Organisational Issues in Implementing an Information Sharing Framework: Lessons from the Matata flooding events in New Zealand

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Abstract: This paper presents a critical review and analysis of issues in implementing electronic data and information sharing frameworks for organisations involved in response activities during disaster. An implementation focused approach is used to understand end-user needs and develop tools that meet their operational requirements. A case study of New Zealand roading organisations examines how information is currently shared both within and between organisations to support crisis decision-making, and the potential benefits and implications of enhanced data and information sharing frameworks. Preliminary results show that considerable performance gains in response activities during disasters can be achieved provided technology is designed to work with and enhance existing operating structures.

Key words: disasters, emergency management, response, information sharing

Introduction

Response to disasters involves multiple organisations collecting, collating and communicating data and information that support resource allocation decisions to minimise social and economic impacts. In order to act in a coordinated and effective way, organisations require access to information characterising the disaster's intensity, location and related damages, as well as the availability of human and physical resources. Such information can originate from multiple organisations.

To facilitate response activities, information also needs to be shared with coordinating authorities such as Civil Defence Emergency Management (CDEM) agencies and other key responding organisations such as the emergency services, lifeline utilities[1] and local and national government etc. Furthermore, intra-organisational exchange of data and information may occur according to several layers of responsibilities and territorial jurisdictions.

There are significant challenges to encouraging enhanced communication and data/information sharing, particularly given that most communications interoperability issues are not technical in nature. Organisational cultures, differences in terminologies, and incompatibility of standard operating procedures all create barriers for progress. These point

[1] Lifelines are those essential "utility" services which support the life of the community - such as water, wastewater and stormwater, power, gas and telecommunications and transportation networks.

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towards the need to take an end-user centric approach rather than a platform centric approach in the design of data/information sharing frameworks. As highlighted at a recent workshop on using information technology to enhance disaster management, "…experience has shown that it is critical, in applying IT to disaster management, to start with real problems faced by real end users, to find solutions, and then to work back from there to overarching themes. Starting with overarching themes will lead to dead-ends, and unimplemented and un-implementable technology" (National Research Council, 2005).

This paper presents a critical review and analysis of issues in implementing electronic data and information sharing frameworks in end-user organisations involved in response activities during disaster. Based upon an examination of the scientific literature, recent disaster response reports, as well as the latest technological advances, opportunities, barriers and challenges are identified and discussed. A New Zealand case study is then presented which describes the development of an electronic data and information sharing framework for New Zealand roading authority organisations. The case study focuses on the process and the steps taken to conceive the framework, and implications for end-user roading authority organisations.

Organisational Issues in Emergency Response

Recently, a series of natural and man-made disasters has prompted the production of reports covering a wide range of topics from human and social behaviour during emergencies to artificial intelligence applied in resource allocation. However, intra and inter organisational issues in emergency response are concentrated into three main topics, namely: organisational coordination; emergent technologies and techniques in data/information processing; and evacuation planning.

Almost unanimously, various scholars and emergency management practitioners have indicated that a lack of coordination reduces response efficiency. At the macro level, some claim that the whole process of emergency management has to be integrated with urban and regional activities (Britton and Clark 2000; Akinci 2004). Montoya and Masser (2005) present a case study in Cartago, Costa Rica in which gaps in current urban planning frameworks and practices are identified. On the other hand, it is often claimed that organisational coordination is also dependent on cultural background. For example Marincioni (2001) uses a cross-cultural perspective to clarify the relationship between two cultures and their different patterns of response to extreme flood events. The results showed that the different human responses observed in floods were linked to basic differences in four cultural elements: experience with floods; socio-political traditions and organisation; levels of integration within the community; and perception of the physical environment. At an operational level, the Turkish experience with the 1999 earthquake (Karanci and Aksit 2000), fire events in Quebec, Canada (Denis 1995) and United States' CERTs (Simpson 2001) highlight the importance of coordination and the problematic nature of multi-organisational collaboration in disasters.

Recent developments in data/information processing and tools have also been captured in the literature. It is observed that there is a growing concern over the need to obtain and share data during emergency events. Popkin and Rubbin (2000) make an informal assessment of the United States' Natural Hazards Research and Applications Information Center (NHRAIC), while Lindell *et al*. (2002) and Hwang *et al* (2001) examined government agencies' access to information about hazards in their communities and concluded that printed products are still used more extensively than internet products. Furthermore, Mendonca and Wallace (2004) present a method for describing both context and substance of improvisation during the response phase. Slayton (2000) highlights the need to identify available sources of information within each participating agency and five key factors that affect the success of local collaborative efforts (the climate in which the initiative begins; the processes used to develop trust and handle conflict; the people involved; the policies that support or inhibit their efforts; the availability of resources to enable their efforts to continue).

Many have already adopted Geographical Information Systems (GIS), Global Position Systems (GPS) and Remote Sensing as essential instruments in emergency management and response activities. Zhang *et al* (2003) present an overview of the Chinese system used to assess damage and provide relief during natural disasters based upon Remote Sensing, GIS and GPS. Hecker *et al* (2000) describes damages and organisational consequences of Hurricane Hugo and how the U.S. Army Corps of Engineers is taking advantage of GIS and GPS in its activities. Waring *et al* (2005) introduces the public health response to tropical storm Allison in the Houston area, USA and how the need to quickly evaluate the immediate health and medical needs of the community would not have been possible without the utilization of GIS methodology. GIS has been also applied in: decision-making processes (Sato 1995; Zerger and Smith 2003), risk and vulnerability assessments (Grangen 1995; Cova and Church 1997; Dalziell and Metcalf 2005), network operations and traffic management (Shibata 1997; Marzolf, Trepanier and Langevin 2005).

