**TECHNICAL PAPER**

# A DIAGNOSIS OF STATE HIGHWAY ORGANISATIONS' DECISION-MAKING DURING EXTREME EMERGENCY EVENTS


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## ABSTRACT:

This paper introduces the conceptualization and application of a method to analyse the decision making process of New Zealand's State Highway Organisations (SHO) during extreme events. The aim is to obtain an unbiased and complete overview of the strengths and weaknesses of the current decision making. Procedures and metrics to analyse the Quality of Decision Making (QDM) are proposed, based upon the study of theoretical and practical concepts of decision making processes. QDM analysis was applied to 3 real events and 4 exercises, which have been observed since 2005. The results of the QDM analysis indicate that SHO are capable, experienced and competent in dealing with major disruption or crises that may affect the State Highway Network of New Zealand. SHO have achieved High and Regular levels of resilience in terms of decision making activities during emergency response events and exercises.

# INTRODUCTION

Extreme events present responding organisations with complex and unprecedented situations, having the potential for catastrophic losses and consequences on communities. In crises and or emergency events there is an immediate risk to life, health, property or environment. Thus, organisations have to quickly respond to observed and changing conditions. These are mostly different to what personnel are used to dealing with on a daily basis, under business-as-usual situations (Fredholm, 1999).

There is limited understanding on how organisations perform decision making in extreme events. Even though a few studies have been observed in recent years (Zografos et al., 2000), empirical evidence and understanding of decision makers are still impaired by complexities observed in real situations. It is often observed through anecdotal evidence that decision makers use their own experience and common sense in order to respond to events.

A particular and critical element of response to extreme events is the roading network. Recent worldwide events (e.g Northridge Earthquake, 1994; Sumatra Earthquake and Tsunami, 2004) have demonstrated that the functionality of road transport networks to respond to emergencies is vital in saving lives and reducing economic impacts as many organisations depend on road transport to conduct their own response activities (AELG, 2005). Road transport networks among other key lifeline utilities (e.g. telecommunications, waste water or sewerage networks or entities that produce and supply water, gas, electricity, petroleum products) are expected to function to the fullest possible extent during and after an emergency event.

This paper introduces the conceptualization and application of a method to analyse the decision making process of New Zealand's State Highway Organisations (SHO) during extreme emergency events. SHO comprise New Zealand Transport Agency (formely Transit New Zealand), its consultants and contractors throughout the country. Building upon our previous research efforts (Dantas et al, 2007 and Ferreira et al, 2007), the aim is to obtain an unbiased and complete overview of the strengths and weaknesses of the current decision making.

This paper is divided into 5 sections. After this introduction, a conceptual framework to observe decision making activities is presented. In the third section the analysis method of the decision making performance is described. The fourth section introduces the application of the observation framework and the quality of decision making analysis method applied to a series of case studies in which SHO are the main subject. Finally, conclusions are drawn from the application of the analysis method and the whole experience in observing decision making processes in New Zealand.

# QUALITY OF DECISION MAKING ANALYSIS

Using the scheme proposed by the Defence Command and Control Research Program, CCRP model (Cheah *et al*., 2000) as the main reference, four interconnected domains of decision making are targeted. They are:

- **Physical domain (*$D_p$*)** is the tangible real world where physical and human resources are moved through time and space to attend the range of operations required to respond to the evolving extreme event. Physical domain is also the space where organisations and the physical and communications networks that connect all the organisations involved in the management of the extreme event reside;
- **Information domain (*$D_I$*)** is the abstract space where information exists and is collected, created, processed, manipulated, and shared and from where information content and flow are created. The quality of the information depends on the accuracy, timeliness, and relevance of

information from all sources. The information domain is the link between the reality of the physical domain and human perceptions, therefore is formed by the intersection of the physical and cognitive domains;
- **Cognitive domain ($D_C$)** is identified with the mind of the decision-makers, where individual and organisational collective consciousness exists, where decision maker's knowledge, capabilities, techniques, and procedures reside; and
- **Social domain ($D_S$)** is the domain where humans interact, exchange information, form shared awareness and understandings, and make collaborative decisions. This is also the domain where culture, set of values, attitudes, and beliefs held and conveyed by leaders to the society reside. It overlaps with the information and cognitive domains, but it is distinct from both. Cognitive activities, by their nature, are individualistic; they occur in the minds of individuals. On the contrary, shared awareness and shared sense-making (the process of going from shared awareness to shared understanding to collaborative decision making) are by definition, a socio-cognitive activity because the individual's cognitive activities are directly impacted by the social nature of the exchange and vice versa.

