A DECADE OF LIFELINES ENGINEERING IN NEW ZEALAND

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SUMMARY

Significant developments have occurred in the field of lifelines engineering over the past decade both in New Zealand and internationally. In New Zealand, this period encompassed both the beginnings of lifelines activity and its development into being an established discipline of earthquake engineering.

There are currently 8 formally constituted lifelines projects or groups in New Zealand, with 4 others scheduled to be established within the next 12 months.

This paper charts the progress of lifelines engineering in New Zealand during this time, outlines the key achievements and critical success factors and discusses current and future developments.

INTRODUCTION

Lifelines are those essential services which support the life of our communities. These are either utility services such as water, wastewater, power, gas and telecommunications, or transportation networks. The term civil infrastructure is also frequently used in a similar context to lifelines, particularly in the United States.

The twin overall objectives of Lifelines Engineering are *firstly* to reduce damage levels following a major disaster event and *secondly* to reduce the time taken by these lifelines services to restore their usual level of service. This saving in time translates directly into a saving for the community as a result of reduced disruption to homes, offices and industries.

While much of this paper refers to earthquake events, a great deal of the recent work associated with lifelines engineering in New Zealand has embodied an all-hazards approach.

At the start of the decade in question, there was a growing realisation that while considerable effort had been put into understanding the seismic response of buildings, relatively little was known about the likely performance of utility services. Similarly, in the case of transportation networks, while the individual structural response of major elements such as bridges had been extensively studied, the post-disaster performance of the networks as a whole had not been considered in anywhere near the same detail.

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THE LIFELINES ENGINEERING PROCESS

In New Zealand a risk management-based approach has been adopted to identify the areas and elements of high risk and to develop strategies to manage this risk. The process of minimising the vulnerability of lifelines in seismically active regions involves the following key steps:

- Identifying the hazards which could affect each lifelines network
- Assessing the vulnerability of the lifeline network to those hazards
- Assessing the potential damage to and consequences for the network
- Identifying and implementing practical mitigation measures.
- Compiling comprehensive emergency response plans.

Assessment of *vulnerability* takes account of the importance of the lifeline component - that is, the degree of disruption if the element is lost to the network. This aspect typically highlights the redundancy (or lack of) in a system. The assessment of *potential damage* takes into account of the impact of an earthquake - that is, the time and effort which is likely to be required to reinstate the component in addition to the cost.

Traditionally, seismic risk issues have been worked through on an organisation by organisation basis. The key focus, and hence advantage, of lifelines work in the New Zealand context is the sharing of technical information relating to seismic hazard and mitigation between lifelines organisations.

The *mitigation and preparedness* aspect of lifelines engineering is embodied in the fourth and fifth bullet points above. A prime example of a practical mitigation measure is the installation of automatic shut-off valves at water supply reservoirs, to stop the loss of vital water through broken mains. This is not simply an engineering exercise, as it requires prior consideration of the post-earthquake response of the fire service, and consultation with them.

The planning of emergency response essentially involves establishing frameworks for organised and immediate responses to such situations. Response Planning acknowledges that full physical mitigation is unattainable for most lifelines, and represents the vital first step in ensuring a rapid restoration of service. A response plan defines the physical sequences to be followed in the event of a regional scale emergency, and defines the roles, responsibilities and authorities of key personnel involved.

Lifelines engineering work in New Zealand is characterised by a regional approach, which involves utility organisations working collectively with hazard analysts and emergency managers to identify the areas of concern to their network. The focus is on regional scale events that are beyond the ability of individual organisations to respond to and control. The responsibility for taking appropriate mitigation and preparedness steps however remains with the individual organisations.

In 1998, Ron Eguchi of the United States was engaged to carry out a review of the methodologies developed in New Zealand. He found that the multi-hazard and multi-disiplinary basis of the New Zealand methodology represents a comprehensive and internationally unique approach, and that the NZ/ Australian Risk Management Standard NZ/ AS 4360:1999 (Ref 1) is very suitable for use as a foundation for lifelines work.

The relationship between the key lifelines task elements and the fundamental risk management steps are indicated in Table 1.

