikōura earthquake response and recovery noting the need to establish a national inventory maps to R.1 in the Transport Domain Plan especially as it relates to developing a profile of fleet, rail, maritime and aviation fleet (along with R1.10, R1.11, R1.4, R1.9).[6]

Finally, a network of relationships needs to be continuously maintained between the organisations that collect and maintain datasets that are relevant to priority indicators and those needing to use them. Again, there are significant efforts already underway across the transport sector (e.g., the Transport Knowledge Hub's aggregation of relevant outputs, regular communications and events). The analysis in Section 5, provides a more structured assessment of the way information flowed between actors in the post- Kaikōura earthquake transport response and recovery. It is, however, notable from the assessment of freight transport performance indicators that to establish a monitoring framework that is useful for multiple parties, data will need to be produced, maintained, updated, and regularly shared in a useable well-documented format (e.g., with minimum metadata requirements where applicable).

Finally, the scope of monitoring can easily become burdensome and unmanageable for agencies involved in the response and recovery. It is therefore prudent to regularly assess the frequency with which indicators are reported and note when collecting indicators becomes redundant or when different indicators should be

[6] "R1.10 Develop a fleet profile for specialist wharf-side fleets; R1.4 Develop an aviation fleet profile; R1.8,1.9 Develop a maritime commercial/ recreational fleet profile; R1.11 Develop a rail fleet profile; R1.12: Explore a data partnership with rail operators to share rail data; R3.12 Develop a workable approach to collecting data from operators on Cook Strait freight" (Ministry of Transport, 2016, p. 37-38).

substituted. As a rule, performance indicators will not provide a complete picture of the situation on the ground. They are designed to provide a systematic assessment which can then be followed up by forming task units to identify and address emerging issues flagged by the monitoring system. It is important with any monitoring system that agencies limit their measurement to what their resources allow or the task at hand requires (Išoraite, 2005). Assessment and reporting itself can quickly become a burden and over-complicated in post-disaster situations. The purpose of the indicator-based processes is to develop a systematic approach to establish and streamline the monitoring of transport systems in a way that is manageable, repeatable, and leads directly to useful action.

3.5 Managing Information Flow for the Monitoring System

How and where information is shared is as important as what is monitored. A monitoring tool necessitates having a clear understanding of how data and other information flows within the transport system in response to and during recovery from adverse events. A ‘map’ of the key agencies, organisations, and decision makers (actors) involved within the transport system and the direction information and data moved between them provides a visual representation of these information flows. Such ‘actor maps’ have been used previously to understand connections within the NZ transport system (Trotter & Ivory, submitted). In this actor map, the agencies, decision-makers and other actors are mapped in relation to their position within the transport system, either relating to government, regulation and monitoring, local government and company management, operational management, individuals or equipment and environment.

The actor map can be used following an event, in the readiness phase of the emergency management cycle and/or in conjunction with the monitoring tool, to ensure that processes can be set up and relationships established that will ensure that in the next event data gets to the actors it needs to in the most efficient way. For example, the actor map can be used to identify where gaps in the data and information flow currently exist, while the indicators produced for the monitoring tool establish more precisely the forms that the information should take.

In the actor map in Figures 2 and 3, the key information flows following the Kaikōura earthquake are represented by arrows. Red arrows arriving at an actor mean that key information was required, and flowed to, that actor from the connecting actor. Outgoing blue lines mean that information was provided to the connecting Actor. Where the provision of information was reciprocal, a double headed arrow (in purple) is used.

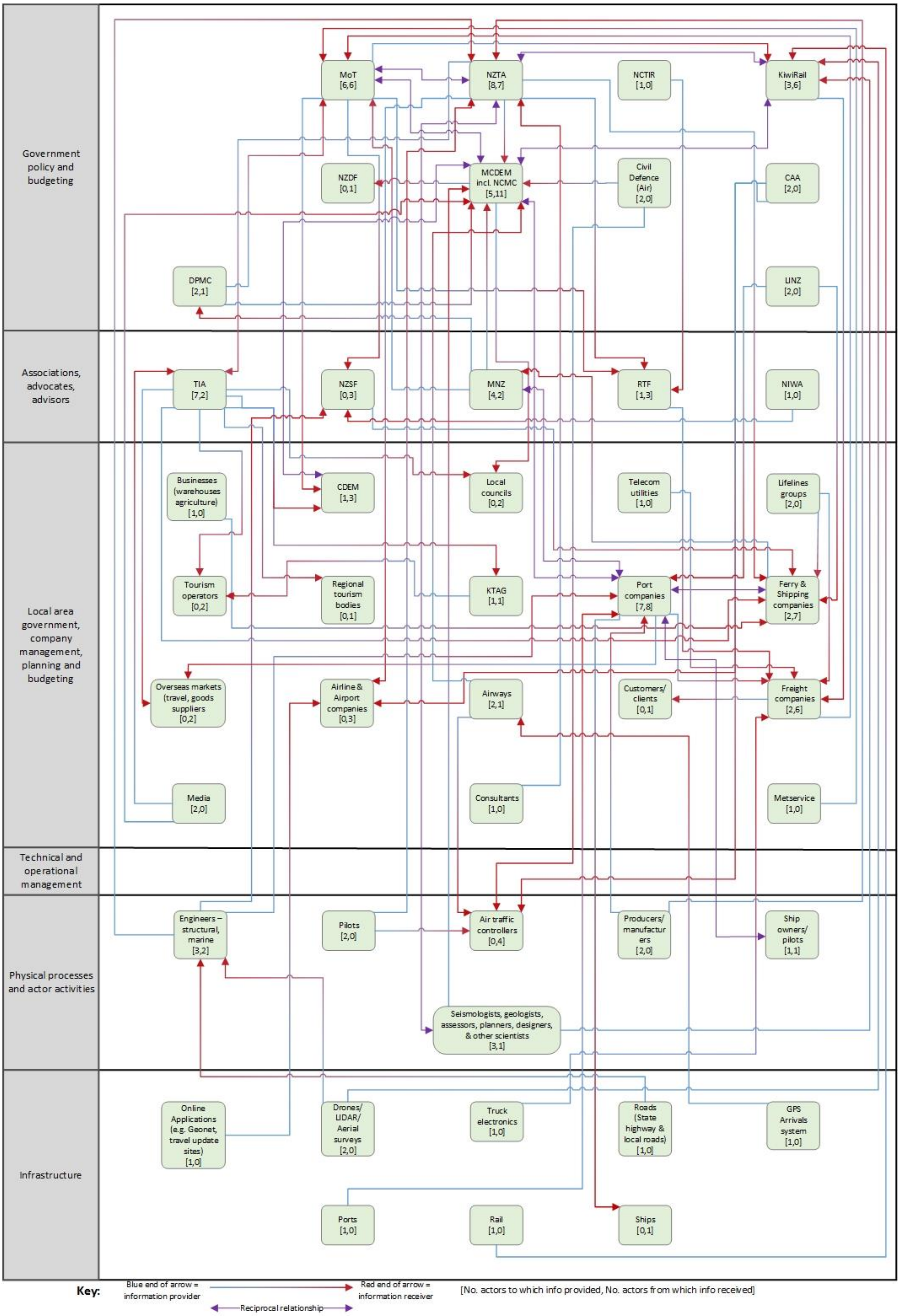


Figure 2. Actor map of the response and recovery following the Kaikōura Earthquake event as drawn from the Stakeholder workshop and interviews