Despite considerable progress achieved in recent years, research and implementation efforts towards utilising the full potential of GIS and other information technology tools and techniques should be contemplated. Many scholars have indicated that geo-spatial modelling provided in most commercial GIS desktop software is inefficient, because they are based on very simplistic representations of response systems characteristics, and do not include multiple inter-relationships observed in reality (Stokes and Marucci 1995). This provides a very static representation of the variables that contribute to decision-making activities. On the other hand, there are serious concerns about the isolationist tendency adopted by some emergency services. It is often observed that each organisation will have its own GIS developed according to its specific requirements, without contemplating data/information sharing needs. For example, Amdahl (2001) describes GIS applications in disaster response, which are very efficient in identifying risks before and after response, but are limited in dealing with the dynamic flow of data and information during response activities. In a few cases, organisations will purchase GIS software without even analyzing whether or not the package will suit its needs during emergency events (Waring et al. 2005; Dash 1997). Furthermore, in Britton's words "…a key need now is making effective and efficient use of new technologies for gathering and evaluating information to best target response and relief efforts…. Nevertheless, the challenge is to ensure the means exist for sharing information across all agencies, not just in terms of the formats used but also overcoming ownership and funding issues. Central to this, however, is the need to replace a focus on organisational arrangements with a focus on resource arrangements based on potential hazard consequences…" (Britton 1999)

The expansion and subsequent reliance on recent telecommunication advances have also been incorporated in the emergency response context (Hunter 2005) in terms of wireless communications, internet and integrated technologies for data exchange. Heavy telephone use by the general population caused sudden and severe congestion in the phone system following the Kobe earthquake and the September 11 attacks in New York. This motivated Fujiwara and Watanabe (2005) to conceive an ad-hoc networking scheme for emergency communications to collect damage assessment information quickly and stably in a disaster. Combining GIS, GPS and telecommunication capabilities, Laurini (2000) describes various applications of Telegeomonitoring in traffic management on toll motorways, fleet management, transport of hazardous materials, river pollution and risk monitoring. In the same direction, Gordin (2001) describes applications of GIS software combined with wireless mobile phone networks in the USA. Telecommunications advances have also contributed to the popularisation of internet-based applications. Harder (1998) describes a series of applications in which maps are made available on the internet. Gruntfest and Weber (1998) reports on the growing value of internet resources for the emergency management profession.

Evacuation studies have also occupied a considerable part of the technical and scientific literature. Jafari et al (2003) present a survey of various approaches and technologies being developed and used for evacuation planning and emergency management. They divide efforts into evacuation planning and emergency management. Evacuation planning covers: site analysis consulting (EPlan and BTG), simulation (EXODUS, OREMS, PedGo, Assisted Evacuation Simulation, SEVEX, CyberSim) and training. In emergency management, High-Level Architecture (HLA), multi-agent systems to support an escalating Non-combatant Evacuation Operation (NEO) and E-Team software packages can be highlighted. Mathematical and statistical modelling have been used to predict evacuee's behaviour. For example, Gladwin et al (2001) focus on individual and household hurricane evacuation behaviour using ethnographic decision tree analysis. Their results show that models can better inform emergency managers, because a better understanding of the characteristics of the affected population, such as wealth, levels of education, access to transport etc, can significantly improve the ability of emergency managers to put in place appropriate measures. Other similar initiatives in modelling are presented in (De Silva 2000; De Silva and Eglese 2000; Cova and Johnson 2002; Partyka and Hall 2000). Goldblatt and Weinisch (2005) describe the benefits of developing systems for training and effective response in evacuation planning. There are challenges however in ensuring that greater modelling efforts translate into better decision making. As the models become more complex and more situation specific, it can become difficult to extract from these basic rules-of-thumb or principles on which to base future planning.

In the inter and intra organisational data/information sharing context, this review demonstrates that outstanding advances have been achieved, but considerable challenges ahead can be pictured in terms of adopting knowledge and information management theory and techniques (Choo 2002). Throughout this review, it can be observed that very limited attention has been given to conducting comprehensive analyses about the nature and background of involved organisations; the characteristics of their involvement; their data/information needs; their data/information sharing needs; and how organisations could or should share data and information.

Emergency Management Co-ordination in New Zealand

According to Cole *et al* (2005) no large-scale events impacting upon large populated areas have been observed in New Zealand, possibly due to the short history of European settlement (160 years). The common incidents in New Zealand have been short-lived, and relatively small scale, mainly associated with storms and floods. Given this, there have been three events of particular note: the 1886AD eruption of Tarawera, 1931 Hawkes Bay earthquake and 1968 Inangahua earthquake. According to Britton and Clark (2000), over the last 50 years less than 3 people a year have died in natural disasters, but average annual flood losses may amount to NZ$180 million and earthquake losses about NZ$15 million. In the most recent significant event (2004), flooding in the Manuwatu-Wanganui area led to 4 bridges destroyed, 21 seriously damaged, 2500 people displaced, and costs of business disruption close to NZ$400 million (Flood Review Team 2004).

In New Zealand, the Ministry of Civil Defence and Emergency Management (MCDEM) is a semi-autonomous body within the Department of Internal Affairs. MCDEM has over-arching responsibility for developing and maintaining the preparedness of the New Zealand community for any natural and technological hazards or disasters (Britton and Clark 2000). Created in 1999 from the former Ministry of Civil Defence, MCDEM also provides policy advice to the Government. In 2002, the Civil Defence Emergency Management Act established a national and regional framework in which an emergency management strategy and plan were adopted. One of the features of the Act is the establishment of CDEM Groups based on regional council boundaries, and the requirement that a risk management-based approach be adopted. CDEM Groups are consortia of local authorities, emergency services and health boards in each region. This Act requires every local authority to plan and provide for Civil Defence and Emergency Management (CDEM) within its district, and to ensure that it is able to function to the fullest possible extent, even though this may be at a reduced level, during and after an emergency. One of the features of the Act is that this requirement also applies to lifeline utilities and central government departments. MCDEM works in coordination with local and regional governments, utilities and the emergency services involved in CDEM. MCDEM's Director acts as Chief Executive of the Ministry in its day-to-day operations. In cases of national emergency, the Director has special powers defined in the legislation.

