

Learning from earthquakes: past; present; future

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ABSTRACT: Post-earthquake investigations for improving the science and practice of earthquake engineering and earthquake hazard reduction have been conducted since 1949 by the Earthquake Engineering Research Institute. Formalized by EERI as their Learning from Earthquakes (LFE) program in 1973, the objective is to accelerate and increase learning from earthquake-induced disasters that affect the natural, built, social and political environments worldwide, accomplished through field reconnaissance, data collection, and analysis, information sharing Clearing Houses (physical and virtual), and dissemination of lessons and opportunities for reducing earthquake losses and increasing community resilience.

The NZSEE programme of LFE builds on over six decades of earthquake reconnaissance, involving more than 30 missions that gathered information and experience from significant overseas earthquakes and tsunami and significant New Zealand earthquakes. All NZSEE missions have been undertaken with the support of the Earthquake Commission (EQC) and, since 2009, the Department of Building and Housing (now MBIE), as well as the employers of mission members. Additional LFE missions from NZ have been undertaken by others, e.g. GNS Science. The lessons disseminated from LFE missions have for New Zealand positively influenced: evolution of the Building Code; establishment of Lifeline Engineering; establishment of Urban Search and Rescue; tsunami mitigation; and adoption and evolution of procedures for emergency building management.

Similar LFE programmes operate in various forms in many other countries. Professional Societies, many with multinational memberships, are the predominant umbrella organisations for national LFE programmes. Relationships between societies such as NZSEE, members, and researchers, as well as evolving internet and remote sensing technologies are increasing global LFE collaborations and benefits.

1 INTRODUCTION

Lessons learnt from earthquakes date back to antiquity, with the pinning of carved stone blocks to give earthquake resistance to columns of Grecian and Roman temples and memorials with some being base isolated by founding them on beds of sand or planar layers of cut rocks, such as the tomb of Cyrus 550 BC (Ahmad Naderzadeh 2009).

Continuous earthquake recording is the domain of seismologists and the increasing number of seismologists/engineers engaged in real-time monitoring of engineered structures.

Learning from earthquake programmes address infrequent but significant (damaging) earthquakes by scientists and earthquake engineers collecting data and observations, some perishable and/or time dependant. The purpose is to improve the science and practice of earthquake engineering and earthquake risk reduction.

Learning from earthquakes has been formally conducted since 1949 by the Earthquake Engineering Research Institute (EERI). Formalized by EERI as their Learning from Earthquakes (LFE) program in 1973, the objective is to accelerate and increase learning from earthquake-induced disasters that affect the natural, built, social and political environments worldwide. The mission is accomplished through field reconnaissance, data collection and archiving, information sharing *Clearing Houses* (physical and virtual), and dissemination of lessons and opportunities for reducing earthquake losses and increasing community resilience.

The generic term *Learning from Earthquakes* has been adopted by the New Zealand Society for Earthquake Engineering (NZSEE) for what it previously called *Earthquake Reconnaissance*. The NZSEE programme of *Learning from Earthquakes* is similar to that of EERI and builds on over six decades of earthquake reconnaissance by NZSEE teams, involving more than 30 missions that have gathered information and experience from significant overseas earthquakes and tsunami and significant New Zealand earthquakes. All NZSEE missions have been undertaken with the support of the Earthquake Commission (EQC; formerly the Earthquake & War Damage Commission) and, since 2009, the Department of Building and Housing (now the Ministry of Business, Innovation and Employment - MBIE) , as well as the employers of mission members. Additional LFE missions from New Zealand have also been undertaken by others, including consultancies, the insurance industry, and GNS Science.

2 PAST LEARNINGS FROM EARTHQUAKES

Reported New Zealand LFE missions have been tabulated (web reference – www.nzsee.org.nz/XXX). The lessons disseminated from LFE missions have for New Zealand, led to at least five significant outcomes:

1. evolution of the Building Code,
2. establishment of National Lifeline Engineering,
3. establishment of Urban Search and Rescue (USAR),
4. implementation of tsunami mitigation measures, and
5. adoption and evolution of procedures for emergency building management, as used post the New Zealand earthquakes of 2007 Gisborne, 2010 Darfield, 2011 Christchurch, 2013 Cook Strait and Grassmere, and 2016 Kaikoura.