Table 1: Relationship Between the Risk Management Elements and Principal Lifelines Engineering Tasks

Risk Management Elements	Lifelines Engineering Tasks
Risk Context	Project Initiation
Risk Identification	Hazard Identification and System Inventory
Risk Assessment	Vulnerability and Potential Consequences Assessment
Risk Evaluation	Establish Criteria, Compare Against and Prioritise
Risk Treatment	Identify Mitigation Options Undertake Mitigation Carry out Emergency Response Planning
Monitoring Progress	Annual Review
Ongoing Risk Communication	External - General Publicity to the Community Internal – Development of Best Practice Guidelines

ESTABLISHMENT, CONSOLIDATION AND EXPANSION

Establishment

Lifelines engineering in New Zealand began as a separate discipline with the undertaking in 1989 of the *Lifelines in Earthquakes: Wellington Case Study*. This project was initiated, produced and largely funded by the Centre for Advanced Engineering, and was completed in 1991 (Ref. 2). This project has provided the impetus and a point of reference for all subsequent lifelines work in New Zealand.

The principal output from this project was the identification of a series of possible mitigation measures that operators of lifelines could undertake to reduce the risk from a major earthquake. The concepts of *interdependence* and *critical areas* were also identified: interdependence relates to the effect of the outage of one utility service (eg. power) on the time taken by another to recover (eg. water supply requiring power for pumping), whereas a critical area is one where a number of lifelines are highly vulnerable in one location (eg. a bridge carrying water, gas and power in addition to roading).

Of greater significance however beyond the technical content was the heightened awareness of this work created by this project amongst utility services providers both in Wellington and elsewhere in New Zealand.

Consolidation

Lifelines engineering in New Zealand was consolidated by two developments in 1993.

Firstly, the Christchurch Engineering Lifelines Project was established (Ref. 3). This project was similar in nature to the CAE Wellington Case Study, but with the enhancement of an all-hazards approach. This project considered not only earthquake, but also severe flooding of the Waimakariri River; a severe rain storm causing a local flood hazard (Heathcote, Avon and Styx rivers); a severe windstorm, a tsunami on the coast, a heavy snowstorm and slope hazards causing damage to surfaces on the Port Hills. The need to take specific account of critical community facilities such as hospitals was also highlighted by this project.

The second of these developments was the establishment of the Wellington Earthquake Lifelines Group. This group operates under the auspices of the Wellington Regional Council, and contains representatives of each of the national, regional and local utility service and transportation providers involved in the metropolitan area, along with consulting engineers and scientists. The Wellington Lifelines Group has involved related disciplines and organisations beyond the engineering and scientific origins of the initial lifelines work.

As well as further developing the preparedness of lifelines operators for major earthquakes, one of the key areas of emphasis of this group is to create and maintain awareness of the importance of lifelines to the community at large. It has been set up as an ongoing organisation rather than as a finite project, and in 1997 also adopted an all-hazards perspective. Project groups were established to build on and take further the key findings of the original project, including rationalisation of the original list of mitigation measures into a shorter list with emphasis on cost-effectiveness and affordability. A great deal of effort has also gone into co-ordinating the generation of utility response plans between the many utility organisations involved.

This work is referred to as the second phase of lifelines work, following on from the first phase work which involved hazard identification and vulnerability assessment.

Expansion

With the continuum produced by the first and second phase work outlined above generating clear benefits, other lifelines groups have been formed in New Zealand. 1996 saw five new groups established (Auckland, Wairarapa, Timaru and Dunedin), with Hawke's Bay and Waikato commencing in 1997. This rapid expansion highlights the major progress made over the past decade.

INTERNATIONAL LIAISON

The value of the original Wellington project was enhanced by the involvement of four United States experts in lifeline earthquake engineering. Don Ballantyne, Dennis Ostrom, Ian Buckle and Tom O'Rourke contributed directly by attending project workshops. International input into the Christchurch project was provided by Ron Eguchi of the United States. This involvement has created a continuing conduit for the exchange of information on lifelines work between New Zealand and the United States, and has led to the participation of key New Zealand lifelines engineers in joint United States-Japan technical meetings.

Major earthquakes in Northridge, California (1994) and Kobe, Japan (1995) have also consolidated the momentum of lifelines work in New Zealand. These events generated a number of technical findings and response lessons for those involved with the management of lifelines systems. Study teams comprising representatives from both the Wellington and Christchurch lifelines groups visited each of these areas appproximately six months after the respective events and held detailed discussions with their counterparts. These events also generated a high level of interest amongst the general public, and highlighted the lack of regional scale emergencies that New Zealand has experienced.