3.5.1 Actor map findings

Complexity

The actor map demonstrates the high level of complexity and cyclicity in information exchanges, with interconnecting actors positioned across almost all system levels: 47 actors in total. It should be noted that these 47 actors do not represent all actors within the transport sector involved in the Kaikōura response, only those identified by participants as key to obtaining information for key decision making (the larger context of the network has been captured in an actor map by Trotter and Ivory (submitted)). The majority of actors are clustered in the 'Government Policy and Budgeting' and 'Local Government, Company Management Planning and Budgeting' levels (10 and 18 actors respectively), but interconnections stretch across all system levels. This supports the conceptualisation of transport resilience as a systems phenomenon. The high level of complexity also establishes the need for a simple step-wise process to determining monitoring needs, rather than attempting to consider the entire network at once, or in an ad hoc fashion. Because the map is highly complex, a simplified version, showing only the key actors and relationships across the system, is included in Figure 3.

Key connections

Three of the most highly connected actors were at the 'Government Policy and Budgeting' level, two of them being Ministries: MCDEM and MoT, and the other a government agency: the NZ Transport Agency (Table 4). This is unsurprising given that the transport response to a major disaster falls directly within the remit of these organisations. It does, however, support the MoT's articulation of its role as being the "conduit of information within the system" (Personal communication, MoT CEO, 2018), and given that the information being received and imparted is approximately balanced. Incoming and outgoing information flows are also approximately balanced for the NZ Transport Agency, indicating that the agency is also acting as an information conduit. The monitoring tool will be a useful way for clarifying which indicators and information flows ensure the most effective response of the system.

It is important to ensure that data received is not filtered if it is required by another group. Several participants in the interviews indicated that they were getting requests for the same data from multiple agencies, which was both frustrating and time consuming. The actor map can indicate where this might be occurring and can be used in conjunction with the monitoring tool to determine who has responsibility for coordinating what data in order to eliminate double ups.

The other highly connected actors were at the 'local government, company management planning and budgeting' levels, including port companies, ferry/shipping companies and freight companies (Table 4). Port companies were identified as the receivers and providers of the largest amount of information. Shipping companies and freight companies were mostly receiving information, most likely because they represent the end of the line in the decision making process in terms of planning how and when to transport goods. It is surprising, however, that at least some of this decision making (and therefore some of the data input) isn't occurring at the 'technical and operational management' level, particularly in the case of road freight, where road conditions impact on travel routes and arrival times daily and even hourly.

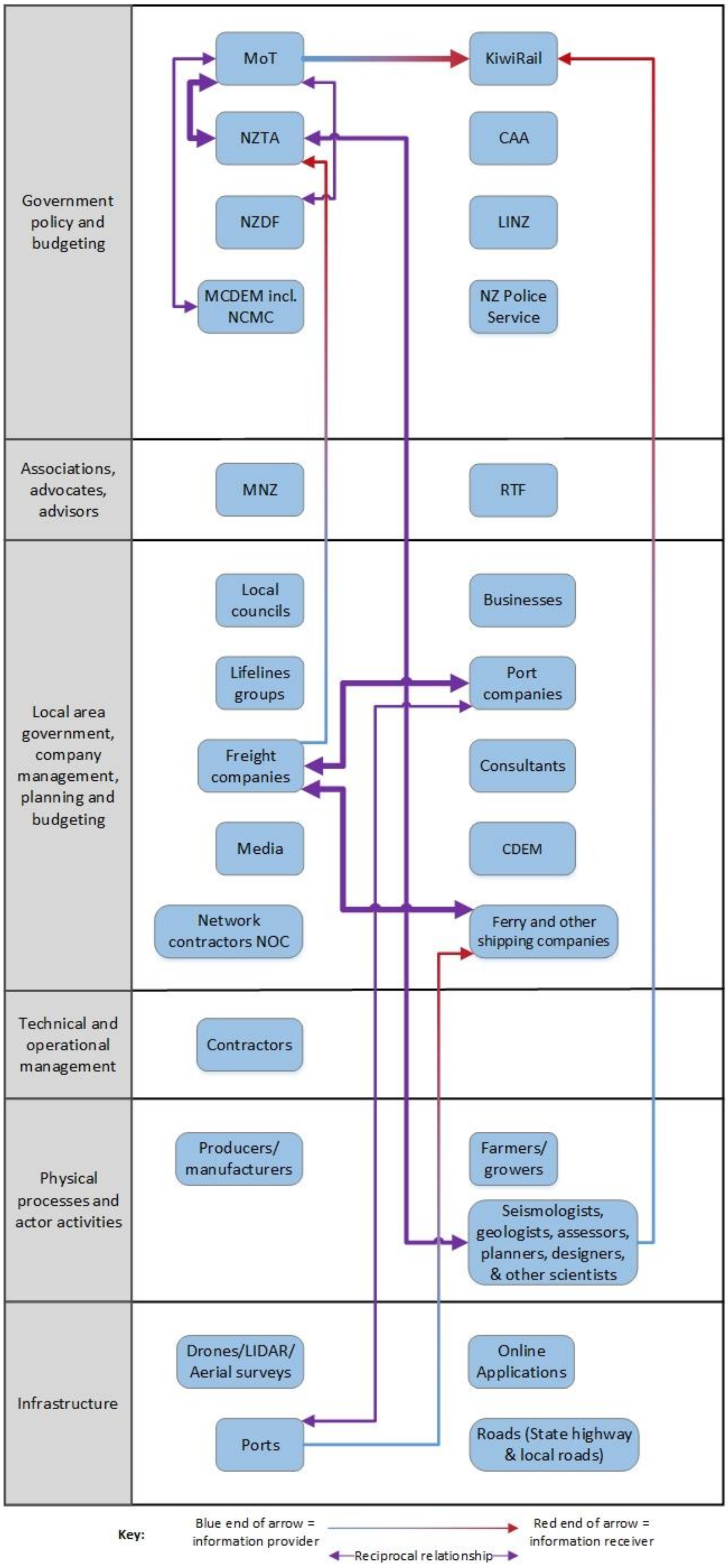


Figure 3. Simplified actor map of the response and recovery following the Kaikōura Earthquake showing key actors and relationships based on the stakeholder workshop and interviews. Line width indicates indicated importance of relationship as identified by participants in the system.