In the event of a Civil Defence Emergency declaration, the CDEM Group (or local) Civil Defence Controller, with support from the regional or local Emergency Operations Centre (EOC), co-ordinates the response and makes decisions about key response actions after communication and consultation with the emergency services, health agencies and key lifeline organisations. Relevant data/information from all the above organisations is expected to be shared with CDEM agencies to facilitate decision making.

Emergency Response for the State Highway Network

New Zealand has about 10 thousand kilometres of state highway network. These roads are a national asset worth approximately NZ$12 billion and Transit NZ is responsible for maintaining these assets. 56% of the annual budget is allocated for the maintenance and rehabilitation of existing roads. Typically, Transit NZ appoints Consultants to undertake technical services to determine work requirements according to Transit NZ Regional office's directives, and Contractors for carrying out the physical works. During an emergency situation it is the responsibility of the Contractor to carry out the physical repairs and reopen the road to the traffic as soon as possible. The Consultants are mainly involved in providing technical details and strategic advice to the Contractors. The Consultants also interact with representatives of Transit NZ, and where appropriate, CDEM agencies. This structure, whereby Transit NZ, the Consultant and Contractor (and where appropriate CDEM agencies) all need to work together and share information to inform real-time decision-making in response to events, provides an excellent case-study for developing a data/information sharing framework.

Emergency situations are classified by Transit NZ into 3 levels according to the time required for road reopening: small, medium and large events. Based on emergency procedure manuals (Transit NZ 2001), Table 1 summarises the roles Transit NZ and CDEM agencies play for these different scaled events.

Table 1. Transit NZ and CDEM participation for different types of events.

		Type of Emergency		
		Small	**Medium**	**Large**
Organisation	**Transit NZ**	Stand-by unless the emergency affects SH system	SH Emergency Procedure and Contingency Plan fully applied.	SH Emergency Procedure and Contingency Plan are fully implemented, however, CD priorities may override defined response priorities.
	CDEM agencies	N/A	- Local CDEM groups play a monitoring role; and - CDEM EOC is kept informed about event characteristics	Civil Defence Emergency declared. Local, Regional or National Civil Defence controller defines overarching response priorities and has the ability to direct resources if necessary

A large event refers to a situation in which severe damage is observed and CDEM agencies may influence the priorities for response and recovery activities to reflect specific community needs. When an emergency is declared during a large event, Transit NZ plays a complementary role. Transit NZ headquarters in Wellington is also involved in a large event and it reports to Land Transport NZ and the Ministry of Transport (MOT). In these situations, Transit NZ also interacts with the community through individuals, external organisations such as telecommunications, energy, water, hospitals and the media etc.

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Figures 1a – 1c show the organisations involved in different scaled events. The challenges involved in co-ordinating an effective response to a large scale event are compounded by the number and variety of organisations involved.