Similar programmes of learning from earthquakes have operated in various forms in many other countries, including the United Kingdom, Italy, Greece, Japan, Australia, China, Taipei, Thailand, Mexico, Chile, Peru, Turkey, India, Pakistan, and Nepal. Government agencies with responsibilities for risk reduction and research and development have funded and participated in learning from earthquakes missions, e.g. NSF, FEMA, and USGS in the U.S.A., EQC, MBIE, GNS Science, and MCDDEM in New Zealand.

National Professional Societies, many with multinational memberships, are the predominant umbrella organisations for learning from earthquakes programmes, including:

1. ACHISINA Chilean Association on Seismology and Earthquake Engineering – <http://www.achisina.cl/>
2. AEES Australian Earthquake Engineering Society – <http://www.aees.org.au/>
3. ANIDIS Italian National Association for Earthquake Engineering – <http://www.anidis.it/>
4. ASCE-IRD American Society for Civil Engineering Infrastructure Resilience Division, incorporating the former Technical Council on Lifeline Earthquake Engineering (TCLEE) – <http://www.asce.org/infrastructure-resilience/infrastructure-resilience-division/>
5. CAEE Canadian Association for Earthquake Engineering – <http://caee.ca/>
6. EEFIT Earthquake Engineering Field Investigation Team, UK – <http://www.eefit.org.uk/>

7. EERI Earthquake Engineering Research Institute, U.S. – <http://www.eeri.org/>
8. GEER The Geotechnical Extreme Events Reconnaissance Association – <http://www.geerassociation.org/>
9. JAEE Japanese Association for Earthquake Engineering – <http://www.jaee.gr.jp/>
10. JGS Japanese Geotechnical Society – <http://www.jiban.or.jp>
11. Japan Building Disaster Prevention Association - <http://www.kenchiku-bosai.or.jp/english/index.html>
12. NZSEE New Zealand Society for Earthquake Engineering – <http://www.nzsee.org.nz/>

2.1 Post-earthquake guidance

Post earthquake guidance publications, addressing response and recovery, have followed. Following from post-earthquake experiences and observations, Italy developed the European Field Manual for post-earthquake damage and safety assessment and short term countermeasures which has been revised following successive earthquake experiences. The latest version in English is AeDES; EUR 22868, 2002 (with building usability shown by three placard colours of Red, Yellow, Green); the more recent version (with four placard colours of Purple, Red, Yellow, Green) is only available in Italian.

The U.S. has published a plan to coordinate NEHRP Post-Earthquake Investigations (Holzer, et. al., 2002),

Careful documentation of earthquake effects is essential to improve prediction and mapping of seismic hazards, to design safer engineered structures, to refine loss modeling, and to formulate better public policy. Nevertheless, post-earthquake investigations typically are conducted with little coordination among a diverse range of professional specialists because damaging earthquakes are infrequent. Recently the U.S. National Earthquake Hazards Program (NEHRP) developed a Plan to coordinate technical post-earthquake investigations. The Plan requires that the NEHRP agencies and their partners convene immediately after a significant earthquake and decide whether or not to formally implement the Plan. Upon implementation, a physical technical information clearinghouse and web site are established to coordinate the immediate post-earthquake reconnaissance (Phase I). All field investigators regardless of affiliation are encouraged to work within the clearinghouse. The Plan requires that a NEHRP Investigations Coordinator (NIC) be appointed within 24 hours to oversee the coordination, to establish long-term research priorities, and to ensure appropriate liaison with emergency managers. The NIC also has the responsibility to convene a meeting at the conclusion of the reconnaissance to establish priorities for substantive collection of perishable data by NEHRP funded investigators (Phase II). In about one month after the event, the Plan calls for a workshop to establish priorities for long-term research to be funded by NEHRP agencies (Phase III). The Plan also recognized that more systematic collection and archiving of observations from post-earthquake investigations are needed in the United States, particularly with regards to damage and loss data.