These domains are linked to decision making tasks and cognitive elements. The next three sub-sections present decision making tasks and cognitive elements, their respective success indicators and vulnerabilities and the procedure to compute the QDM performance levels.

## Decision making tasks and cognitive elements

The key elements under observation are identified and specified for the case of roading organisations facing crises/extreme events. In particular, specific tasks and sub-tasks associated to the Physical and Information domains are listed in Table 1. Similarly for the Cognitive and Social Domains specific cognitive and sub-cognitive elements have been depicted. The observation framework proposed in Table 1 is not intended to be a rigid reference. Alternative and more suitable tasks and cognitive elements can be identified and specified depending on the event under observation. Furthermore, it is emphasized that the tasks and sub-tasks as well as the cognitive and sub-cognitive elements are not expected to be observed as independent events. It is acknowledged that functions of a decision making process are always accomplished concurrently and interactively.

**Table 1 -** Tasks/sub-tasks to be observed, cognitive/sub-cognitive elements to be investigated during the decision making process.

| Domains of Decision making | Tasks | Sub-tasks | Acronyms |
|---|---|---|---|
| ***PHYSICAL*** | *Response Actions* | Deployment of Human Resources | **DHR** |
| | | Deployment of Physical Resources | **DPR** |
| | | Temporary Traffic Management | **TTM** |
| | | Damage Assessment and Management | **DAM** |
| ***INFORMATION*** | *Data Processing* | Data collection | **Data C** |
| | | Data analysis, storing, summarising | **Data A** |
| | | Data sharing, disseminating | **Data S** |
| | | Data maintaining, updating | **Data U** |
| | *Communication* | Communication intra-organisations | **C_INTRA** |
| | | Communication inter-organisations | **C_INTER** |
| | | Communication with media | **C_MEDIA** |
| | | Communication with public | **C_PUBLIC** |
| **Domains of Decision making** | **Cognitive elements** | **Sub-Cognitive elements** | |
| ***COGNITIVE*** | *Situation Awareness* | Perception of the evolving scenario | **Perception** |
| | | Understanding of needs | **Understanding** |
| | | Projection of future | **Projection** |
| ***SOCIAL*** | *Collaboration and Coordination* | Collaboration intra-organisations | **S_ INTRA** |
| | | Collaboration inter-organisations | **S_ INTER** |

## Success indicators and vulnerabilities

Specific success indicators are identified for each one of the decision making domains. They are:

- **Physical Domain** ($S_P$) reflects optimisation of the actions to ensure that the road network is able to function to the fullest possible extent, even though this may be at a reduced level, during the emergency and in the recovery and reconstruction phases. These include:

  $S_{P1}$) minimization of road closures duration and variability;

  $S_{P2}$) maximisation of accessibility to strategic services and places; and

  $S_{P3}$) minimization of response and recovery costs.

  They can be assessed by quantifying post-emergency phase costs and the time required to complete the response and recovery phases to the emergency/crisis event or judging qualitatively the identification of priorities and the resource allocation.

- **Information Domain** ($S_I$) measures the degree of connectivity achieved between the various decision makers in a network-enabled environment and the quality of the information exchanged. These include:

  $S_{I1}$) the degree of connectivity achieved;

  $S_{I2}$) the information richness; and

  $S_{I3}$) the extent of information reach.

  The degree of connectivity between the various decision makers can be assessed qualitatively by investigating the characteristics of the interactions between the decision makers. Similarly, the information richness can be assessed qualitatively, as a function of the degree of sharing of various forms of information – visual, audio, multimedia, and tools (Albert and Hayes, 2003). Finally, the extent of information reach can be assessed along the dimensions of whether it facilitates simultaneous, selective, and universal communication

- **Cognitive Domain** ($S_C$) focuses on the judgement of the decision-makers behaviour in order to understand decision maker's knowledge, capabilities, techniques, and procedures. These comprise:

  $S_{C1}$) the individual situation awareness;

  $S_{C2}$) the level of training and experience; and

  $S_{C3}$) intangibles of leadership and unit cohesion.