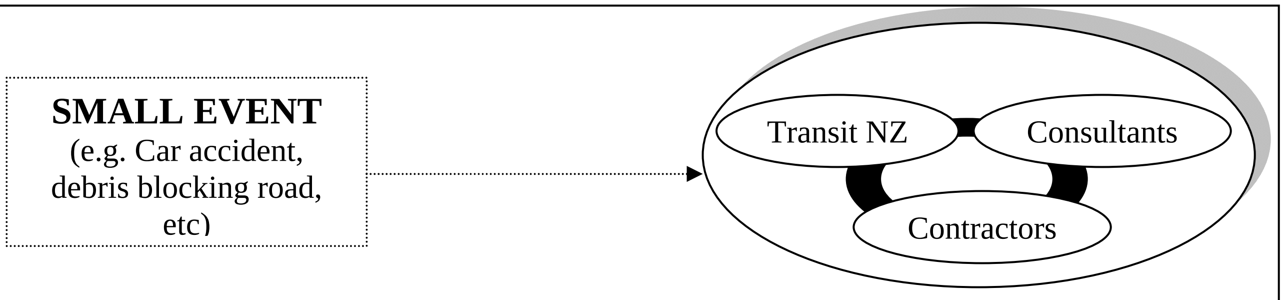

Figure 1a: Organisations involved in a small event response

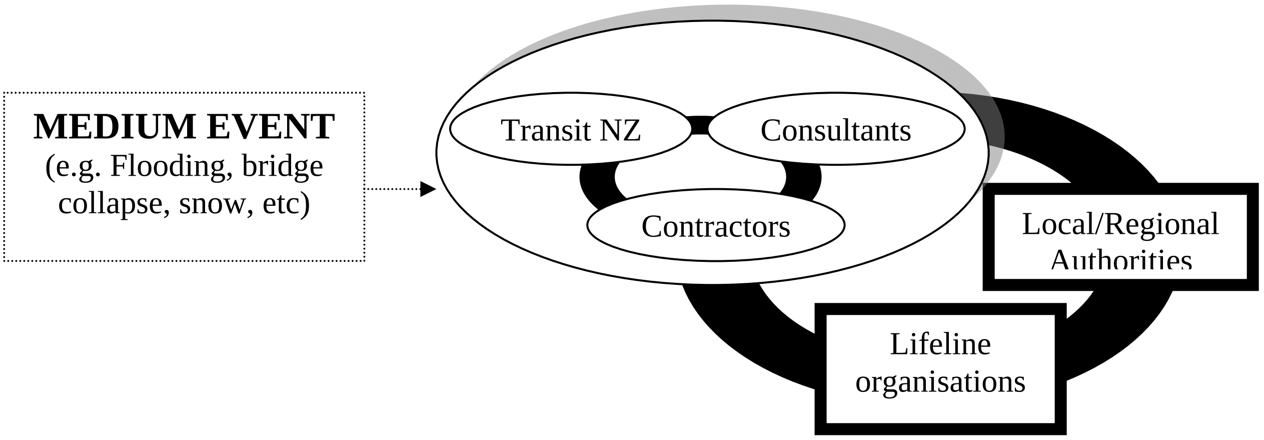

Figure 1b: Organisations involved in a medium event response

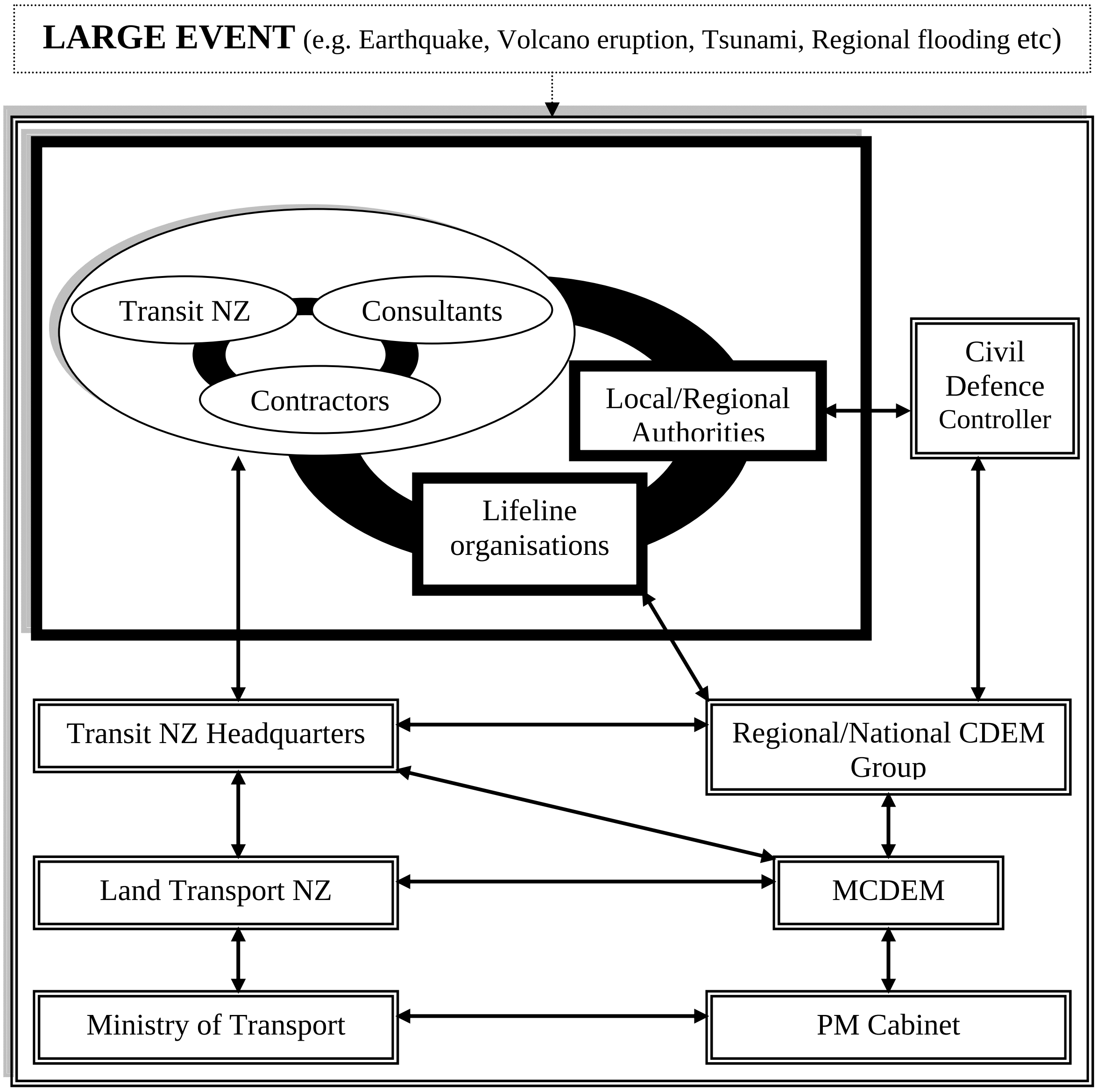

Figure 1c: Organisations involved in a large event response

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Case Study: Observed Organisational Response during Emergency

Matata is a seaside village of approximately 500 people in the Bay of Plenty region, North Island of New Zealand as shown in Figure 2. Matata is located halfway between Whakatane, which is a forestry industry region, and Tauranga, where one of the busiest ports of New Zealand is located. Whakatane and Tauranga are connected by railway and road, where the State Highway (SH) 2 is the most important part of the network with heavy traffic observed daily in both directions.

The 2005 Matata township flooding was a small-medium emergency event in which the practical issues in data/information sharing among roading organisations were observed. The event was localized mostly in the Matata township and its nearby coastal area, which comprises the SH 2 Straight (approximately 5 km of road). As emergency response was concentrated in very specific parts of the roading infrastructure, involved organisations and their resources were coordinated locally by the Transit NZ area engineer and Consultant.

After initial TV news reports, members of the research team contacted the regional office of Transit NZ in Hamilton to obtain permission to observe the response activities in Matata. This allowed us to establish *in situ* interaction with the involved parties. The remainder of this sub-section is based on *in situ* interviews and examination during our two visits (May 20 and May 26/27) to the damaged area.

