INFRASTRUCTURE RESILIENCE PUBLICATION NO. 4

LIFELINES 2022

1971 SAN FERNANDO EARTHQUAKE AND LIFELINE INFRASTRUCTURE

SELECTED PAPERS FROM THE LIFELINES 2022 CONFERENCE

January 31–February 11, 2022

SPONSORED BY
University of California Los Angeles

Infrastructure Resilience Division of the
American Society of Civil Engineers

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ASCE AMERICAN SOCIETY OF CIVIL ENGINEERS

Published by American Society of Civil Engineers
1801 Alexander Bell Drive
Reston, Virginia, 20191-4382
www.asce.org/publications | ascelibrary.org

Errata: **Errata, if any, can be found at https://doi.org/10.1061/9780784484432**

ISBN 978-0-7844-8443-2 (PDF)
Manufactured in the United States of America.

Front cover: Photograph courtesy of the United States Geologic Survey.

Preface

There has been a half a century of progress in lifeline earthquake engineering since its inception as a primary field of practice following the February 9, 1971 San Fernando Earthquake in Los Angeles, California. This was a devastating yet seminal event, which, for the first time, demonstrated the extent of seismic threats to lifeline systems, which critically support our modern communities. Knowledge gained from this event initiated the study of lifelines, including water, wastewater, electric power, gas and liquid fuels, communications, transportation, and solid waste management systems. The founding efforts of the ASCE Technical Council on Lifeline Earthquake Engineering, a predecessor unit to the current ASCE Infrastructure Resilience Division (IRD), by international leaders like the late Charles Martin Duke from the University of California, Los Angeles (UCLA) established lifelines engineering into a mainstream discipline, which over time, has been applied worldwide and extended to address additional hazards beyond earthquakes.

To celebrate the advances that lifelines engineering made since the landmark 1971 seismic event, the ASCE Infrastructure Resilience Division (IRD) and The University of California, Los Angeles (UCLA) entered into a partnership in 2018 to organize and host the San Fernando Earthquake Conference – 50 years of Lifeline Engineering (Lifelines2021) in February 2021, focusing on "Understanding, Improving & Operationalizing Hazard Resilience for Lifeline Systems." However, impacts from the COVID-19 pandemic required the conference to be delayed to February 2022 (Lifelines2021-22). Nevertheless, Lifelines2021-22 conference activities were still launched on February 9, 2021, with a webinar commemorating the 50th Anniversary of the San Fernando Earthquake. Prior to the in-person conference during February 1-3, 2022, at UCLA, the conference held several on-line activities throughout the 2021 calendar year related to the conference theme. Also, a book[1] of abstracts featuring more than 300 contributions, submitted and accepted to the conference was compiled.

The present volume features 155 technical articles and is published as the proceedings of the Lifelines 2021-2022 conference by ASCE. Each article appearing in the proceedings was reviewed by at least two experts and went through revisions, as needed, before acceptance. As further elaborated in what follows, they address the full spectrum of technical areas pertinent to lifelines engineering, ranging from hazard characterization to risk and resilience quantification, governance and management, and socioeconomic impacts of loss of functionality. The volume, as such, is a snapshot of state-of-the-art and practice lifelines engineering, as well as new research directions that are forming within the community due to recent advances along multiple fronts including sensor technologies, high-performance computing, and artificial intelligence.

[1]Davis, C. A., K. Yu, and E. Taciroglu (2021). San Fernando Earthquake Conference - 50 years of Lifeline Engineering: Book of Abstracts, Lifelines2021-22, University of California Los Angeles Natural Hazards Risk and Resiliency Center Report No. GIRS-2021-05, Version 1, March 22, 2021, doi:10.34948/N3QP4X, https://doi.org/10.34948/N3QP4X.

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Introduction

The ASCE Lifelines Conference 2021-2022 was initially scheduled to be held in Los Angeles, California, in 2021 on the 50th anniversary year of the February 9, 1971, San Fernando Earthquake. Due to the COVID pandemic. The conference was delayed to 2022 but did have a kick-off event on February 9, 2021. The San Fernando Earthquake was a moderate earthquake event, but it caused significant damage to transportation and utility systems. In 1972, the late Professor Charles Martin Duke of the University of California, Los Angeles (who also served as the President of the Earthquake Engineering Research Institute) introduced "lifelines" as a new term to replace "support systems" that had commonly been used to describe transportation and utility systems by earthquake professionals at that time. "Lifelines" was intended to properly capture and elevate the criticality of transportation and utility systems to a modern society. He envisioned integrating both professional and government solutions to address the then-low state-of-the-art of lifeline earthquake engineering, hoping to leverage the San Fernando Earthquake to spur improvement for seismic performance of lifelines, just like how the 1933 Long Beach, California Earthquake transformed the seismic design provisions for buildings. Professor Duke envisioned how professional solutions would be developed leveraging the collective efforts of professional societies, universities, industry associations, and individual operating agencies. These professional solutions would serve as the foundation for a variety of potential governmental solutions (or regulations). Inspired by how the Structural Engineers Association of California (SEAOC) improved seismic performance of buildings in the time since the 1933 Long Beach, California earthquake, he initiated a vision of creating a professional organization that would play a leading role for lifelines at a national level in the U.S. After much planning and preparation work by a core group of professionals who shared the same vision as Professor Duke, the ASCE Technical Council on Lifeline Earthquake Engineering (TCLEE) was officially established in 1974 to carry out the responsibility for the professional solutions to elevate the state-of-the-art of lifeline earthquake engineering and sustain progress in the field over generations. The notion of "lifeline earthquake engineering" (as a subset of Earthquake Engineering) also resonated broadly with international researchers, initiating research and technical development for lifelines worldwide. This has also resulted in much fruitful international collaboration with many earthquake-prone countries, including Japan, New Zealand, China, and Italy, in the decades following the establishment of ASCE TCLEE and leading up to this conference.