  Individual situation awareness can be investigated by using ad-hoc questionnaires or interviews targeting the assessment of the perception of evolving scenarios, the understanding of needs, demands and implications and the participants' projection of future. Codified techniques such as the Situation Awareness Global Assessment Technique, SAGAT (Endsley, 1995a and Endsley, 1995b) might also be adapted to suit the needs of the assessment.

- **Social Domain** ($S_S$) includes the responsiveness to the needs of emergency management agencies and the technical advice provided to leading emergency management agencies and lifeline groups. These include:

  $S_{S1}$) responsiveness to the needs of emergency management agencies;

  $S_{S2}$) technical advice to leading emergency management agencies and lifeline groups; and

  $S_{S3}$) coordination of actions with all involved agencies.

The level of responsiveness and technical advice provided to the emergency management agencies and lifelines groups can be assessed based on the expert judgment after the observation phase. The coordination of actions with all involved agencies can be assessed by quantifying the level of self-synchronisation and of team collaboration achieved. Self-synchronisation measures the capability of low-levels to operate nearly autonomously and to re-task themselves through sharing awareness to achieve strategic and operational objectives in accordance with the high level decision maker's intent. Self-synchronisation can be investigated by critically analysing the different types of communication exchanged between different levels of decision makers. In the context of roading organisations, self synchronization is investigated by analysing whether or not contractors and consultants are able to work out the details of their response activities as new information about the external situation becomes available, without having to continuously rely on decision makers to provide specific directions. Team collaboration measures the degree and quality of collaboration between the various team members and can be inferred from the analysis of messages exchanged during the decision-making process, focusing on information, action and coordination requests and transfers (in terms of frequency counts and the ratio of transfers to requests) and on the communication check.

Tangible and intangible vulnerabilities affecting the fulfilment of the decision making success indicators are identified and recorded. For the sake of simple data processing and analysis, observed tangible and intangible vulnerabilities are annotated in a matrix. Tables 2 and 3 show examples of how physical and information vulnerability matrices would be filled for an event. As shown in Table 2, the example represents an event in which deployment of human resources (DHR), deployment of physical resources (DPR) and damage asset management (DAM) were observed. For each observed task and/or subtask, comments on observed tangible and intangible vulnerabilities are also recorded. For example, amongst all other vulnerabilities, it is noted that no standardized damage survey form was associated to DAM task (Table 3).

**Table 2 –** Example of decision making vulnerability matrix for the Physical Domain.

| ***PHYSICAL DOMAIN*** | | | | | |
|---|---|---|---|---|---|
| *$S_{P1}$ - Minimisation of road closures duration and variability* | | | | | |
| ***Task/Sub-tasks*** | | | | ***Tangible Vulnerabilities*** | ***Intangible Vulnerabilities*** |
| **DHR** | **DPR** | **TTM** | **DAM** | | |
| ☑ | ☑ | - | - | Insufficient Resources | |
| - | ☑ | - | - | | Lack of Situation Awareness about available resources |
| - | - | - | ☑ | No standardised damage survey form | |

**Table 3 –** Example of decision making vulnerability matrix for the Information Domain.

| ***INFORMATION DOMAIN*** | | | | | |
|---|---|---|---|---|---|
| *$S_{I1}$ - Level of Connectivity* | | | | | |
| ***Task/Sub-tasks*** | | | | ***Tangible Vulnerabilities*** | ***Intangible Vulnerabilities*** |
| **INTRA** | **INTER** | **MEDIA** | **PUBLIC** | | |
| ☑ | ☑ | - | - | - | Poor degree of interactivity |
| *$S_{I2}$ - Information richness* | | | | | |
| **INTRA** | **INTER** | **MEDIA** | **PUBLIC** | ***Tangible Vulnerabilities*** | ***Intangible Vulnerabilities*** |
| ☑ | ☑ | - | - | Technical problems limiting the information sharing in visual form via voice or multimedia transmissions | - |
| ☑ | ☑ | - | - | Absence of supporting tools like Geographical Information System, or Decision Support System. | - |

## QDM performance level

Using the qualitative or quantitative information previously recorded, the overall decision making performance is assesed considering the applicability, the peformance level and the degree of fulfilment of all success indicators for all four domains under analysis. These elements of the QDM peformance assessment are defined as follows:

- **Applicability:** identify whether or not a success indicator is relevant to the specific decision making process under analysis;
- **Performance Level:** report the suitability and quality achieved in performing the different sub-tasks. For each *i-th* sub-task/sub-cognitive element pertinent to a certain *j-th* success indicator within the analysed domain *d*, a performance levels $P_{i,j,d}$ is assigned within a five-level qualitative scale (Excellent = 5; Very Good = 4; Good = 3; Regular = 2; and Poor = 1). A zero score, corresponding to a Non Performed = 0 condition is furthermore considered;
- **Degree of fulfilment:** assess the performance level achieved for each success indicator, based on observed sub-tasks and sub-cognitive elements. Mathematically, the degree of fulfilment $F_{d\,j,}$ is evaluated combining, according to a weighted average, the performance levels $P_{i,j,d}$ attributed to the sub-task/cognitive elements pertinent to the *j-th* success indicator.

$$F_{dj} = \sum_{i=1}^{t} \alpha_i P_{i,j,d} \qquad \text{(Eq. 1)}$$

where $\alpha_i$ is a normalised weight associated to the *i-th* sub-task/cognitive element pertinent to a *j-th* success indicator; referred to as **sub-task/cognitive elements normalised weight**. The normalised weighted average allows accounting for the different proportional relevance that each sub-tasks/cognitive element could have in the fulfilment of a certain success indicators.

- **Decision domain global score:** compute a global score representing the quality of the decision making process pertinent to the specific domain. The decision domain global score $D_d$ is computed combining, according to a normalised weighted average, the degree of fulfilment $F_{j,d}$ evaluated for the success indicators pertinent to the domain $D_d$ according to Equation 2.

$$D_d = \sum_{j=1}^{r} \beta_j F_{j,d} \qquad \text{(Eq. 2)}$$

where $\beta_j$ is a normalised weight associated to each success indicators *j-th* pertinent to the domain *d* and referred to as **success indicator normalised weight***.* The normalised weighted average allows accounting for the different proportional relevance that each success indicator could have in the quality achievement of a certain domain.

Finally, a global score for the decision making quality is measured combining the scores evaluated for the 4 different domains, as follow:

$$DM = \sum_{d=1}^{4} \gamma_d D_d \qquad \text{(Eq. 3)}$$

where $\gamma_d$ is a normalised weight associated to each domain $D_d$ and referred to as **success indicator normalised weight**. The normalised weighted average allows to account for the different proportional relevance that each domain could have in the global quality of the decision making process. The values of the sub-task normalised weight, $\alpha_i$ are supposed to be defined before the implementation of the QDM analysis liaising with decision-makers. Sub-task weights accounts for issues that can influence the decision making processes such as pre-defined strategies and priorities, expectations from end-user and other responding organisations, resources availability, organisation's role, etc. Multi-criteria analysis approaches can effectively support the process of priority and expectation identification and weighting (Ferreira *et al*., 2009).

Using the decision domains ($D_d$) and global score (*DM*) obtained respectively through Equations 2 and 3, a roading organisation can assess, on one hand its performance relative to each single domain and on the other hand its performance relative to the overall decision making process. A five level qualitative scale has been assumed to this aim categorising the performance of the decision making process in terms of: Poor Resilience, Limited Resilience, Regular Resilience, High Resilience and Outstanding Resilience. Table 4 shows the graphical output of the QDM analysis method. Attributes summarising the strengths and weakness affecting the single domain and the overall decision making processes of the organisation, have been identified for each one of the five levels identified (Table 4). According to the assumed scale, the decision making process of an organisation that achieves a global score *DM*=1.42 is classified at a Limited Resilience Performance Level, which means that the organisation is/has: dysfunctional; limited adaptability, not effective in various circumstances; limited in solutions delivery; and incapable to provide feedback to involved organizations.