Table 3. Most highly interconnected actors on actor map

Actor	System level	Info. being provided	Info. required	Total connections
New Zealand Transport Agency	Government Policy and Budgeting	8	7	15
Port Companies	Local Government, Company Management Planning and Budgeting	7	8	15
Ministry of Civil Defence and Emergency Management	Government Policy and Budgeting	5	11	16
Ministry of Transport	Government Policy and Budgeting	6	6	12
Ferry/Shipping Companies	Local Government, Company Management Planning and Budgeting	2	7	9
Freight Companies	Local Government, Company Management Planning and Budgeting	2	6	8

Information exchange gaps

No actors provide or receive identified information or data at the 'technical and operational management' level and the density of connections at the two lower levels of the actor map is low compared to the upper levels of the system. Information from those on site, and their direct supervisors can provide key insights when responding to highly dynamic situations where uncertainly is high and decisions are needed rapidly. It is therefore important to the network's resilience that information from these lower levels can feed back up the system to the decision making level. Likewise, those on the ground are also the medium for direct action immediately following a disaster, so equally it is important for information to reach them to support the decisions they will necessarily be having to make in difficult situations. The actor map indicates there is room for improvement in the flow of information to and from the bottom three levels of the system. By examining the actors at these levels in conjunction with the monitoring tool it will be possible to identify what data would be most useful from these levels and where it needs to flow. This could mean the addition of more actors, particularly into 'technical and operational management' level. Likewise, it will be important to identify what data at higher levels needs to reach these levels in order to ensure that the resilience of the system as a whole improves.

3.5.2 Example: Freight Transport following the Kaikōura Earthquake

The freight transport example discussed above is used here to demonstrate how the actor map can be used to identify interactions and potential process improvements that can be made to enhance resilience in future events. Figure 4 highlights the interconnection between freight companies and other actors, both directly and indirectly. The Map illustrates how information from a company's fleet, such as real-time vehicle speed, position and route choice can be obtained and analysed by freight companies and the data passed on to the MoT should they request it. This information could also be of use to the NZ Transport Agency in devising accurate travel time information for motorists and determining heavy vehicle usage on alternative routes. Such information could then feed into decision making for aviation and maritime companies as they coordinate their schedules. Within this system, the RTF can act as an information coordinator and conduit to and from decision-makers within the MoT and NZ Transport Agency and the freight companies it represents. This can help ensure the provision of consistent communications and data presentation.

Understanding these exchanges gives the MoT and NZ Transport Agency the opportunity to establish which parts of this information is useful for them to provide and in what form. It also allows these groups to work with freight companies to obtain this data in the most useful format so as to minimise further data processing. Such information may be of use to tourism and business industries. This connection does not currently exist on the actor map, highlighting an area where further relationship building may be warranted to enhance the resilience of the transport system.

A further research output, following the population of the monitoring tool framework, could be to combine the visual format of the actor map with the specific indicators that need to be communicated from one actor to another as identified by the monitoring tool. This would produce an indicator map aligned with other monitoring tool outputs.

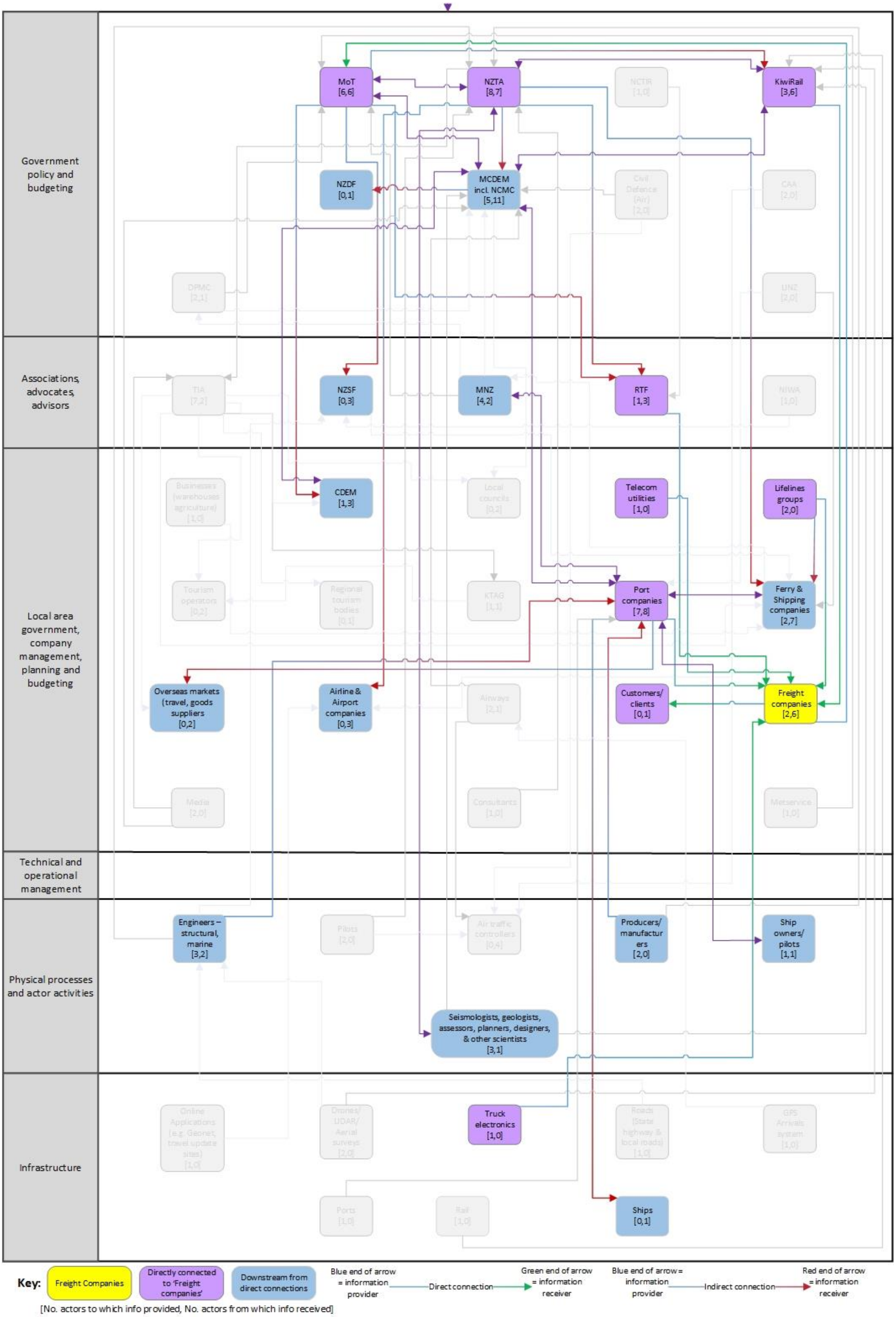


Figure 4. Actor map highlighting the interconnections, both direct and one step removed, between freight companies and other actors in the system.