The valuable lessons for New Zealand lifelines operators were conveyed by various means, including the *1994 Report* and the *1995 Report* produced by the Wellington Earthquake Lifelines Group (Refs 4, 5). The key lessons learnt from these events were firstly the importance of re-establishing transportation links as quickly as possible and secondly the need to have an integrated response plan at national, regional and local levels. The third aspect was the indication of the time taken to restore the various utility services in each of these events, which provide a good basis for establishing likely scenarios following a major earthquake in New Zealand.

Closer to home, the Tasmanian Lifelines Project was established in Australia in 1995, and with the benefit of appropriate backing has also made very good progress in a short space of time.

KEY NEW ZEALAND ACHIEVEMENTS

In the relatively short period of time that lifelines engineering has been actively undertaken in New Zealand, there have been a number of key achievements. At a general level, probably the most significant has been the level of acceptance of the discipline of lifelines engineering and the rapid spreading of this work throughout the country.

The following specific key achievements are selected from project considerations. The criteria adopted in listing these achievements is principally that the work involved would not have been undertaken without the focus that lifelines engineering provided. While most of them relate to projects undertaken in the Wellington Region, this is simply a reflection of the progression of lifelines work in that area following the initial CAE study.

Thorndon Overbridge Retrofitting

The CAE study identified the Thorndon area as being the most critical area in the Wellington Region, due to the combination of proximity to the Wellington Fault, the extent of early harbour reclamation, and the proliferation of lifelines that pass through this narrow strip of land. Such was the emphasis given to this area in the CAE project that Transit New Zealand commenced a study into the likely seismic performance of the Thorndon Overbridge, which is the main highway entrance to the city and also crosses the main trunk railway in the Wellington railway yards. This overbridge was designed progressively through the 1960s and early 1970s to design standards that are now recognised as not being as comprehensive as those of today. The study confirmed a number of structural shortcomings, and a range of strengthening measures totalling approximately NZ$20 million were completed in 1998.

The Kaitoke Flume Bridge

This concrete aqueduct carries half of the daily water supply to the Wellington metropolitan area across a deep gorge and was designed in the late 1950s. An engineering assessment was commissioned immediately after the CAE Wellington Case Study Project, and this identified that the strength of the supporting structure was less than a quarter of that required by current standards (Ref. 6). A retrofit to full current seismic standards resulted, for a completed cost of approximately NZ$250,000. Given the major task of reconstructing this key element of the water supply network should it fail, this project demonstrates a very high inherent value for money.

The Hutt Estuary Bridge Assessment

In addition to the primary roading function, this bridge carries five other lifelines; two regional council watermains (the remaining half of the water supply to the Wellington metropolitan area), the Hutt Valley main trunk sewer, a medium pressure gas main, 11kV power supply and 6 Telecom duct lines. The bridge was designed and constructed in the early 1950s, and recent studies have shown the bridge to be situated in an area that is known to have a high potential for liquefaction.

As a result of the identification of this element as being the second most critical lifelines area in the region by the Wellington Earthquake Lifelines Group in 1993, sufficient encouragement and financial support was given by the affected lifelines operators that the seismic assessment of this bridge was brought forward by the Hutt City Council several years ahead of its programmed date.

Lifelines Co-ordination Centres

With the emphasis on response planning as outlined earlier, there has been an increased awareness that the post-disaster co-ordination of utility services is a specialised skill. This awareness was heightened by the NZ lifelines study tours following the Northridge and Kobe earthquakes. The approach developed by the California Utilities Emergency Association was used as a basis for establishing a Lifelines Co-ordination Centre model for New Zealand. This regional centre is a place where lifelines information can be co-ordinated, analysed and directed to where it is needed. A Lifelines Co-ordination Centre has been established in Wellington as a co-operative effort between emergency management agencies and the Wellington Lifelines Group. This concept has formed the basis of proposals associated with the new national emergency management structure, and has also been used effectively as the basis for monitoring incidents due to Y2K.

CRITICAL SUCCESS FACTORS

In analysing the developments and achievements in New Zealand lifelines engineering over the past decade, a number of critical success factors are apparent.

- ***The close linkage between scientific and engineering interests and the Emergency Management and insurance sectors***

  With lifelines engineering being somewhat more an applied field than theoretical, a close linkage has been formed between engineers, scientists, emergency managers and the insurance industry.

- ***Lifelines engineering has a practical face that the public, politicians and management of private sector organisations can relate to***

  A key benefit of lifelines studies is the generation of a much clearer picture of what the real situation is likely to be following a major earthquake. This work is capturing the imagination of communities very effectively; people react to the thought of being without water or sewerage facilities for a week far more readily than the threat of being injured by a damaged building.