**Table 4 - Visual representation of the performance levels observed for the decision making**

| | | Levels of Performance ($D_d$ / *DM* scores) | | | | |
|---|---|---|---|---|---|---|
| | | **Poor Resilience (0-1)** | **Limited Resilience (1-2)** | **Regular Resilience (2-3)** | **High Resilience (3-4)** | **Outstanding Resilience (4-5)** |
| **DOMAINS** | $D_P$ | - No optimisation consideration | - Limited efforts<br>- to improve resources allocations | - Significant efforts towards optimisation | - Minimization of road closures<br>- Maximization of accessibility<br>- Minimization of costs | - Dynamic minimization and maximization efforts |
| **DOMAINS** | $D_I$ | -No connectivity amongst orgs | - Casual connections with limited information exchange | - Informal and formal connections<br>- Limited coverage<br>- No information sharing standards | - Comprehensive connections<br>- Extensive coverage<br>- Information sharing standards adopted | - Long-standing connections Full coverage<br>- Dynamic info sharing practice |
| **DOMAINS** | $D_C$ | - No situation awareness | - Limited individual awareness | - Individual awareness<br>- Limited training and experience | - Individual awareness<br>- High levels of training and experience<br>- Limited leadership and cohesion | - Individual awareness<br>- High levels of training and experience<br>- High levels of leadership and cohesion |
| **DOMAINS** | $D_S$ | - No responsiveness to others | - Very limited responsiveness to emergency management ( EM)agencies | - Partial responsiveness to EM agencies<br>- Limited technical advise provided | - High level of responsiveness to EM agencies<br>- Comprehensive technical advise<br>Limited coordination | - Total responsiveness to EM agencies<br>- Accurate and timely technical advise<br>- Full coordination |
| **OVERALL** | ***DM*** | - Disfunctional;<br>- No Adaptability;<br>- Not effective in most circumstances;<br>- Severly limited in solutions delivery;<br>- No feedback to involved orgs | - Significantly dysfunctional;<br>- Very limited adaptability<br>- Not effective in many circumstances<br>- Very limited in solutions delivery;<br>- Very limited feedback to involved orgs. | - Partly dysfunctional;<br>- Limited adaptability<br>- Not effective in a few circumstances<br>- Limited in solutions delivery;<br>- Limited feedback to involved orgs. | - Mostly coordinated<br>- Mostly adaptable<br>- Effective in most circumstances<br>- Comprehensive in solutions delivery;<br>- Comprehensive feedback to involved orgs. | - Timely<br>- Adaptive<br>- Robust<br>- Adaptive<br>- Effective<br>- Learning-oriented |

## CASE STUDIES

The observation of decision making during events and exercises followed a three-step process: Step 1 comprises knowledge elicitation, including the observation of the decision making process and the development of descriptive accounts of the events/exercises; Step 2 entails debriefs including in-depth interviews with subject matter experts. This aims at identifying the cognitive elements that underlie goal generation, decision making and judgements. Debrief and interview activities focus on gaining information to analyse situation assessment strategies, identification and interpretation of critical cues, patterns and meta-cognitive strategies; and Step 3 includes the analysis and process of acquired data/information in order to perform the QDM analysis.

The QDM analysis was applied to 3 real events and 4 exercises, which have been observed since 2005. The observed events and exercises were: Floods affecting State Highway 2 (Matata, 2005); Mount Ruapehu Eruption (North Island, 2007); Floods affecting State Highway 1 (Kaikoura, 2008); Capital Quake Exercise (November 2006, Wellington); Marconi Exercise (June 2007, Auckland); Icarus Exercise (November 2007, Wellington); and Ruamouko Exercise (March 2008, Auckland). Dantas *et al* (2010) describe in detail the characteristics of all observed events and exercises.

The overall performance of SHO is within the High and Regular Resilience ranges. As shown in Tables 5, 6 and 7, each event and simulation exercise presented different characteristics in terms of decision making performance. This was mostly due to consistently high performance observed in the Cognitive ($D_C$) and Social Domains ($D_S$), which contrasts with low achievements in the Physical ($D_P$) and Information Domains ($D_I$). SHO were generally capable of providing good levels of responsiveness and technical advice, as well as showing good individual awareness. The best performance occurred in the Matata Flooding event, where there was a combination of highly experienced staff involved, good timing/coordination and efficient usage of information.