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5 Appendix A: Method

5.1 Data Collection Aims and Objectives

The workshop and interviews were designed to explore the decision making process and information usage of key stakeholders. A range of organisations were brought together in a collaborative workshop setting, enabling the sharing of response and recovery strategies and identifying important links. Agencies who were unable to attend were followed up with interviews. The workshop and interviews focused establishing key decisions and the information and data that contributed to them. A key focus of the workshop was to understand what data was available and what data was not available that would have been important for decision making following the earthquake, including:

- Data coverage (data ownership/stewards, acquisition frequency)
- Understanding data barriers (consistency of meta data standards)
- Data governance issues (what data can be made public and at what level)

The workshop and interviews covered data and decision making under the following broad categories:

- Physical transport infrastructure.
- Levels of service including conditions, quality, closure information, disruption of individual modes (e.g. rail or road). This will leverage off the RNC funded Project A.
- Transport services for people and freight across all modes.
- Aviation (scheduled and non-scheduled services); maritime (national & international shipping, ferry services); rail; road.
- Fuel supply and fuel infrastructure.
- Access to fuel security, fuel infrastructure impacts.
- Indirect impacts, including substitution and pricing effects.
- Travel times, additional business costs, additional personnel requirements, just-in-time practices, freight pricing dynamics, use of alternative business practices (e.g. teleconferencing).
- Displacement of residents and transient populations.
- Tourists, seasonal workers, etc. This will leverage off the RNC funded Project B and E.

5.2 Participant Recruitment

Stakeholders from the main public and private transport entities, central and local government, infrastructure providers, industry groups, freight providers, and tourism representatives were invited to the workshop via direct email from the MoT. Invitations to attend the workshop outlined that participants would explore the types of transport system impacts experienced and observed following the Kaikōura earthquake; how decisions were made with and without 'good' information; and the ability to observe impacts and monitor the response and recovery. Stakeholders were also sent a detailed outline of the activities for the day. Those wishing to participate responded to the MoT, who collated the final attendee list and noted for subsequent follow-up, any key stakeholders in areas of interest that could not attend. Those who could not attend were contacted following the workshop and interviewed.

5.3 Materials

5.3.1 Workshop Materials

Workshop participants sat at tables in groups of five to ten people. Each workshop group was provided with the following interactive props:

- *Maps*: Two A3 Maps covering an area of New Zealand extending southwards from the Auckland region and northwards from the north of the Otago region, one with territorial boundaries and one with heat mapping of earthquake shaking intensity.
- *Timeline*: One large timeline was attached to two long walls of the venue (approx. 30m total). This timeline was divided into a short 'pre-event' section, then into individual days for the first 30 days post-quake, then into weeks up to 12 weeks, then into months up to the 12 month (November 2017),

then finally an 'ongoing' section. Only odd numbered days, weeks and months were displayed due to the limited extent of wall space in the venue.

- *Note pads*: Pink and orange A5 post-it note pads and pens. Pink for recording decisions and orange for recording data.
- *Stars*: Star stickers for placing on notes on the timeline to indicate decisions that were particularly important.
- *Dots*: Green, orange, and red dot stickers for placing on notes on the timeline describing data used for decision making. Green for data of high quality/availability/usefulness, orange for average, and red for poor. Red dots with a star in the centre were also used, to indicate data that would have been very useful but was not available/accessible at the time of the event.

5.3.2 Interview schedules

Two semi-structured interview schedules were developed, one specifically for CEOs and the other for other interview participants.

CEO schedule

1. How do you see the position of [ORGANISATION] in the transport resilience 'movement' – what is its function and place in the strategic picture around gathering, managing and sharing data and information?
2. Who are the [ORGANISATION] targeted communications partners and what is their position in the chain of information exchange? How do you identify and manage key communication channels? Do the key partners and communication processes change in an emergency from the standard reporting / information chain? If so how?
3. How is [ORGANISATION] looking to enable adaptive management? And how do you see the role of data and information for that? (for example, for monitoring and benchmarking, identifying emerging hazards and vulnerabilities)
4. If [ORGANISATION] were to have the chance to redo the response to the Kaikōura earthquake, is there any organisation you would work with differently? Particularly with regard to sharing information? Are there any organisations that weren't included whose data and information you now see as useful (or would bring in earlier)? Is there anything else you would change? What wouldn't they change?
5. What are the biggest remaining challenges to resilience in the future?

Generic Schedule

Background: How was your organisation / sector affected by the transport disruption following the earthquake? Prompt for geographic scale, temporal scale, secondary disruption (e.g., to clients & users)

1. Can you describe the role played by data and information to your organisation / sector over the response and recovery from the earthquakes?
    - (a) What was most critical to decisions and when? (e.g., for situational awareness, monitoring, managing resources, forward planning)
    - (b) Where did it come from and/or go to? How easily was that information sourced, managed and shared?
    - (c) How confident were you in the information you were using? And how much did your level of confidence matter to making decisions?
2. How different was your need for / use of data and information from BAU?
    - (a) e.g., type of data, volume, speed, quality, source
    - (b) Standard chain of reporting / communication?
3. What were the most frustrating barriers to better access and use of data? (yours and others)
4. What was the most useful data for your needs? What made it work well? (Type, processes, communication etc.)

5. Were there any new useful data / information opportunities that emerged over the response and recovery? Either ones that you gained from or that you realise now would have been good?
    (a) New data sources
    (b) New communication partners
    (c) Ways of managing data (standards, classification methods, cataloguing and recording etc.)

5.4 Procedure

5.4.1 Workshop

The workshop was held between 09:30 and 15:30 on 22 November 2017 at Wharewaka Function Centre in Wellington, New Zealand. It was jointly facilitated by the research team listed at the start of this document, with specific exercises led by staff from Opus and Resilient Organisations.
The participants divided themselves into groups around seven tables and listened to an introduction of the aims and objectives of the workshop and the project as a whole. Participants were then led through a series of six exercises, which proceeded as follows:

Spatial Considerations

Mapping consequences

- *Exercise 1*: In their groups, participants used the maps to describe and record the location of direct and indirect consequences of the earthquake event across the country. A representative from each group then used their maps to assist in presenting the consequences back to the whole group.

Temporal Considerations

Identifying decisions on the timeline

- *Exercise 2*: Participants discussed in their groups and then identified individually, the details of key decisions they, other staff at their organisations, or other agencies made in the response and recovery of the earthquake event. These details, which included what was decided and who made the decisions (sector, agency, level) were recorded on pink note pads and placed appropriately along the timeline.
- *Exercise 3*: Once all decisions were posted, participants were asked to examine the timeline and classify decisions by their significance using the stars provided. Each person had one sheet of stars that they could allocate to notes as they saw fit.
- Discussion: A facilitator identified decisions with a large number of stars and the group as a whole discussed these further.

Identifying information activities on the timeline

- *Exercise 4*: Participants discussed in their groups and then identified individually, the details of the information and data that was sought, used, or generated in order to respond to and recover from the earthquake. These details were recorded on orange note pads and placed appropriately along the timeline.
- *Exercise 5:* Once all information and data sources were posted, participants were asked to examine the notes on the timeline and classify the information and data sources by quality, quantity, accessibility and usefulness using a 'traffic light' colour scheme of dot stickers. Each person could use as many green, orange, and red dots as they needed.
- Discussion: A facilitator identified data with a large number of both red and green dots (i.e. contrasting opinions) and these were discussed further by the group as a whole, as were data sets with many red starred dots, which indicated that the data was desired but was not usable, accessible, or available at the time.

