

Critical Infrastructure and Earthquakes: Understanding the Essential Elements of Disaster Management

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SUMMARY

The effects of earthquakes upon critical infrastructure, and hence the community, are significant. The need to take appropriate planning steps is apparent to earthquake engineers, but not always to the managers of critical infrastructure in the face of many competing time and financial demands. This is particularly the case in regions of low and moderate seismicity.

This paper considers the essential earthquake preparedness elements for critical infrastructure across the 4Rs of Emergency Management - *Reduction, Readiness, Response* and *Recovery*. The appropriateness of each of these preparedness elements for individual infrastructure operators needs to be assessed with due regard to community consequences as well as the seismic risk.

The important role of earthquake engineers working in conjunction with emergency managers to promote more effective risk management by critical infrastructure operators with respect to earthquake is outlined. It is concluded that earthquake engineers are well-placed to facilitate this risk management process.

1. INTRODUCTION

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This paper considers the essential earthquake preparedness elements for critical infrastructure across the 4Rs of Emergency Management - *Reduction*, *Readiness*, *Response* and *Recovery*. The role of earthquake engineers working in conjunction with emergency managers to promote more effective risk management by critical infrastructure operators with respect to earthquake is outlined.

2. DEFINITIONS, CONCEPTS AND CONTEXT

Critical infrastructure and *disaster management* are broad subject areas that mean different things to different people. The concepts involved need definition, and to be placed in an appropriate context. Similarly, while *earthquakes* are well appreciated from a technical perspective, they need to be put in context with respect to other emergency events.

Critical Infrastructure

Critical infrastructure comprises the essential services and facilities on which communities depend. These can be further subdivided as follows:

- *utility services* - water, wastewater, power, gas and telecommunications
- *transportation networks* - roading, rail, ports and airports
- *critical facilities* – hospitals, police, fire and ambulance stations, emergency management Emergency Operations Centres

The physical elements of critical infrastructure include buried services (pipes and cables); overhead cables; switchyards, exchanges and control rooms; roads; bridges and buildings.

Earthquakes

Earthquakes are low probability but high impact (or consequence) events. Both aspects are well appreciated by the earthquake engineering fraternity, whereas the operators of critical infrastructure seem to only register the former!

Two key points put earthquakes in context for critical infrastructure and the community:

1. Earthquakes affect all elements of critical infrastructure across a region simultaneously and to an extent greater than any other emergency event (with the exception of volcanic activity)
2. The most significant influence on the ability of an affected community to recover is the rate of restoration of utility services and transportation functions

The direct impact of earthquakes upon key utility services from the community perspective is best represented by the service restoration curves from the 1995 Kobe earthquake (Figure 1).

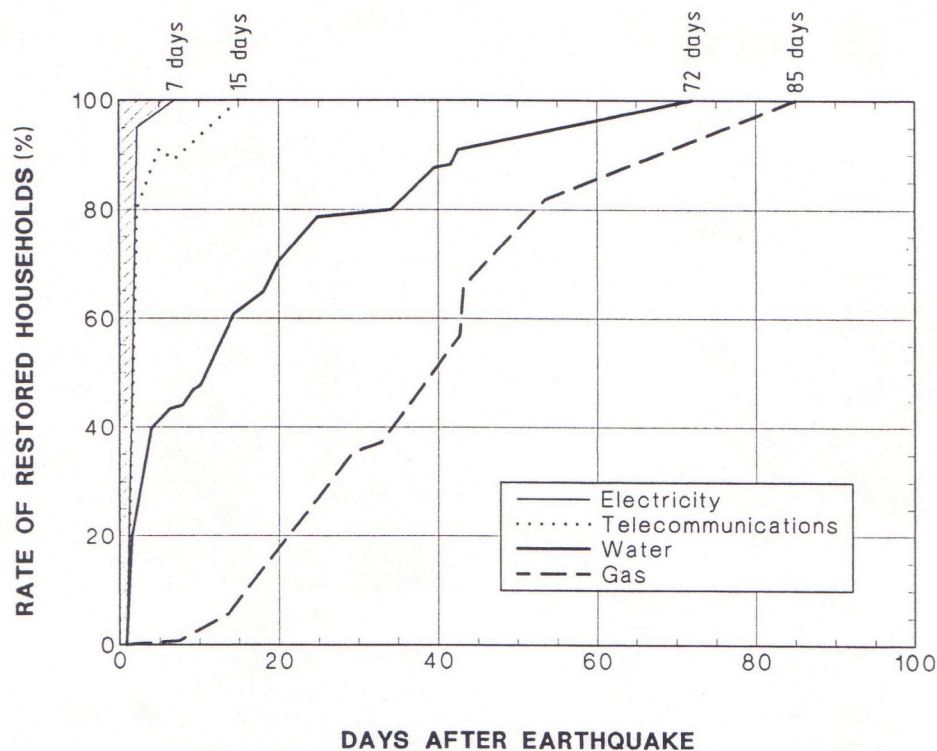


Figure 1: Service Restoration Curves From Kobe (WELG, 1995)

This hierarchy of restoration times is essentially the same as observed following the Northridge and Taiwan earthquakes. Water is clearly the critical service – in addition to the real difficulties for households struggling without water over extended periods, businesses cannot operate. The ability of businesses to resume even limited operations is one of the key determinants of the overall community recovery.