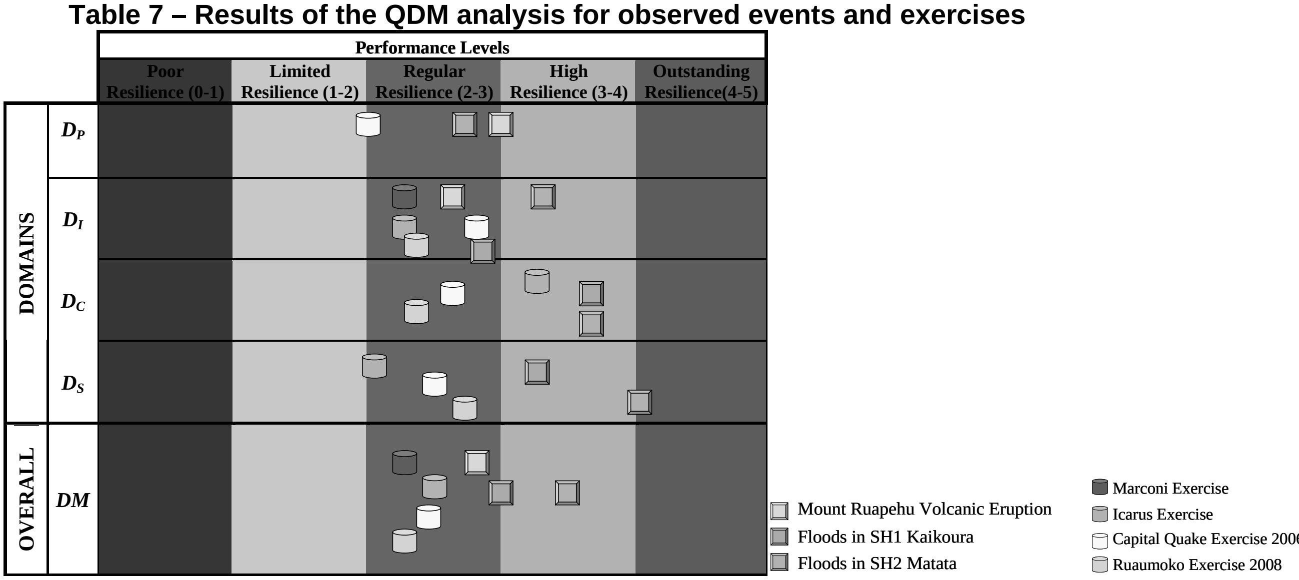
**Table 5 - Decision Domain Scores and Decision Making global scores for simulation exercises.**

| | **Domain** | | | | |
|---|---|---|---|---|---|
| | **Physical** | **Information** | **Cognitive** | **Social** | **Overall** |
| **Exercises** | $D_P$ | $D_I$ | $D_C$ | $D_S$ | ***DM*** |
| *Marconi Exercise* | | 2.33 | | | **2.33** |
| *Icarus Exercise* | | 2.33 | 3.33 | 2 | **2.55** |
| *Capital Quake 2006* | 2 | 2.86 | 2.67 | 2.5 | **2.51** |
| *Ruaumoko Exercise 2008* | - | 2.44 | 2.33 | 2.67 | **2.48** |
| **Average score** | **2** | **2.49** | **2.78** | **2.39** | **2.47** |

**Table 6 - Decision Domain Scores and Decision Making global scores for real events.**

| | Domain | | | | |
|---|---|---|---|---|---|
| | Physical | Information | Cognitive | Social | Overall |
| **Real Events** | ***$D_P$*** | ***$D_I$*** | ***$D_C$*** | ***$D_S$*** | ***DM*** |
| *Mount Ruapehu Volcanic Eruption* | 3 | 2.67 | - | - | **2.84** |
| *Floods in SH1 Kaikoura* | - | 2.97 | 3.67 | 2.33 | **3** |
| *Floods in SH2 Matata* | 2.67 | 3.33 | 3.67 | 4 | **3.42** |
| **Average score** | **2.84** | **2.99** | **3.67** | **3.17** | **3.08** |

**Table 7 – Results of the QDM analysis for observed events and exercises**




SHO performed slightly better in real events than in simulation exercises. The average scores show that the performance in real events reached a High Resilience level, whereas simulation exercises were mostly in the Regular Resilience level. SHO also performed better in real events for all observation domains. According to the resilience performance scale, the most important observed characteristics were individual awareness but limited training and experience in simulation exercises. However, good individual awareness and high levels of training and experience but still limited leadership and cohesion were observed managing real events.