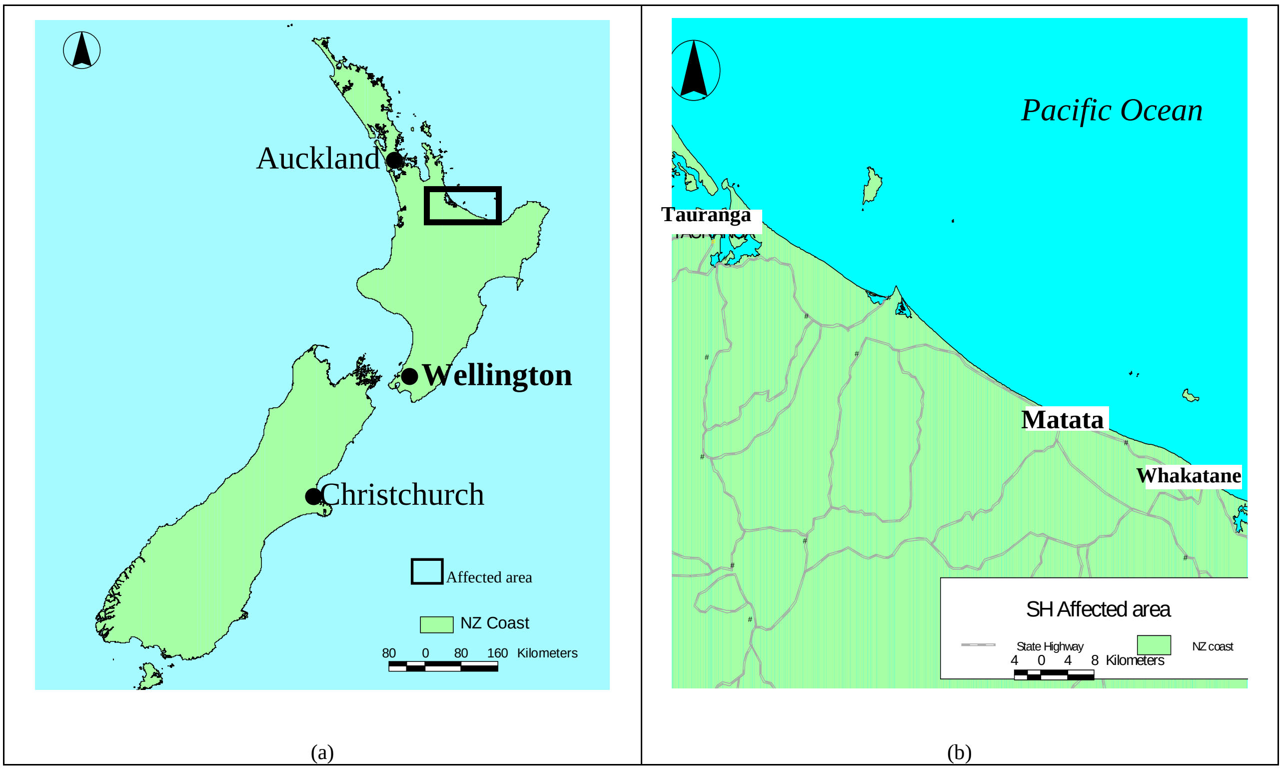

Fig. 2 Location maps: (a) New Zealand and affected region; (b) Matata Township

On the evening of May 16, 2005, MetService issued a heavy rain warning to the local and regional authorities. They also notified all infrastructure and lifeline providers in the region, including Transit NZ offices in Hamilton and Gisborne.

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In the early hours of May 17, the Transit NZ area engineer and the Consultant engineer, who were coincidently meeting together in Whakatane, received initial reports from the local community and Transit NZ Contractors about partial road closures on SH 2 due to water on the road surface and localised slips blocking traffic. An additional Transit NZ Contractor crew was mobilised from various parts of the region via mobile phone. SH 2 was reopened approximately 12 hours after the first warnings were received. The poor weather conditions continued overnight however and during road inspections the following day (May 18) the Transit NZ area engineer and Consultant engineer together, actually witnessed the washout of one bridge embankment. Subsequent reports from road users about more washouts prompted the Transit NZ area engineer and the Consultant engineer to hire a helicopter in Whakatane and conduct a fly-over inspection. Immediately after the inspection, complete road closure of SH 2 was declared and supplementary personnel and equipment from the Transit NZ Contractor were requested.

Up to that point in time, communications and exchange/sharing of data and information were very limited. Transit NZ Headquarters in Wellington had been informed of the road closure, without any precise estimation of the reopening time. The Transit NZ area engineer liaised with local and regional councils sharing the same level of information available to Transit NZ Headquarters. Press releases were given to the media about the road closures. Interaction between the Transit NZ area engineer and the Consultant engineer occurred almost instantly as both were *in situ* coordinating and making decisions together.

The Consultant engineer, originally based in Whakatane, reported back to his office via mobile phone communications and using his deputy road technician. Consultant's reports were used to produce maps of road closures and initial estimates of damages and costs. Transmitted data comprised very general instructions referring to road assets per kilometre. No specific data on previous road asset conditions (e.g. location and characteristics of roading elements) was made available to the involved parties (Transit NZ, Consultant and Contractors).

On the afternoon of May 18, a Civil Defence Emergency was declared by the Western Bay of Plenty EMO. Subsequently the Whakatane District Council also declared a state of local emergency for the Edgecumbe-Tarawera Ward (Matata township) on the evening of the same day (May 18). Late that night, a band of intense rain passed over the catchments behind Matata and triggered many landslips (*debris avalanche*), which destroyed 27 homes and seriously damaged 87 properties (McSaveney et al 2005).

Initial response actions commenced immediately. Resources were already available in the area for dealing with the earlier road closures. However, a major drawback was a lack of suitable gear for operating during the night because batteries for the spotlights available were faulty. The landslips in Matata and complete closure of SH 2 also created difficulties in transporting equipment and personnel from Tauranga. Alternative routes through mountainous areas had to be used, which incurred delays in the response actions.