Information Flows

Evaluating and classifying information flows

- Discussion: As a whole group, based on the mapping and timeline exercises, participants reviewed how information was able to flow from data to decisions, focussing on timeliness, sufficiency, and fit for purpose.

Addressing information flow issues

- *Exercise 6:* As a whole group, participants identified possible solutions to existing and future information issues, including:
- Information gap filling priorities
- Supplementary sources of data
- Sharing information.

5.4.2 Interviews

Interviews were conducted in person at participants' offices where possible, or by telephone where participants were in different cities to the research team. Interviews were conducted at a time convenient to participants between January and March 2018. In each interview, one member of the research team would take the participants through the questions while noting their responses. Interviews lasted between 30 minutes and 1.5 hours depending on participant availability and level of involvement in response and recovery activities.

5.5 Analysis

5.5.1 Workshop and Interview Data Collation

Following the workshop, decisions and data notes were collated by date according to the timeline and were photographed and transcribed by a member of the research team. Double-ups were removed and a master timeline constructed electronically. Star counts were used to identify key decisions. These were then analysed by two additional members of the research team in order to iteratively identify and develop key themes. Information and data sources were analysed in terms of quality, accessibility, and usefulness through examination of the coloured dot stickers and additional notes based on the group discussion of these. Flows of interaction between data and decisions were also qualitatively assessed, and key themes and relationships identified.

Following the interviews, participant responses to each question were combined within an excel matrix and scrutinised for themes. Key information/data providers and receivers were identified, along with challenges to the transfer of information and enablers of effective transfer. Data was tabulated and additional insights beyond the workshop identified and documented.

5.5.2 Monitoring process and tool

The monitoring tool development process is based on the Kickstart to Measurement (K2M) tool that is being developed through the Resilience to Nature's Challenges Trajectories Toolbox. The K2M is a heuristic decision making process that facilitates a structured enquiry into system monitoring requirements and structures. The demonstration of this tool for the freight transport system following the Kaikōura earthquake drew on indicators based on actual data from the post-event workshop and interviews, and also from indicators and processes identified as part of the Transport Knowledge Hub's "Stocktake of Data and Information Sources" (2017) and from the NZ Transport Agency Framework for investment performance measures for the transport system (2017).

5.5.3 System map

Using information from the workshops and interviews, the key agencies providing and receiving data were identified and categorised according to a systems level framework to aid usability. This framework has been used to perform systems analyses in events across multiple domains, including transport and is currently being employed elsewhere in the Resilience to Nature's Challenges National Science Challenge to describe the NZ transport system. The identified agencies were then positioned on the framework at their appropriate system levels and the interconnections identified in the data depicted by linking these agencies together across the map.

6 Appendix B: Interview Results

Tabulated summaries from each interview question are presented below.

6.1 Participants

Thirty-seven participants took part in the workshop in addition to the research group and 24 participants participated in the post-workshop interviews. These participants represented the 35 key stakeholders listed below:

- Airways New Zealand
- Beef and Lamb New Zealand
- Canterbury Civil Defence and Emergency Management
- Canterbury Lifelines Group
- CentrePort
- Christchurch Transport Operations Centre
- Chartered Institute of Logistics and Transport
- New Zealand Defence Force
- Foodstuffs (NZ) Limited
- Halls Group
- Interislander
- KiwiRail
- Land Information New Zealand
- Maritime New Zealand
- Mainfreight
- Ministry of Civil Defence and Emergency Management
- Ministry for Primary Industries
- Ministry of Transport
- Napier Port
- North Canterbury Transport Infrastructure Recovery
- Opus New Zealand
- New Zealand Police
- Port Marlborough
- Progressive Enterprises (Countdown)
- Road Transport Forum
- Royal New Zealand Air Force – Air Traffic Control
- New Zealand Search and Rescue
- New Zealand Shipping Federation
- Strait Shipping
- Tourism Industry Aotearoa
- New Zealand Transport Agency
- Transport Consultant - Independent
- New Zealand Treasury
- Wellington Lifelines Group
- New Zealand Wine

6.2 The role played by data and information in the response and recovery from the earthquakes

Participants were asked to describe the role played by data and information to their organisation / sector over the response and recovery from the earthquakes. They were prompted to address what was most critical to decisions and when? (e.g., for situational awareness, monitoring, managing resources, forward planning), where the data came from and went to, how easily it was sourced, managed and shared, and how confident they were in the information received.

6.2.1 Key information sources and receivers and their roles in the "resilience structure"

Participants identified both key sources of data and key people they passed data on to. These are listed below.

Q1 Key Information Sources		Q1 Key Information Receivers
● Media		● Customers/clients – Freight movers – Oil companies
● NZ Transport Agency Highway app		● Other modes
● NCTIR	X2	● CAA
● NZ Transport Agency		● Airways
● MoT Teleconference		● Tourist operators
● Truck electronics		● KE-TAG members
● RTA Emails		● MoT
● Engineers – Structural – Marine	X4	● NCMC incl. MCDEM (Situation reports)

- Civil Defence
- CAA
- Airways
- Pilots – mobile
- Local councils
- Regional tourism bodies
- VSEG-KTAG
- Ports

- Centre, POAL, Napier, Marlborough

- Ships/shipping companies
- DPMC
- NCMC
- NIWA
- RTF
- NZSF
- TIA
- Police

- Overseas markets – travel/tourism – goods suppliers
- Ship owners/pilots
- Port companies
- TIA
- DPMC
- MCDEM
- Local councils
- RTF x2
- NZSF
- MNZ
- Police
- NCTIR

CEOs were asked a number of different questions to the other participants, including about their organisation's key partners, structure and management.

CEO Q2 Key Partners
● *RFT key partners*: MoT, NZ Transport Agency, KiwiRail, NZSF. Communicated with key partners by email then phone/text if not reached by email. Also communicated with drivers via truck tablets. ● *Mainfreight key partners*: MoT, customers. Communicated in person or via email. ● *MoT key partners*: NZ Transport Agency, KiwiRail, CentrePort, Shipping companies, Transport Response Team Can't be too prescriptive with lists of partners as each event is different.
CEO Q1 Role in resilience 'structure'
● *RTF and NZSF* = sector representative bodies – conduits of information between members and government, as well as providing advocacy, support, and innovation. ● *MoT* = coordinating role bringing together and distributing information, providing an overview of whole system, a holistic perspective.
CEO Q3 Adaptive Management
● Need the 'right' people not prescribed people ● Mindset – a barrier to obtaining information was the desire for agencies and analysts to hold on to data until they were certain that it was highly accurate. In times of crisis, this information is needed sooner and it is more important to have access to a lot of data, even if it is not 'perfect' in order to iterate toward a solution.

6.2.2 Key information critical to decision making

Participants identified the information that was critical to their decision making following the quake, including the information they felt was most useful. This information is listed here.