On one hand, these results demonstrate that SHO have strong technical and leadership capabilities, which are clearly and efficiently used in real events. On the other hand, these results could be perceived as concerning indication of lack of experience and leadership when non-senior staff are subject to pressure and complex situations. A plausible reason for the different performances may be signs of only partial commitment shown by some exercise participants. SHO personnel involved in real crises performed very well under pressure.

The most common vulnerabilities observed in exercises were:
- Physical Domain: insufficiency and/or difficulties in deploying human and physical resources;
- Information Domain: lack of alternative ways of communication and lack of dedicated personnel to collect, process and share information and the impossibility for all the decision makers to have access to intra-organisation information; and
- Cognitive Domain: lack of individual situation awareness combined with deficiencies in decision makers' training and experience.

The most common vulnerabilities observed during Real Events were:
- Physical Domain: the response activities were delayed, because of the lack of redundancy in the network or more importantly because of the lack of awareness or unwillingness to use alternative routes, which would facilitate temporary traffic management; and
- Information Domain: inadequate information systems, lack of alternative ways of communication and lack of dedicated personnel to collect, process and share information and the impossibility for all the decision makers to have access to intra-organisation information.

Comparatively, similar vulnerabilities were identified in both exercises and events. This may indicate that decision makers tend to act quite similarly in both contexts, expect for the fact that in events vulnerabilities are observed in specific problems. For instance, temporary traffic management is usually a common problem affecting the physical domain. In real events, involved SHO are under pressure to achieve immediate and localized solutions. Hence, they tend to make decisions without major considerations about the network implications. On the other hand, exercise participants have the opportunity to conceptualize and rationalise various action scenarios, but are incapable to guarantee and test in situ allocation of resources. Similar observations could be drawn in terms of information sharing needs and procedures during exercises and events.

The best performance occurred in the Matata Flooding event. A combination of highly experienced staff involved, good timing/coordination and efficient usage of information were computed and analysed as high scores in the Cognitive, Social and Information domains. Even though the event created substantial pressure on all involved parties, SHO managed to overcome difficulties and re-established partial network accessibility within a reasonable timeframe.

Despite the solid performance for most exercises and events, it is remarkable the deficiencies associated to the Physical and the Information Domains. In the Physical Domain, the scores shown clearly show that there needs to be a series of actions towards improving resource allocations and optimisation. Similarly, Information Domain scores show there is still a limited coverage in the information sharing process and no information sharing standard has been adopted so far. Nevertheless, it should be highlighted that SHO have excelled in terms of both formal and informal connections.

## CONCLUSIONS

This paper introduced a novel approach to analysing the quality of SHO decision making. The QDM method was conceptualised and applied to several case studies of real events and simulation exercises observed in New Zealand over the last 4 years.

The results of the QDM analysis indicate that SHO are capable, experienced and competent in dealing with major disruption or crises that may affect the State Highway Network of New Zealand. SHO have achieved High and Regular levels of resilience in terms of decision making activities during emergency response events and exercises. Depending on the event or exercise, this means that SHO can: be mostly or partially coordinated; be mostly or limited adaptable; be effective or partially effective in most circumstances; be comprehensive or limited in solutions delivery; and provide comprehensive or limited feedback to involved organisations.

Our analysis revealed that SHO performed slightly better in real events than in simulation exercises. The differences in performance is mostly due to the fact that exercises have exposed non-senior staff to situations which they do not fully understand and/or have the required experience to deploy and coordinate resources allocation. SHO's major strengths were mostly observed in terms of their ability to perceive, assess and act based upon outstanding experience and technical sills, which were most often combined with extensive networking (informal and professional) with key individuals involved in emergency response. Senior SHO staff demonstrated high levels of situation awareness and leadership in various situations.

SHO's major weaknesses in terms of decision making during emergency response are mostly related to resource allocation and information sharing. Most decisions were performed without clear and/or rationalized/ structured processes supporting them. SHO did not have instruments/tools for assisting decision makers. Due to the level of complexity and risky nature of events, decision making can be overwhelming, because some decision makers could not grasp all the potential response actions, implications and benefits/costs throughout all the emergency response stages. Also, lack of reliable and well presented information did not help those deeply involved in the decision making process.

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## ACKNOWLEDGMENTS

This research was partially supported by the Foundation for Research Science and Technology (FRST) of New Zealand. The authors would like to thank all NZTA, consultants and contractors who shared their knowledge and experience about emergency procedures and events.