On May 20th SH 2 partially reopened overnight (5pm to 5am) to heavy and commercial traffic only. On May 30th SH 2 was completely reopened to general traffic. At that point in time, Transit NZ had no specific assessment on road repair costs.

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During the response activities, members from the research team observed interactions between Transit NZ, Consultants and Contractors. In comparison with previous hazard events (such as the 2004 flooding in the Manuwatu-Wanganui region), flooding and damages in this instance were much more localised. This simplified the allocation of resources somewhat. The prioritisation process consisted of visual inspection by the Consultant deputy technician and the Contractor representative. Together they listed assets and decided on a ranking and treatment options, without considering the previous state of the assets or costs.

The Transit NZ Consultant noted that there would be clear gains in efficiency if Contractors knew the exact location and prior characteristics of the roading elements such as signage, culverts, etc. The Transit NZ Consultant observed that another lifeline organisation (Telecom NZ) had recovered very quickly, because advanced technology (GPS and GIS) had been applied intensively. The research team confirmed that Telecom's contractor utilized mobile monitoring devices to locate fiber optic cables in the rubble. Therefore, in a few hours after the event, Telecom's system had been restored to its full capacity. In contrast, Transit NZ consultant and contractors could not access the Road Assessment Maintenance Management (RAMM) information database employed in Transit NZ daily operations Ironically, Contractors and Consultants managed to download television reports about the events while on-site, from the internet using their mobile phones, but they were unable to know what roading assets lay underneath the mud.

An overview of communications and of data/information sharing during the Matata events indicates that informal linkages and assessment were predominately observed. Involved roading organisations depended heavily on individuals' previous knowledge about the area and assets. Obviously, previous knowledge was very important, but there are concerns about how efficiently it can be employed on its own to solve more complex problems such as would be the case in a larger scale event. Moreover, "common sense" overwriting information (or lack of it) was constantly employed. On the other hand, the current information system (RAMM) was perceived as not suitable to cope with the dynamic nature of such an event. This has probably forced Transit NZ, Contractors and Consultants to respond as observed.

A potential framework for data/information sharing

Based upon the need for efficient inter and intra organisational data/information sharing, a conceptual framework for achieving this is proposed. This framework was developed following the concepts of knowledge and information management (Choo 2002). The first step in the process was to identify the information needs of the organisations involved in response.

The Transit NZ response process can be divided into 6 core elements, these are: (1) event warning; (2) event observation; (3) event assessment; (4) organisation action; (5) organisation reporting; (6) organisation re-evaluation. During re-evaluation (6), the outcomes are used to decide whether the response is considered over or should be continued from event assessment (3). The dynamic nature of emergency response is such that many elements of the response process are conducted simultaneously and as the event develops, the appropriateness of different response strategies needs to be constantly re-evaluated.

During each stage of the response process, different organisations are involved. External organisations such as research institutes, meteorological services, regional and local councils etc provide initial warnings and updates of potential events. During or after the event, as part of event observation, the Contractor along with external organisations and the public verify initial damages caused to the transportation system (pavement and bridge collapses, obstruction of lanes, etc.). Depending on the extent of damage, these conditions are reported to the Consultant, Transit NZ, Local Road Controlling Authorities, the emergency services and other lifeline organisations, or if a Civil Defence Emergency has been declared, the regional or national CDEM EOC. In the subsequent phase (event assessment), again depending on the type of the emergency, all the above organisations except external organisations and the public are involved. Organisation action involves the same organisations deploying their physical and personnel resources according to their response responsibilities. Most of the field operation is conducted by the Contractors in small and medium events. In large events the CDEM Controller, lifeline organisations and Local/Regional Authorities are also involved. These actions are supervised by the Consultant and Transit NZ. As part of organisation reporting, the Contractor, CDEM, Local/Regional Authorities and lifeline organisations describe current road conditions after the initial round of measures and any further development of the original event (better information about damages, more events, etc.). These reports are then taken into consideration during organisation re-evaluation, in which the organisation evaluates the measures taken and their efficiency. Finally, decisions are made as to whether to continue or stop response activities depending on the efficiency assessment. If a decision is made to continue, the process restarts again from event assessment.

Next, the information needs of those organisations involved in the response process were identified. This was done by examining Transit NZ's emergency procedures and reports and translating these using the Integrated DEFination (IDEF0) modelling language (semantics and syntax) (FIPS 1993), into a summary of information needs and sources during each phase of the response and recovery effort (Table 2).

These information needs were then considered in the conception of the data/information sharing framework (Gohil 2005) that is presented in Figure 3. The framework utilises Transit NZ's current inventory database to generate a Dynamic GIS (DGIS) for emergency response. Transit NZ's inventory database (RAMM), comprises historic data on roading assets and their condition over time. In an emergency response event, the framework proposes that data from RAMM is dynamically retrieved, organised and distributed amongst Consultants, Contractors and Transit NZ using the DGIS. The data/information framework establishes the linkages, templates and sharing standards to enable the conversion of road maintenance data (RAMM) into information required during emergency response activities (DGIS).