The Plan recognizes that a fundamental tenet of emergency management is that the execution of a plan is as important as the plan itself. Thus, upon completion of the Plan, three exercises were conducted with “surprise” earthquake scenarios to familiarize the NEHRP agencies with the Plan. In the likely absence of frequent opportunities to implement the Plan, an annual review of the Plan was also recommended to maintain institutional familiarity with it and to ensure it is up to date (Holzer 2008).

In 2013 NIST proposed to revise the NEHRP Plan for post-earthquake investigation (NEHRP Consultants Joint Venture, 2013). However a revised plan is not yet evident.

The Applied Technology Council (ATC) has published and revised the ATC-20 suite of publications on post earthquake procedures for the evaluation of buildings (ATC, 1989-2005; with building usability shown by three placard colours of Red, Yellow, Green), first used following the Loma Prieta earthquake (when it was noted by a NZSEE LFE mission and brought back to New Zealand). ATC has adopted and

promotes the Indicator Building concept that an ATC Learning from Earthquakes team learnt of in Christchurch in 2011.

GEER maintains and provides reconnaissance tools, including the GEER Reconnaissance Manual (2014). An introduction to GEER is available from Bray et al (2015) and from - <http://www.geerassociation.org/>

Earthquake experiences and observations have also informed US guidance published by FEMA, NIST, USGS, CalEMA, and Structural Engineers Association of California (SEAOC).

Japan implemented post-earthquake building inspection procedures in 1995 (with building usability shown by three placard colours of Red, Yellow, Green). The Ministry of Construction, local governments and private construction organizations cooperated with each other to implement the quick inspection of damaged buildings for the first time following the Great Hanshin-Awaji (Kobe) Earthquake. Some 46,610 buildings were inspected. The Japan Building Disaster Prevention Association maintains the “Postearthquake Quick Inspection of Damaged Buildings”, first published in 1990, and revised in 2001, and 2016. It is published in Japanese. An explanation in English is available at - <http://www.kenchiku-bosai.or.jp/files/2013/11/epanfall.pdf>

New Zealand has published the Earthquake Reconnaissance Manual (NZSEE, 2000); Building Safety Evaluation in a State of Emergency: Guidelines for Territorial Authorities (NZSEE, 2009); the report of The Canterbury Earthquakes Royal Commission of inquiry, and following a recommendation of the Canterbury Earthquakes Royal Commission of Inquiry, Post Disaster Building Management guidance (MBIE, 2014).

The Canterbury Earthquakes Royal Commission of inquiry was an in-depth inquiry that addressed, documented, and made recommendations following significant learning’s from the Canterbury earthquakes sequence. The Royal Commission was established to report on the causes of building failure as a result of the 2010-2011 earthquakes as well as the legal and best-practice requirements for buildings in New Zealand Central Business Districts (See more at: <http://canterbury.royalcommission.govt.nz/#sthash.sdh4lPkZ.dpuf>).

The Commission reported on building management after earthquakes in Section 2 of Volume 7 - <http://canterbury.royalcommission.govt.nz/Final-Report-Volume-Seven-Contents> . The Commission’s work was informed by a report they required of NZSEE (Brunsdon, 2011).

Government has responded to the Commissions’ recommendations as summarised in its report (MBIE 2017) where the Minister of Building and Construction is quoted:

“While significant progress has been made to improve our buildings following the events in Canterbury, we cannot afford to be complacent about earthquakes and the devastation they can cause our communities. The changes made today will improve their safety so fewer families will face the loss of a loved one, and cities and towns will remain resilient into the future.”

“The Canterbury experience has provided a much greater national awareness of resilience. While the social and economic consequences have been significant and tragic, it has presented an opportunity and a responsibility to learn from the earthquake sequence; to improve processes responding to emergencies, to improve our understanding of building and land performance in rare events, and to review the structure of the building sector. By setting up the Royal Commission and instructing MBIE, (then the Department of Building and Housing) to investigate specific building failures in mid-2011, the New Zealand Government provided this opportunity. Indeed, it strongly signalled our responsibility to those who have experienced loss to make sure lessons are learned and improvements made to decision making processes and in the way buildings are designed and constructed. Many of the developments are a step-change in how building regulation will monitor and improve building performance in the future, through a combination of better informed, skilled and collaborative design teams.”