Disaster Management, Emergency Management and Risk Management

Disaster Management is the aspect of Emergency Management which addresses extreme emergencies. To many, it only involves planning the response to such an event. It is however important to consider the broader facets of Emergency Management, which can be defined as:

A range of measures to manage the identified risks to a community before, during and following an event or disaster

This involves consideration of the 4Rs of *Reduction, Readiness, Response* and *Recovery*. It is also integrally tied to the process of risk management, as encapsulated in AS/NZS 4360:1999 (SA & SNZ, 1999).

In New Zealand, the Lifelines Engineering process has been developed to assist utility and transportation network operators in their planning for regional scale emergencies. It is based around the following risk management steps (Brunsdon, 2001):

- Identifying the *hazards* which could affect each lifelines network
- Compiling common *inventories* of the various utility and transportation networks
- Assessing the *vulnerability* of the lifeline network to those hazards (the *potential damage* to and *consequences* for each network)
- Identifying and implementing practical *mitigation* measures
- Facilitating the preparation of comprehensive *emergency response* plans

All critical infrastructure operations undertake risk management to varying degrees. In many instances however, this still tends to be internally focused. The response of a utility organisation after a major emergency is heavily influenced by the performance of other utilities. The regionally-based Lifelines Engineering process provides the much-needed external perspective by systematically highlighting the *interdependencies* involved.

3. RECENT INFLUENCES ON CRITICAL INFRASTRUCTURE PREPAREDNESS FOR EARTHQUAKE

It is the view of the author that a number of critical infrastructure operators are not as well prepared for earthquake events as they might be. This is believed to be the case even in higher seismicity areas such as in central New Zealand. In evaluating the current level of preparedness of critical infrastructure for major events such as earthquake, there are a number of recent influences to be considered.

Privatisation and Associated Restructuring

The utility and transportation sectors have undergone considerable transformation over the past decade throughout Australasia. Privatisation has led to a greater commercial focus, particularly for those with revenue directly at risk. The dividing up of some utility sectors into component pieces (eg. generation, transmission and distribution for electricity) and highly competitive sectors working within anti-competition legislative frameworks (telecommunications and energy) has led directly to a 'silo' approach for emergency response. This clearly has an adverse influence on the ability of these sectors to develop integrated plans to respond to a major event such as earthquake. Studies of the 1995 Kobe earthquake highlighted that the effective response of utilities such as Kansai Electric Power Company was due to their integrated nature, covering generation, transmission and distribution (WELG, 1995).

Restructuring has also led to extensive outsourcing for design and maintenance, with a resulting heavy dependence of many utility organisations on contractors, some of whom are shared with other organisations. While maintenance contracts place a heavy influence on 24 hours/ 7 days a week response as part of 'business as usual', they need to be subjected to more careful scrutiny to ensure that the procedures will also be effective for extreme events such as earthquake. For example, the ability of external contractors to carry out the critical initial impact assessment immediately after a significant earthquake is open to question.

Also, while the restructuring has led to significant advances in financial risk management, the heavy emphasis on economic justification for capital development and other activities creates a real obstacle for earthquake mitigation. Feeding the low annual probabilities of damaging earthquake events into a Net Present Value calculation typically results in an unfavourable outcome. This is usually the case even in high seismicity regions, and inevitably the case for regions of moderate and low seismicity.

The development of a consistent economic framework for justifying investment for mitigation and preparedness for low probability/ high impact natural hazard events remains a significant challenge for the earthquake engineering fraternity.

General Asset Condition

The IEAust 2001 Australian Infrastructure Report Card (Yates, 2001) revealed that the average age of many of the infrastructure sectors is increasing, with the lack of both capital and maintenance funding being of concern. The absence of long-term integrated planning was also highlighted. For water supply, it is noted that the amount currently being spent on rehabilitation is not sufficient to keep pace with the rate of asset deterioration. The ageing nature of electricity infrastructure was also commented on.

These observations underscore the inherent physical vulnerability of key utility networks, which typically have only nominal (if any) provision for the effects of strong ground shaking.

Legislative Drivers

The new Civil Defence Emergency Management legislation in New Zealand requires key lifeline utilities to be actively involved in regional and national emergency management planning. This legislation places particular emphasis on utility organisations having a plan to respond to foreseeable emergency events, including earthquake. A copy of the Ministry of Civil Defence and Emergency Management information guideline for lifeline utilities (*Working Together: Lifeline Utilities and Emergency Management*) can be downloaded from www.civildefence.govt.nz.

It is understood that there is no equivalent legislation in place or proposed for Australia.

Heightened Awareness of Terrorist Potential

The United States events of September 2001 have made critical infrastructure operators realise that ‘anything goes’ in terms of physical and organisational attacks. The particular lesson for operators is the potentially prolonged nature of the response and recovery phases – not unlike that for earthquake.