Table 2. Transit NZ and response partners' information needs in response activities

	Regional Consultant info needs	Regional Contractor info needs	Transit NZ Regional Office info needs	CDEM Group info needs
Event Occurrence		-Potential damaged area/region -Type of event -Intensity and expected duration -Available resources		
Event Observation	-Damaged area/region -Type of event -Damaged asset type -Partial or complete road closure -Alternative roads -Traffic flow composition -Contractors' resources -CD emergency declaration?	-Damaged area/region -Type of event -Attributes of potentially damaged assets (location; original condition; characteristics; costs; priority repair availability).	-Damaged area/region and event type -Damaged asset type; -Partial or complete road closure -Alternative roads -Traffic flow composition -Contractors/Consultants' available resources -Initial road closure time/ costs estimation -MCDEM emergency declaration?	
Event Assessment	Comparison before and after / damaged asset Location Original condition Characteristics Treatment options Costs Priority Repair availability -Contractors' available resources		-Report on before and after / damaged asset -Summary of damaged assets per type -Summary of treatment options -Summary of Costs/Priorities Repair availability -Consultants and contractors available resources -Initial road closure time estimation -Initial cost estimation -MCDEM emergency declaration?	-Report on road closures (Location; Partial/complete; Expected road opening -Consultants and contractors available resources -Initial cost estimation
Resources Deployment	-Location of Contractors' equipment and personnel -Deployment times -Allocation plan of resources and personnel per damaged asset (location; original condition; characteristics; treatment; priority; effectiveness) -Traffic management plan MCDEM emergency declaration?	-Allocation plan of resources and personnel per damaged asset (location; original condition; characteristics; treatment; priority; effectiveness) -Deployment times -Traffic management plan -MCDEM emergency declaration?		
Event Reporting	Damaged area/region -Attributes of damaged assets: (location; original/current conditions; characteristics; treatment; costs; priorities; repair availability)	Damaged asset type Attributes of damaged assets: (location; original/current conditions; characteristics; treatment; costs; priorities; repair availability) -Partial or complete road closure -Alternative roads -Traffic flow composition -Contractors' available resources	-Damaged asset type -Partial or complete road closure -Alternative roads -Traffic flow composition -Contractors/Consultants' available resources -Road closure time/costs estimation -MCDEM emergency declaration?	
Event Re-assessment	-Comparison before and after / damaged asset (location; original condition; characteristics; treatment options; costs; priority; repair availability) -Contractors' available resources Stop response/Initiate Recovery mode/Continue Response?		-Report on before and after / damaged asset -Summary of damaged assets per type, treatment options, Costs and Priorities -Repair availability -Consultants and contractors available resources -Initial road closure time cost estimation	-Report on road closures (Location; Partial/complete; Expected road opening -Consultants and contractors available resources -Initial cost estimation

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			-Stop response/Initiate Recovery mode/Continue Response? -MCDEM emergency declaration?	

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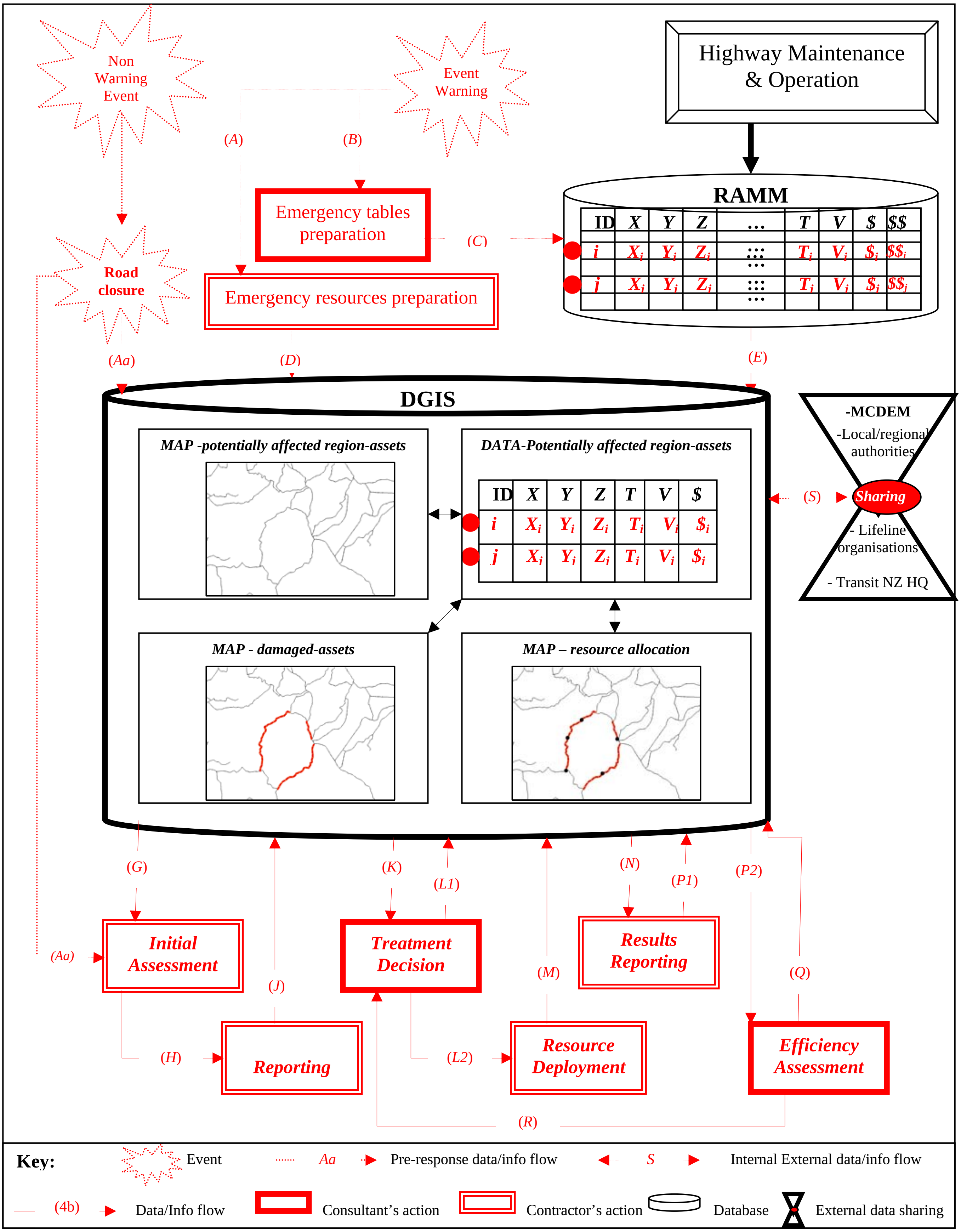