2.2 International responses to the Canterbury 2010-2012 earthquakes and other deployments

The international *Learning from Earthquakes* and *USAR* responses to the 2010 – 2012 Canterbury earthquakes, particularly Darfield 4 Sep 2010 and Christchurch 22 Feb 2011, were significant, with

participants from some five countries joining and augmenting local New Zealand responders to help in search and rescue and also to assess: building usability; liquefaction impacts; rockfall risks; lifeline utility status; emergency services functions such as health care; and monitoring social media for impact information sharing.

Physical and virtual clearing houses significantly aided the collaborations, information sharing, and emergency management. Following the Darfield earthquake, a physical clearing house that became known as *The Canterbury Technical Forum* was initiated by GNS Science and NZSEE. Under the leadership of Dr Bruce Deam the Forum ran for six years, the initial need being further stimulated by the 2011 Christchurch earthquake and the Canterbury earthquake sequence. The Forum was attended by up to 300 engineers, academics, local and central government personnel, and international peers. While initially a venue for sharing information on impacts, it developed into briefings on the evolving management of both earthquake damaged buildings and ground. Several relevant international participants contributed to the collective learning's, many of which have aided the Greater Christchurch recovery management. However, the National Controller for the State of National Emergency that resulted following the Christchurch earthquake (John Hamilton) has noted that while the Canterbury Technical Forum was invaluable, the information aired at it could have been better communicated to those managing the emergency (Hamilton, in press).

Other recent significant earthquakes of 2014-2016 in California, Chile, Nepal, and Kaikoura New Zealand have continued the evolution of *International Learning from Earthquakes* collaborations and information sharing, increasingly using public web services and social media and with the attendant increases in privacy and security dimensions yet to be fully and collectively addressed.

2.3 An international LFE framework - the Sendai Declaration for Disaster Risk Reduction

The Sendai Declaration is relevant to objectives of LFE. The Sendai Declaration was agreed to by the Heads of State and Government at the third UN World Conference on Disaster Risk Reduction (WCDRR) in Sendai, Japan, in March 2015. New Zealand was represented by a delegation led by the Canterbury Earthquake Recovery Minister and Minister Responsible for the Earthquake Commission, Hon Gerry Brownlee.

The Sendai Declaration is implemented through the Framework for Disaster Risk Reduction 2015-2030 (UN ISDR 2015), endorsed by the UN General Assembly. The framework will apply to the risk of small-scale and large-scale, frequent and infrequent, sudden and slow-onset disasters, caused by natural or manmade hazards as well as related environmental, technological and biological hazards and risks. It aims to guide the multi-hazard management of disaster risk in development at all levels as well as within and across all sectors.

The Sendai Framework has four priorities for action to reduce existing disaster risks and to prevent new ones:

1. Understanding disaster risk;
2. Strengthening disaster risk governance to manage disaster risk;
3. Investing in disaster reduction for resilience; and
4. Enhancing disaster preparedness for effective response and to “Build Back Better” in recovery, rehabilitation and reconstruction.

Past and current *International Learning from Earthquakes* actions address all four of the Sendai 2015 Framework priorities, as they relate to earthquake disaster risk. However, the strategic, tactical, and operational aspects of *International Learning from Earthquakes* programmes can be and have been applied to other hazard events, such as tsunamis, landslides, and volcanic eruptions.

2.4 International Learning from Earthquakes Developments

International collaborations are an increasing trend in LFE missions. In recent decades LFE teams from different organisations and countries have deployed their own independent missions, with or without agreement from the impacted country. Physical Clearing Houses in the affected area have often provided excellent opportunities to share information on the state of understanding of impacts and the emergency

arrangements. Increasingly, collective International LFE teams have provided consolidated briefings to government officials and authorities of the impacted country. Post earthquake conferences and meetings typically have international participants.