Q1 Key Information		Q4 Most useful info
• Road/bridge conditions and restrictions	X3	✓✓
• Roadworks locations		
• Real time updates (emails)		
• Infrastructure/asset status/integrity – engineering data - wharfs, berths, rail lines, bridges, roads	X5	✓✓✓✓✓ + system for prioritisation

• Air traffic schedule/flight info		
• Harbour floor status – sonography		
• Number of visitors & vehicles in area		
• Cargo esp. hazardous goods		
• Vessel status/info		
• What is needed for the government?	x2	✓
• Who is in charge? – Command structure		
• Fuel flow		
• EDCIS information		
• Travel times		
• GIS – damage mapping		
• LiDAR – hill movement		
• Traffic concentrations		
• Aerial photography	X2	✓✓
• Operational data – freight, shipping volumes	X3	✓✓✓

6.3 How information needs differed from business as usual

Participants were asked how their data needs differed from business as usual in the aftermath of Kaikōura. They were prompted to consider the type of data, as well as the volume, speed, quality, sources. They were also prompted to consider the standard communication structure within their organisations. The results are described below.

Q2 Comparison to Business as Usual	
Same…	- People involved - Translation, feedback to ministries - Detail required - Time pressure/urgency - Cooperation required - Desire to work for common good
More…	- Greater scale - Changes in priority to quake related work - Changes in cargo type - More communications with customers - Novel communications techniques - More details and context to off-shore markets - Air traffic control equipment – improvised radio set up - Need accurate visitor numbers, road closures, travel times

6.4 Enablers of effective data access and use

As part of considering what data was most useful, participants were also asked to think about why the process of obtaining it worked well. The various enablers of data use are described here.

Q4 What worked well	
• Main contact at MoT/NZ Transport Agency – 'sector coordinators'	
• Sector representative bodies to coordinate info	
• Direct liaison with regulator	
• Good relationships already established with clients/government/other agencies/engineers	x4

- Skilled available staff
- Public/private industry group (KE-TAG)
- People part of decision making groups
- Data control person and consistent data processes
- Data visible on large scale (e.g. KiwiRail's mural)
- NCTIR – helped groups think of each other as well as their own response
- Contacts in media
- Checklist of priority infrastructure
- Good communications equipment and processes

6.5 Barriers to better access and use of data

Q3 Barriers
● Lack of communication link between ports/marinas and CDEM ● Frustrating tsunami alerts ● No list of approved operators in restricted air space, or process to check ● Lack of understanding as to where and when information was being received (systemic knowledge) ● Gap in communications between KiwiRail and GNS and consultants so didn't know who was out on the line and didn't know how assessments were being done ● Lack of visibility of overall response ● Lack of understanding by clients as to how badly ports damaged ● Lack of Cook Strait freight tonnage data ● GNS reports and papers don't highlight applicability to KiwiRail or NZ Transport Agency ● Large amount of information requested by multiple people at multiple agencies/ministries – lack of coordination between agencies and no single source of truth, "people don't want to go to government too" ● Command hierarchy and structure not clear ● Lack of understanding as to what Tourism can help with x3 ● Unrealistic assumptions and discussions by MoT and others as to what can be done with shipping in emergencies (e.g. ferry evacuation, running ferries to Christchurch) ● Ports, ferries, Rail not on MoT teleconference, lack of consistency in participants on teleconferences ● Risk profiles developed based on unknown data ● SOPs inadequate for magnitude of situation ● No list of approved aircraft operators in area ● Data conflicts as a result of large amounts coming in ● Lack of data sharing due to commercial sensitivities (e.g. between ports) ● Having to download asset inventories (some resolved now)

Several discussions and interviews indicated that events and data transfer activities could have unfolded very differently given different spatial and temporal characteristics. For example:

- If the Kaikōura earthquake occurred much longer after the Christchurch 2011 earthquake, other factors would have come into play (e.g. the different management associated with the SCIRT - NCTIR transitions, loss of direct knowledge from organisations losing staff).
- A lack of staff resources (particularly skilled drivers) in the trucking industry and limited skilled staff resources close to ports was noted as a potential issue. The strain imposed by alternative routes and accessibility issues on staff resourcing should be explored further.
- An earthquake event with more severe impacts on the lower North Island and upper South Island transport network and Cook Strait intermodal freight and passenger transfer facilities. For example,

more severe damage to berths at ports and SH1 road bridges leading to accessibility issues for structural engineers.

- Tsunami effects that are more widespread and/or impact urban centres more severely with consequent impacts on transport infrastructure and operations.

6.6 New data opportunities and sources

Participants were asked if there were any new useful data / information opportunities that emerged over the response and recovery, including ones that may not have been recognised at the time, but are now considered useful. Participants were prompted to consider new data sources, new communication partners and new ways of managing data. Participants identified a range of new opportunities which are listed below.

Q5 New info acquired	Q5 New info needed
● NCTIR daily info releases	● Better information about alternate routes (assurances of a Plan B)
● Conference calls with MoT (could be better)	● Better alternative routes
● Now have checklists – key inventory – key contacts	● Clearer command structure for restricted air space
● New single source contacts in government agencies	● Key 'aviation liaison person' between CAA-Airways-MoT
● Desire to engage more with industry	● WREMO plans that reflect reality and practicality not assumptions e.g. evacuation by ferry.
● Desire to engage more planners in team	● MoT to have checklist of sector representative body contacts and use them - "other people need info too, e.g. Google, tourists, tour operators"
● Desire to maintain international relationships and agreements / sharing of info	● MoT to have agreement from potential participants in teleconference and practice the system
● Passenger data for ferries – is this useful to tourism?	● Coordination between ferries and stop/go traffic management
● Customs data	● Stronger relationships prior to events
● LiDAR information	● Communicating info to the public x3
● New mapping technologies e.g. Heat maps, 'Hill shade'	
● Aerial photographs	
● Network of contacts developed e.g. Civil defence air and RNZAF	

Since the response activities following the Kaikōura earthquake, there have already been several steps taken by infrastructure providers which assist in improving transport system resilience. For example, new seismic monitoring equipment has been installed, emergency response plans and resources have been assessed and improved with new back-up facilities established, and asset inventories have been compiled or updated.
Information gaps:

- A year following the earthquake (i.e. around the time the workshop was held), there were reports of ongoing uncertainty about the status of SH1 due to ongoing closure and reopening changes to slope stability and safety, and repair timelines. Additionally, many stakeholders would like to receive regular information on road enhancements occurring elsewhere. This has made planning for a number of interested parties difficult.
- Increased recognition for achievements and things done well.

6.7 Remaining Challenges

Finally, participants considered what challenges remained to creating a resilient transport network. They identified a number of significant challenges that will need to be overcome.

Q4 What do differently?
● Stronger work with ports (Mainfreight) to help coordinate response ● Need greater capacity on coast, led by government ● MoT – need NZ Transport Agency and other to change thinking away from needing to be 100% right before giving information – some info is better than none! This requires culture change. ● Have key players in one room, even if virtually ● Improve internal capacity – have business continuity plan the deals with vulnerabilities of Wellington. E.g can now run from Auckland.