4. KEY ELEMENTS OF EARTHQUAKE PREPAREDNESS

The appropriate level of earthquake preparedness by critical infrastructure operators can only be established following a comprehensive risk assessment. However, essential elements of critical infrastructure earthquake preparedness can be summarised across the 4Rs as follows:

Reduction

- Identify seismic vulnerabilities for major assets and facilities, and prioritise mitigation measures based on assessment of possible impacts and what is needed to provide minimum acceptable short and medium-term service
- Incorporate high priority seismic mitigation measures within asset renewal programmes
 - *eg. for water supply, priority measures are the installation of automatic shut-off valves for key reservoirs, and upgrading key mains leading down from reservoirs and brittle mains in soft ground*
- The bracing and tying down of control cabinets and computers in control rooms is well proven as a low-cost but highly effective mitigation measure. Consideration can be given to increasing the level of pipes and fittings held for emergency repairs, and the method of storage (eg. horizontal storage of critical and brittle spares to minimise damage)

- Essential post-earthquake facilities such as hospitals and civil defence and utility emergency operations centres must be situated in seismically robust buildings, with alternative locations. Seismic evaluation of key buildings must be undertaken.

Readiness

- Ensure appropriate mutual aid agreements are in place for key utility sectors such as water and energy
- Ensure that operators of critical infrastructure have dependable access to technical resources such as engineers
 - *Critical facilities and utilities to have Priority Response Agreements with engineers*
 - *Consideration to be given to the establishment of a register of engineers*
- Upgrade the level of emergency water supplies retained by critical facilities (eg. hospitals)
- Hold exercises to test preparedness and effectiveness of response plans and communications processes

Response

- Ensure that response plans have appropriate emphasis for earthquake with respect to
 - *the role of external contractors (prepare additional Standard Operating Procedures where necessary)*
 - *inter-agency communications*
 - *the mechanics of distributing core community supplies such as emergency water over an extended period of time*
- Clarify currently available resources for impact assessment and initial repairs
- Establish hierarchy of critical supply points
 - *eg. hospitals as a priority for the restoration of water supply, electricity*

Recovery

- Identification of contractors who could assist with repairs and reconstruction of specialist equipment and facilities
- Strategy for management of mutual aid over an extended period of time

5. THE ROLE OF ENGINEERS IN PROMOTING BETTER PREPAREDNESS

Engineers typically advise operators of critical infrastructure on risk mitigation (or *Reduction*) measures. There is however a need for earthquake engineers to convey the message to those operators that there are also basic preparedness measures across the *Readiness*, *Response* and *Recovery* phases that need to be given specific consideration.

Earthquake engineers need to be pro-active advocates for the range of earthquake preparedness measures outlined in the previous section.

The key characteristic of a post-earthquake situation is overloaded and ineffective communications, and disrupted access. In this context, engineers represent a scarce technical resource that will not be used effectively without prior planning. Accordingly, critical infrastructure operators need to establish Priority Response Agreements with engineers in order to address two key objectives:

- *Ensuring the availability of designated engineers and/ or technical personnel who are familiar with their facilities; and*
- *Minimising the response time of the designated engineers by defining in advance the specific actions they are to undertake.*

More information on Priority Response Agreements can be found in a recent NZSEE Working Party discussion paper (NZSEE, 2002) which can be downloaded from www.nzsee.org.nz

6. CONCLUDING OBSERVATIONS

In considering the range of earthquake preparedness measures that critical infrastructure operators could implement, the following key observations are made:

- District or regionally-based lifelines engineering processes for utility and transportation operators should be actively encouraged, having due regard to the risk profile of each area. This process enables the vital interaction between different agencies, leading to a better understanding of the interdependencies involved, as well as providing a ‘safe’ platform to cut across commercial considerations
- Emergency Managers are the flagbearers for promoting more effective mitigation and preparedness by critical infrastructure operators. Earthquake engineers must work more closely with Emergency Managers, particularly in regard to conveying the *likelihood* and *consequences* of a major earthquake
- Designated Emergency Operations Centres for lifelines, critical facilities and emergency management agencies need to be capable of functioning after a major earthquake

- All critical infrastructure operators need to have direct relationships with earthquake engineering advisors in order to have dependable assistance for assessment of their facilities for re-occupancy following an earthquake. This should be addressed in their Business Continuity Planning.

The need for some of the measures outlined in this paper across the 4Rs may not be as great in low and moderate seismicity regions as for high seismicity locations. However it is argued that critical facilities in even low seismicity locations need to have basic preparations in place for earthquake. Critical infrastructure operators need to be made aware that low seismicity does not mean that only weak earthquake shaking can be expected – it just means that strong earthquakes occur even less frequently. Also, a number of the items involve relatively low cost measures (eg. the seismic restraint of control cabinets, etc).

The appropriateness of these various measures for individual infrastructure operators needs to be judged in the context of the physical and operational risks. Earthquake engineers are well-placed to facilitate this risk management process.

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