EERI has used its extensive International membership to access in-country information on earthquake impacts, as has GEER and NZSEE but to a lesser extent given their smaller International membership. In some recent earthquakes EERI has had sufficient members' in-country to provide information to the EERI Virtual Clearing Houses, reducing the need for international deployment of a dedicated mission.

Increasingly, LFE missions recognise the need to improve collaborations and standards in data collection and sharing (Comerio et al 2003; NEHERP Consultants Joint Venture 2013). Three International workshops have been held for this purpose, in 2012, 2014, and 2016.

2.4.1 2012 Oakland Learning from Earthquakes Workshop

EERI and EFIT convened an International Workshop on *Learning from Earthquakes* in Oakland, 2-3 August 2012. Invited attendees were from USA (EERI, GEER, and TCLEE), UK (EFIT), Australia (Geosciences Australia), and New Zealand (NZSEE, GNS Science). The workshop had a focus on International collaboration and technologies for post earthquake data capture.

2.4.2 2014 Anchorage workshop on post-earthquake data collection

EERI and the University of British Columbia (K. Elwood & S. Chang) convened an International Workshop on post-earthquake data collection in Anchorage, 20-22 July 2014. Attendees were invited from USA, Canada, Italy, Chile, New Zealand, Japan, and the UK.

The workshop addressed data collection practices from recent earthquakes in Italy, Chile, Japan, and New Zealand, and explored the development of consensus-based data collection protocols. The scope of the workshop was limited to building structures, but types of data included both physical damage and socio-economic impacts.

The workshop noted potential benefits of pre-earthquake data for post earthquake comparisons (including identifying "Indicator" buildings) and the value in recording "no damage" as well as "damage".

The workshop concluded and resolved "Empirical evidence from past earthquakes, documented through standardized collection of data, is essential to understanding and improving community resilience to earthquake disasters. The participants involved in this workshop are dedicated to reducing earthquake risk and increasing resilience of communities to future earthquakes by enhancing and improving the practice of pre- and post-earthquake data collection worldwide".

The 2014 workshop is documented under - <https://www.eeri.org/projects/learning-from-earthquakes-lfe/eq-data-collection/> and summarised at - <https://www.eeri.org/wp-content/uploads/Executive-Summary-FINAL-2015-01-21.pdf>

2.4.3 2016 Christchurch Third International Learning from Earthquakes Workshop

NZSEE and EERI convened the 31 March 2016 Christchurch Third International Learning from Earthquakes workshop to further advance international post disaster collaborations and build on the 2012 and 2014 initiatives.

Panellists were invited from the USA, Canada, Italy, Chile, the UK, Japan, Australia, and New Zealand via invitations to EERI, EFIT, AEES, NZSEE, GEM, UNOCHA, and to national agencies such as USGS, Emergency Management Australia, Geoscience Australia, South Pacific Engineers Association (SPEA), as well as New Zealand agencies (MBIE, EQC, MCDEM, LINZ, LandCare, and GNS Science). Some relevant parties were overlooked, including GEER, and the workshop was the poorer for their absence. On the day, some 30 panellists and 20 observers participated, from the USA, Canada, Italy, Chile, the UK, Australia, and New Zealand. A Nepal perspective on earthquake impact management issues for developing countries was also presented.

The objective was to gather experienced international practitioners to explore and document how a LFE

response, that includes domestic and international parties, can best be integrated into and inform, and be informed by, other response elements, such as the local emergency management authorities (LEMA), and better utilisation of evolving geospatial data collection and management, remote sensing technologies, and of social media, within the local Sendai Framework for Disaster Risk Reduction.

The workshop outcome was to increase integration of international LFE actors into and informing of, and by, other response and recovery elements, such as the local emergency management authorities (LEMA) and building and infrastructure managers; efficient and effective data and information management and exchange were shown to be fundamental.