Q5 Remaining Challenges
● Skills shortages, especially drivers ● Machinery and vehicle shortages, especially trucks ● No national inventory for transport/ machinery assets ● Fuel supply threat ● Lack of funding/investment ● Lack of capacity and facility on alternative routes (e.g. few passing lanes, poor condition) ● Lack of long term strategy and associated engagement with sector on national scale ● Resilience not prioritised by organisations/agencies next to other issues ● Lack of systems/holistic perspective – Silo mentality ● Geographical challenges ● Central-local government interactions and interactions and expectations of utilities infrastructure ● Local councils have limited capacity and experience ● Need faster feedback mechanism to learn lessons –just because info is not perfect it isn't a reason not to use it at all ● Need open data ● Private sector has additional restraints and responsibilities that need to be considered.

7 Appendix C: Indicator assessment framework

7.1 Indicator prioritisation for the freight transport network example

Prioritise Indicators							
Category	Indicator	Metric	Response	Recovery	Importance	Timeliness	Priority Score
Disruption context	Impacts/functionality assessments for State Highways	NZ Transport Agency damage classification (kms/category) and Total length of network open (#kms or %kms in affected area)/ total distance based accessibility (km)/ total distance based accessibility	x	x	5	5	10
	Impacts/functionality assessments for Local Roads	NZ Transport Agency damage classification (kms/category) and Total length of network open (#kms or %kms in affected area)/ total distance based accessibility (km)/ total distance based accessibility	x	x	5	5	10
	Impacts/functionality assessments for National Rail	NZ Transport Agency damage classification (kms/category) and Total length of network open (#kms or %kms in affected area)/ total distance based accessibility (km)/ total distance based accessibility	x	x	5	5	10
	Impacts/functionality assessments for Metro Rail	NZ Transport Agency damage classification (kms/category) and Total length of network open (#kms or %kms in affected area)/ total distance based accessibility (km)/ total distance based accessibility	x	x	5	5	10

	Impacts/functionality assessments for Sea Ports	# routes, buildings, and components affected (by damage classification)	x	x	5	5	10
	Impacts/functionality assessments for Airports	# routes, buildings, and components affected (by damage classification)	x	x	5	5	10
Category	Indicator	Metric	Response	Recovery	Importance	Timeliness	Priority Score
Disruption context	Physical impacts to routes all modes	# and type of physical/ geophysical impacts (e.g. displacements, landslides, wash-outs),	x	x	5	5	10
		# routes affected	x	x	5	5	10
	Physical impacts or disruption to bridges and other components (road and rail).	# components affected or	x	x	5	5	10
		% components affected on route	x	x	5	5	10
	Physical impacts or disruption to intermodal components (e.g. airports, port berths, ship-to-shore connections)	# components or	x	x	5	5	10
		% components affected in area	x	x	5	5	10
	Disruption to Cook Strait Crossing	Projected hours affected	x	x	5	5	10
	Changes to seabed /depth	Bathymetric re-survey	x		5	5	10
	Closure or relocation of freight support facilities (e.g. food distribution centres)	# of facilities affected by type or	x	x	5	5	10
		% of facilities affected by type	x	x	5	5	10
	Transport asset registers	#, location, and transport capacity of helicopters, barges, truck and trailer units etc.	x		3	5	8
	Accessibility of key transport hubs (e.g. ports / berths, airports, railway stations)	Change in # of access routes available post-disruption compared to pre-disruption in affected area	x	x	5	5	10
	Projected closures and restrictions based on hazard forecasts (e.g. aftershocks, weather, tidal)	# closures or restrictions, or	x	x	4	5	9
		km affected, and	x	x	4	5	9
		time affected (hours / days)	x	x	4	5	9
	Alternative route capacity	# and estimated vehicle throughput capacity of alternative routes available per closure	x	x	5	5	10

	Forecast restoration time for route or component	hours / days / weeks / months / years	x	x	5	5	10
	Number and duration of planned route closures and diversions	# by road type, <u>or</u>	x	x	5	5	10
		km road affected, <u>and</u>	x	x	5	5	10
		hours per days	x	x	5	5	10

Category	Indicator	Metric	Response	Recovery	Importance	Timeliness	Priority Score
Disruption context	Number and duration of unplanned route closures and diversions	# by road type, <u>or</u>	x	x	4	4	8
		km road affected, <u>and</u>	x	x	4	4	8
		hours per day	x	x	4	4	8
	Temporary restrictions (e.g. speed, vehicle limitations)	# by road type, <u>or</u>	x	x	4	4	8
		km road affected	x	x	4	4	8
Network Performance & Capability (Accessibility & Availability)	Vehicle throughput	# vehicles by class, <u>or</u>	x	x	4	4	8
		% of pre-disruption vehicles by class		x	4	4	8
	Vehicle Kilometres Travelled (VKT)	km (by vehicle category and route)		x	4	4	8
	VKT by freight type (bulk, containerised)	km (by vehicle category and route)		x	4	3	7
	Average load of vehicle	Average load in metric tonnes for vehicles travelling through the affected area		x	4	4	8
	Throughput weight	# vehicles * weight per vehicle (tonnes)		x	4	4	8
	Change in transport mode share (weight or value)	% change between modes		x	4	3	7
		total weight tonnes <u>or</u> total value NZD		x	4	3	7
	Freight throughput ability to meet demand	Freight throughput (by weight or volume) / demand for freight throughput (by weight or value) on selected routes		x	5	5	10
	Predicted traffic concentrations	# vehicles per hour		x	4	4	8
	Import vs. exports at ports and airports	% change in import		x	4	4	8
		% change in exports		x	4	4	8
	Fuel availability	# of stations without fuel, or	x	x	5	5	10

Network Performance & Capability (Reliability & Efficiency)		Change in volume of fuel supply	x	x	5	5	10
	Change in travel time (point-to-point)	Change in vehicle kilometres travelled per hour, or	x	x	5	4	9
		% by vehicle class and between key points (pre-post disaster or over time post-disaster)	x	x	5	4	9

Category	Indicator	Metric	Response	Recovery	Importance	Timeliness	Priority Score
Network Performance & Capability (Reliability & Efficiency)	Change in travel time (area/route)	Change in vehicle kilometres travelled per hour, or	x	x	4	4	8
		% by vehicle class within affected area or along a specified route (pre-post disaster or over time post-disaster)	x	x	4	4	8
	Variability of travel time from previous average	Hours by vehicle class, or	x	x	4	4	8
		% by vehicle class	x	x	4	4	8
	Travel time reliability	Average of actual travel times minus the usual or forecast travel time (hours)	x	x	4	4	8
	Route and road safety improvement	# routes improved, or		x	4	4	8
		NZD spent on route improvement in affected area		x	4	4	8
	Breach of cordons or restrictions	# or frequency of breaches	x	x	5	5	10
	Accident and fatality accident rate	# accidents per VKT	x	x	5	5	10
		# of crashes by severity on damaged, repaired, or ‘alternate’ routes (#crashes by severity/ day or crash density)	x	x	5	5	10
	Change in accident and fatal accident rate from usual	% change between predicted and actual accident or fatal accident rate along affected routes	x	x	4	4	8
	Tourism mobility	Change in # of access routes available post-disruption compared to pre-disruption that are key for tourism		x	3	4	7