Figure 3 –Data/Information framework for roading organisations

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For example, during an emergency event with warning (e.g. flooding), the framework (see Figure 3) is applied following the steps below:

- Preliminary information (arrows ***A*** and ***B***) on the potentially damaged region and assets is used by Transit NZ, Consultants and Contractors in generating data/information related to the potential emergency using RAMM (***C***) and emergency response resources are placed on alert (***D***);
- The relevant information is then extracted from RAMM by the Consultant (***E***) and linked to maps using the DGIS;
- During and after the hazard event, Contractors receive information from the police and the public about road closures and damage;
- Using data from DGIS (***G***), the Contractors perform an *in situ* ***Initial Assessment*** comparing observed conditions with pre-event roading characteristics (e.g. bridge abutment collapsed, signpost missing);
- The observed conditions (***H***) are summarized and ***Reported*** back to the Consultant via the DGIS database (***J***);
- The Consultant retrieves data on the damaged assets (***K***) and considering available resources a ***Treatment Decision*** is made (***L1***) and shared with the Contractor (***L2***);
- The Contractor ***Deploys Resources*** to implement the treatment; actual resource deployment is recorded (***M***) into the DGIS database;
- After the completion of the work, the Contractor compares before/after event conditions (***N***) and conducts a ***Results Reporting***, which is subsequently recorded (***P1***) into DGIS;
- The Consultant retrieves data (***P2***) and conducts an ***Efficiency Assessment*** in which either the response is finalized (road opening - ***Q***) or continued (***R***); and
- If the response is continued, the Consultant re-starts the process from the ***Treatment Decision*** phase.

During all the response phases, data is simultaneously shared with all other involved organisations (S). These organisations also input new information which is shared among Transit NZ's Consultants and Contractors. Transit NZ regional engineers can either act as observers for small events or become involved with the decision making process. For events without warning (e.g. car accidents; earthquakes; etc), the same phases are followed except for the initial preparation (emergency tables preparation and emergency resources preparation).

This proposed DGIS information framework was applied in a desktop case study in the South Island of New Zealand to establish the approximate magnitude of potential benefits. Results show that a potential reduction in time and cost of emergency response activities could be reached if the conceptual framework was implemented through reduced response times, faster access to relevant information and therefore enhanced decision making. The road user costs of road closures per year in New Zealand are estimated to be approximately NZ$2.9 million. By using the data/information framework, the cost of road closures could potentially be reduced by between 1.7% (worst case) and 5.5% (best case), representing a saving, in road user costs alone, of between $50,000 and $160,000 (Gohil 2005). Gohil (2005) estimated these road user savings by taking the recorded road closure times for historic events and breaking these down into the different phases for road closure response and recovery, namely: External agency or police contact Consultants; Consultants contract Contractors;

Contractor reach site of road closure; Contractors inform Consultants of actual site conditions; Decision made on repair strategy by Contractors and Consultants; Waiting time until conditions are suitable to undertake repairs; Complete repairs; Contractor reporting back to Consultants. Depending on the characteristics of the road closure event, the total road closure time was proportioned between each of these phases (for example taking into account the location of the road closure, traffic flows on the route, and the reasons for the road closure). Estimates were then made about how the response times during each of these phases might be reduced with enhanced data and information sharing technologies. This desktop case study was a preliminarily evaluation of the potential benefits of implementing a data and information sharing framework, but was able to clearly demonstrate to end users the potential value of enhanced communications in emergency response.

The implementation of such a framework would require personnel training, equipment purchase (PDA or mobile phones with GPS receiver units, PC data projectors for Transit NZ control rooms), considerable commitment in changing the organisational culture and further technological and methodological advances. Both training and equipment can be justified based upon the reduction of road-user costs by reopening roads more quickly, as well as the minimisation of social and economic disruption.

Nevertheless, preliminary findings not only about Transit NZ but also other New Zealand organisations indicate that there is a need for clearer understanding and communication of intra-organisational responsibilities and duties across divisional and geographical boundaries (Brunsdon and Dalziell 2005). Effective implementation of any information sharing frameworks requires that all involved parties understand that technology by itself will not solve the problem. Instead, there must be a clear notion that organisations need to interact and agree on joint response standards, responsibilities and protocols as well as on how to share data/information in order to efficiently respond to emergency events. In summary, before creating/buying any technology (or technologies), organisations must have a clear idea on what, how, when they respond to emergencies.

As for the technological and methodological advances, major disaster events require the manipulation of a large variety of data sets for national, regional, local and site specific levels. This has to be seriously taken into consideration because speed and size of each data set will certainly influence the final data/information sharing outcome. Specific processing technology to efficiently manipulate the data sets has to be developed and implemented. Fortunately, New Zealand has a solid culture of geospatial data collection and storage, which is provided by Land Information New Zealand (LINZ). In countries where such geospatial culture and dissemination is not well developed, considerable efforts will be required to conceive, implement and apply data-information sharing frameworks as discussed in this paper.

Conclusions

The challenges involved in coordinating an effective response to large scale emergency events are compounded by the number and variety of organisations involved. These complexities emphasise the need to develop robust yet simple frameworks for sharing information and communicating decisions within and between organisations involved in response and recovery activities.

Considerable opportunities lie in exploring new paradigms for emergency response with extensive telecommunications and geo-spatial technologies. Greater focus however is needed on defining data/information sharing requirements and how the characteristics of the organisations involved affect implementation.

A major outcome of this research is that perceived barriers can be reduced if technology is employed according to an organisation's needs rather than the other way around. This is possible by involving end-users during all development stages of the electronic data and information sharing framework to develop a framework that complements the organisational structures, cultures and existing interfaces between the organisations involved.

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