For New Zealand, the workshop outcome was expected to lead to actively enhanced integration and support of the proposed new response provisions of the NZ Building Act for emergency building management (MBIE, 2014), also new arrangements post-the Canterbury Earthquakes Royal Commission (2012), the Emergency Management review and the review of the EQC Act, as well as existing emergency services and Civil Defence Emergency Management arrangements, including those of the 2015 National Civil Defence Emergency Management Plan (NZ Government 2015). For other countries, it was expected there will be enhancement of their response under their LEMA frameworks. For all workshop participants, future LFE deployments were expected to be better integrated within the Sendai Framework for Disaster Risk Reduction and with the attendant actors.

3 PRESENT LEARNINGS FROM EARTHQUAKES

3.1 Earthquakes of note

1. L'Aquila, Italy
2. Maule, Chile
3. Christchurch, New Zealand
4. Tokohu, Japan
5. Cook Strait and Lake Grassmere, New Zealand
6. Napa, California, USA
7. Ghorkha, Nepal
8. Central Italy
9. Kaikoura, New Zealand

3.2 New Lessons

Earthquake information networks, so much is now virtual, but people and their networks still matter and people are both key to LFE and also benefactors.

Clearing houses are strategically and operational important, both physical and virtual.

3.2.1 Physical Clearing Houses

In opening the 2016 Third International LFE workshop and in reference to the Canterbury Technical Forum – John Hamilton, former National Controller during the Christchurch earthquake State of National Emergency, noted:

“One of the big challenges in trying to make sense out of the wealth of data and information that is available in the response, is finding a way to ensure that what is plotted and acted on, is valid and reliable. The “clearing house” ... was an innovative and successful endeavour to share knowledge and information among the experts in an effort to provide cohesion and get closer to a single point of truth. The system lasted for over five years having been started just after the 2010 Darfield earthquake. ... I believe the clearing house was successful in achieving its goals, but perhaps its full potential was not realised because of limited and irregular communications to the Controller and weakness in getting the advice to the decision-makers.

The clearing house concept deserves further development, which could include establishing clear terms of reference to state its purpose and who it serves. It should have a statement of the principles under which it would operate and enable those taking part in it and their parent organisations to accept the conditions and acknowledge they are prepared to collaborate and share. In this way the concept should be incorporated as a regular feature of managing the more complex emergencies. Establishing the clearing house concept should probably be something for the Ministry of Civil Defence & Emergency Management to lead assisted by the science and hazards cluster.”

Lake Grassmere: one Clearing house meeting

Napa: A Clearing house; innovate uses of drone and Terrestrial LiDAR

Kaikoura: Technical Clearing house; interactions between EERI, GEER, GNS, T+T, etc;

3.2.2 *Virtual Clearing Houses*

Darfield and Christchurch “Clearing Estates”, a loss of focus through diffusion;

Napa, California, an EERI clearing house and webinar;

Gorkha, Nepal, an EERI clearing house and webinar;

Kaikoura – NZSEE supported an EERI clearing house - <http://www.eqclearinghouse.org/2016-11-13-kaikoura/>

The newest LFE virtual clearing house development may be that at - <https://www.designsafe-ci.org/rw/reconnaissance/>

3.3 **Evolving technologies**

Remote sensing: satellite radar dINSAR; High resolution digital imaging and virtual realities; Terrestrial and airborne LiDAR;

Sensor platforms: satellite; fixed wing and helicopters; drones; CCTV and other video surveillance, e.g. demolition in Wellington after the Kaikoura earthquake - <https://youtu.be/r-jhOYhVXUQ> e.g. floor failures during demolition - https://youtu.be/KSHV_q5UiWw?t=49

Image analysis: differencing – before v after (Christchurch, repeated LiDAR)

Structural health monitoring: e.g. BNZ Centre and Kaikoura earthquake - Response of Instrumented Buildings in Wellington in Kaikoura Earthquake, e.g. [response-of-instrumented-wellington-buildings nzsee](https://www.nzsee.org.nz/research/updates/2016/01/response-of-instrumented-wellington-buildings-nzsee)

- Animation of the recorded displacement history of the BNZ building [here](#).
- Animation of the recorded displacement history of the Wellington Regional Hospital [here](#)

Mobile phone applications – e.g. ‘GeoNet Quake’ - <http://info.geonet.org.nz/display/home/Information+at+your+fingertips>

3.4 **Dynamic funding environments**

NZSEE LFE activities are fortunate to have been financially supported by stable funders (EQC, and since 1990 DBH, now MBIE). In the UK funding has been stable from NERC and commercial sponsors including the insurance industry. However, in the US there has been an increasingly dynamic funding environment. NSF, NEHERP, RAPID, and World Bank, with a requirement for increasingly agile and rapid proposal writers and responders.