Category	Indicator	Metric	Response	Recovery	Importance	Timeliness	Priority Score
Transport Organisation Performance & Capability	Staff availability (e.g. truckers, pilots, dispatchers, ferry crew)	# staff available by role	x	x	5	4	9
	Capacity of contracting industry	# contracting firms available		x	5	4	9
	Access to communications	Yes/No – Have organisation representative been contacted?	x		5	5	10
		Yes/No – Are there mechanisms in place to update them regularly?	x		5	5	10
	Personal security incidents	# of personal security incidents reported / day	x	x	3	4	7
	Delay time for customer (receiving cargo/goods)	hours / days	x	x	4	3	7
	Resource needs assessments	# and type of resources organisations need to enable their response	x		5	5	10
	Accommodation needs and availability for drivers	# beds available, or	x	x	4	3	7
		% change from average # beds available along transport routes	x	x	4	3	7
	Empty backloads / running	#, or		x	4	3	7
		by km, or		x	4	3	7
		% vehicles or journeys		x	4	3	7
	Levy added to journey	%, or		x	3	3	6
		NZD		x	3	3	6
	Timeframe of levy added to journey	days / weeks / months / years		x	3	3	6
	Load sharing	% of fleet sharing loads		x	4	3	7

Category	Indicator	Metric	Response	Recovery	Importance	Timeliness	Priority Score
Community Health & Wellbeing	Transport needs assessment of communities in disrupted areas	Evacuation needs	x		5	5	10
		Economic transport needs (e.g., milk tankers)	x	x	5	5	10
	Traffic noise	Change in dB community along affected routes is exposed to		x	4	3	7
	Access to essential services	#, or	x	x	4	4	8
		Hours / days, or	x	x	4	4	8
		% change	x	x	4	4	8
	NO_x concentration	PPM		x	5	3	8
	Carbon dioxide emissions	g per km driven, or		x	5	3	8
		additional g per journey, or		x	5	3	8
		% change		x	5	3	8
	Energy use per VKT	MJ/100km		x	3	3	6
Economic Impacts & Costs	Fleet improvements Purchases of new equipment (e.g. new truck and trailer units)	#, or NZD		x	3	3	6
	Total transport cost or total operational cost	NZD		x	5	3	8
	Cost against budget for ongoing repairs to damaged infrastructure	NZD		x	5	5	10
	Forecast expenditure for planned repairs to damaged infrastructure	NZD	x	x	5	5	10
	General economic impact information (e.g. retail activity, employment, regional economies)	NZD		x	3	3	6

7.2 Connecting Indicators with Data

Indicator	Data available (Y/N)	Data Owner/ Maintainer	Desired Frequency of data collection	Actual frequency of collection	Data category	Response	Recovery
Impacts/functionality assessments for State Highways	Y	Multiple (MoT TRT)	Daily/ Weekly	Daily/ Weekly	Visual obs + GIS/ Remote sensing	x	x
Impacts/functionality assessments for Local Roads	Y	Multiple (MoT TRT)	Daily/ Weekly	Daily/ Weekly	Visual obs + GIS/ Remote sensing	x	x
Impacts/functionality assessments for National Rail	Y	Multiple (MoT TRT)	Daily/ Weekly	Daily/ Weekly	Visual obs + GIS/ Remote sensing	x	x
Impacts/functionality assessments for Metro Rail	Y	Multiple (MoT TRT)	Daily/ Weekly	Daily/ Weekly	Visual obs + GIS/ Remote sensing	x	x
Impacts/functionality assessments for Sea Ports	Y	Multiple (MoT TRT)	Daily/ Weekly	Daily/ Weekly	Visual obs + GIS/ Remote sensing	x	x
(Geo)Physical impacts to routes all modes	Y	Multiple (LINZ, NZDF, MCDEM, KiwiRail)	Daily/ Weekly	Weekly	Visual obs + GIS/ Remote sensing	x	x
Physical impacts or disruption to bridges and other components (road and rail).	Y	Geotech companies	Daily/ Weekly	Daily/ Weekly	Visual obs + GIS/ Remote sensing	x	x
Physical impacts or disruption to intermodal components (e.g. airports, port berths, ship-to-shore connections)	Y	Ports/ Airports/ Sector Orgs	Daily/ Weekly	Daily/ Weekly	Visual obs + GIS/ Remote sensing	x	x
Disruption to Cook Strait Crossing	Y	Ports/ Sector Orgs	Daily/ Weekly	Daily/ Weekly	Visual obs + existing knowledge	x	x
Changes to seabed /depth	N	LINZ	Following ruptures		GIS/Remote sensing	x	x
Closure or relocation of freight support facilities (e.g. food distribution centres)	Y	Multiple (asset owners)	As needed	As needed	Visual obs	x	x
Accessibility of key transport hubs (e.g. ports / berths, airports, railway stations)	Y	Multiple (asset owners)	Daily/ Weekly	Daily/ Weekly	Visual obs	x	x
Alternative route capacity	Y	NZ Transport Agency/ MoT/ Police	Daily/ Weekly	Daily/ Weekly	Visual obs + Existing records	x	x

Indicator	Data available (Y/N)	Data Owner/ Maintainer	Desired Frequency of data collection	Actual frequency of collection	Data category	Response	Recovery
Forecast restoration time for route or component	Y	NCTIR/ MoT	Monthly	Monthly	Desk based	x	x
Number and duration of planned route closures and diversions	Y	NCTIR/ NZ Transport Agency	Weekly	Weekly	Desk based	x	x
Freight throughput ability to meet demand	N	Multiple (Transport orgs)	Weekly/ Monthly		Instrumentation/ desk- based		x
Fuel availability	Y	MBIE (fuel resilience working group)	Daily/ Weekly	Daily/ Weekly	Instrumentation/ desk- based + existing knowledge	x	x
Breach of cordons or restrictions	N	Police/ NCTIR/ Other asset owners	As needed	As needed	Visual obs	x	x
Accident and fatality accident rate	Y	Police/ NZ Transport Agency	Daily/ Weekly	Daily/ Weekly	Visual obs	x	x
Access to communications	N	Multiple coordinated by MOT+MCDEM (asset owners/ sector representative bodies)	Daily		Desk based / survey (Calls/ emails)	x	
Resource needs assessments [Transport Orgs]	N	Multiple coordinated by MOT+MCDEM (asset owners/ sector representative bodies)	As needed	As needed	Desk based / survey (Calls/ emails)	x	
Transport needs assessment of communities in disrupted areas	Y	Multiple (CDEM/ Rural Support trust/ Red Cross)	As needed	As needed	Field assessments/ survey based	x	x
Cost against budget for ongoing repairs to damaged infrastructure	Y	NCTIR	Monthly	Monthly	Field assessments/ desk- based		x