  In the same way as for the public, politicians are also more sensitive to the implications of utility failure. Ultimately they have a degree of accountability to the ratepaying public if a local authority is found after an event not to have taken appropriate steps to mitigate vulnerability.

  Reduced disruption to utility services and access also has a clear benefit to managers of private sector organisations and insurers in terms of reduced business interruption.

- ***Linkage between Asset Management and Risk Management***

  There has been considerable emphasis through this decade for the formal development of asset management plans within both local authority and private sectors. Risk Management is an integral part of Asset Management, and lifelines engineering provides the vehicle for collective risk management across utilities at a regional level. From this platform, the individual organisations can then carry out their specific mitigation and preparedness tasks and integrate this with their Asset Management plans.

- ***Technological developments***

  There have been a number of technological developments that have enhanced aspects of the lifelines engineering process during this period. The most significant of these is the increased availability of Geographic Information Systems (GIS) mapping software which has greatly facilitated the overlaying of infrastructure networks on seismic hazard maps. This very simple process remains one of the cornerstones of the lifelines engineering process.

CURRENT AND FUTURE DEVELOPMENTS

Lifelines engineering projects in the four main metropolitan centres have now completed their work. The newer groups that have commenced over the past three years are in the provincial areas. These projects face different challenges as they feature a collection of smaller communities with typically separate utility systems. Adaption of the methodologies developed by the metropolitan groups to reflect these differences is currently underway.

There is currently a move towards a more formal and integrated national organisational structure for lifelines in New Zealand. Three annual National Lifelines Forums have now been held, with emphasis being placed on assisting the new groups with respect to methodology and organisational issues.

In a parallel development, one of the key elements of the new emergency management structures in New Zealand (Ref. 7) is the active encouragement of lifelines groups to participate in the Emergency Management Group arrangements. While the proposed new emergency management legislation will not prescribe the pre- and postevent inputs required from utility organisations, the expectations in terms of participating in planning processes will be clearly indicated.

There is also a desire to introduce a research component, given that work to date has been strongly practitioner driven. This is a significant point of difference from lifelines work carried out in the United States and Japan, where there is an established link between major utilities and research organisations.

A current project of particular significance to lifelines organisations both in New Zealand and internationally is the development by the Wellington Lifelines Group of a standardised approach for the economic justification of lifelines work. Previously projects could be undertaken essentially at the recommendation of the engineer in charge (in either the private or public sector context), based on his or her appreciation of the risk issues, implications of failure and cost of the project. However, projects involving either staff or physical resources are now typically subject to detailed economic analysis, irrespective of the nature of the organisation. This is one of the major changes through this decade, and has brought sharply into focus the need for a comprehensive and consistent approach to economic benefit-cost analyses appropriate to the various stages of lifelines projects. There are two levels at which benefits and costs need to be considered; firstly on a single organisation basis, and secondly on a multi-organisation basis extending to involve a community or region.

A major project that is about to be commenced is to integrate the work done to date on Fire Following Earthquake. While elements of this topic have been the subject of extensive study, this project is proposing to adopt a broader risk management approach, including consideration of public awareness, mitigation and preparedness aspects (risk communication). The ultimate project report is to be the focal point of a proposed international conference to be held in Wellington in 2001 to consider the future direction of lifelines studies, including progressing the incorporation of social aspects.

CONCLUDING OBSERVATIONS

New Zealand's regionally-based approach to lifelines work is considered to be unique internationally. This is due to both the seriousness with which this work is taken at a local authority and corporate level, and the close technical co-operation between the various organisations involved which cuts across commercial considerations.

The key to the success of lifelines work in New Zealand lies in its ability to portray the wider view of risk from natural hazards, with particular emphasis on earthquakes given New Zealand's seismic context. The main product of lifelines studies is the generation of a much clearer picture of what the real situation is likely to be following a major earthquake. A balanced but informed scenario is a fundamental tool in seeking community involvement.

Lifelines engineering in New Zealand has made tremendous progress in the past decade, and important developments are anticipated in the future. The level of interest in lifelines engineering is currently very high, as evidenced by the recent establishment of a number of new groups around New Zealand. This expansion is likely to continue, for although the lifelines process follows a general pattern as outlined earlier in this paper, every area has its own set of lifelines systems in their unique geological and seismic setting.

One of the areas of current emphasis is the development of a standardised approach to the economic justification of lifelines work. Being able to demonstrate the economic benefits of lifelines mitigation and preparedness to management, politicians and the community is the key to the future progress of these activities.

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