4 **FUTURE LEARNINGS FROM EARTHQUAKES**

To address future learning’s from earthquakes, in 2002, the Earthquake Engineering Research Institute hosted an invitational workshop with 70 experts in the fields of earthquake engineering, earth sciences, and the social and policy sciences, to identify the major issues in developing an Action Plan for an

earthquake damage and loss data collection and management framework. The need for such a workshop grew out of EERI's Learning from Earthquakes Program, supported by the National Science Foundation. The Preface to the workshop report (Comerio et al 2003) reads:

“Under EERI's Learning from Earthquakes Program, rapid changes in information technology are allowing participants to consider electronic data collection and storage in a much more systematic manner. It was intended that workshop participants would identify an Action Plan that would define a schedule and the needed resources and steps to establish a more systematic database within the next five years. It was expected that workshop participants would make recommendations for lead agency responsibilities, clarify data collection and access issues, identify training needs, and detail maintenance and repository concerns. However, once at the workshop it became apparent that developing such an Action Plan is more complicated process than originally thought. Workshop participants did not want to limit the discussion to post-earthquake data collection. Instead, the group (which represents a diverse range of disciplines and experience), wanted to expand the discussion to include the broad range of data needed to study and learn from earthquakes. These include pre-earthquake conditions and building inventories, post-earthquake damage assessments, human impacts, social and economic conditions before and after the event, and long term recovery issues. The group not only expanded the kind of data to be discussed, they also reviewed the time frame for data collection and the mechanisms for sharing and archiving data for future research. Given the expanded scope, this report [Comerio et al 2013] has evolved from an “Action Plan” to a document which defines the issues for an action plan. This document lays out a broad approach to understanding earthquake data issues that should ultimately result in a much stronger and more effective set of action plans.” (Comerio et al 2003)

The above from 2002 is highly relevant to LFE today, in 2017. It emphasises the importance of information, from before and after an earthquake (or other hazard impact), and the breadth of that information and of timeframes. It also implicitly illustrates the need for data collection standards and protocols, as well as access to pre- and post- earthquake information, across the natural social, built, and economic environments, in addition to the dynamics of mixed LFE response initiatives.

Additional to information requirements, future LFE objectives can be expected to be addressed by a diversity of professionals, including researchers; not all of whom will associate with traditional LFE organisations such as NZSEE, AEES, EEFIT, and EERI. Increasingly, government agencies, private enterprise, and academia are standing up and actively and collaboratively participating in LFE objectives, across the natural social, built, and economic environments.

Governments are the major beneficiaries of LFE programmes, as proxies for their citizens. Yet there is a need for independent voices, as from professional societies such as IPENZ, RSNZ, and NZSEE to help communicate public opinion when that differs from political or commercial agendas.

5 CONCLUSION

Learning from earthquakes has a long history.

Lessons learnt have brought benefits to social, economic, and built environments that have been significant.

In spite of past lessons learnt from earthquakes and the significant benefits, each significant new earthquake results in new losses, variously of people, business continuity, infrastructure, and buildings, with new lessons to be learnt.

The earthquakes of Maule (Chile), Darfield and Christchurch (New Zealand), Tohoku (Japan), Napa (California), Gorkha (Nepal), and others, all had lessons for New Zealand. How well those, and earlier lessons, have been implemented will be evident in New Zealand's next significant earthquake (or other hazard event).

The communication of evidence that defines lessons and of the implementation of learning's still appears fragmented in New Zealand. The linkages between earthquake engineers and scientists with the regulators, property managers, and insurance industry, while strong, are not open – are not in the public

domain. Yet, the public of New Zealand has never been so receptive to earthquake information.

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