In 1975, Professor Duke envisioned a reasonably ambitious long-term goal for lifeline earthquake engineering – development of a comprehensive set of seismic design standards and criteria of lifelines and institutionalization of lifeline earthquake engineering within 20 years after the San Fernando Earthquake. As part of his government solution, he called for establishing a national lifeline/earthquake research and development laboratory and enacting special state and/or federal legislation to provide funds for supporting lifeline research. In 1977, U.S. Congress passed the Earthquake Hazards Reduction Act, establishing the National Earthquake Hazards Reduction Program in 1978. This set the stage for the subsequent creation of key institutions, including a national earthquake engineering research center, to help move forward the field of lifeline earthquake engineering. In addition to advancing the state-of-the-art practice of lifeline engineering through its members, ASCE TCLEE became a major participant in government solutions. In 1985, FEMA commissioned the Building Seismic Safety Council of the National Institute of Building Sciences to develop a plan for abating seismic hazards to lifelines. ASCE

TCLEE members made significant contributions to the plan and helped FEMA conclude that abating the risks to lifelines from earthquakes and other hazards is best approached by a nationally coordinated and structured program. The NEHRP Re-authorization Act of 1990 required FEMA—with the support of NIST—to establish a detailed plan for developing and adopting seismic design standards for lifelines. Leveraging the knowledge and practice of lifeline earthquake engineering developed over the two decades after the 1971 San Fernando Earthquake, ASCE TCLEE members, especially Ronald T. Eguchi, then Chair of ASCE TCLEE, played instrumental roles in assisting FEMA and NIST to develop the plan, focusing on improving system-level functionality of lifelines. Following some of the recommendations in the plan, FEMA funded the American Lifelines Alliance (ALA) in 1998, a public-private partnership first managed by ASCE (1998-2001) and later by the Multi-hazard Mitigation Council of the National Institute of Building Sciences (2002-2005), to facilitate development, adoption, and implementation of design and retrofit guidelines to improve the performance of lifeline systems in the event of natural hazards. Following the terrorist attacks on September 11, 2001, the scope of ALA was expanded to include man-made threats. ALA successfully created more than a dozen design and/or assessment guidelines related to electric power, oil, natural gas, water, and wastewater systems before it dissolved in 2005 due to shifts in hazard priorities and funding cuts in the NEHRP budget.

There have been several significant developments during the past two decades. ASCE TCLEE used to focus on the response of lifelines to only earthquakes. Over time, it has slowly moved into the multi-hazard space, as evidenced by its investigation of transportation systems during the 2005 Hurricane Katrina and its investigation of lifeline system performance during the 2007 Pacific Northwest Storm. Another major development is related to community resilience. In 2008, the San Francisco Planning and Urban Research Association (SPUR) started a multi-year initiative called the Resilient City to ensure San Francisco can recover rapidly following earthquakes to meet the social and economic needs of community members. From 2010 to 2012, the State of Oregon and the State of Washington used the methodology of the Resilient City initiative to develop state-wide 50-year resilience plans to prepare for a future CSZ earthquake and tsunami. Numerous ASCE TCLEE members assisted both states in estimating expected seismic performance and recovery time for each lifeline system and developing recommendations to close resilience gaps. During the same time, NEHRP agencies, the National Research Council, and Presidential Policy Directive 21 were calling for the improvement of buildings and lifeline systems to achieve community resilience. In 2012, NIST, with the assistance and participation of many ASCE TCLEE members, started to develop a 10-year research, development, and implementation roadmap for producing new model earthquake-resilient design and construction standards for key lifeline systems and components. To respond to this call for resilience at local, state, and national levels, the ASCE Committee on Technical Advancement (CTA) formed a Working Group in March 2014 to develop a new technical division concentrating on infrastructure resilience. From this Working Group, the Infrastructure Resilience Division (IRD) was formed through the merging of three existing ASCE units: the Committee on Critical Infrastructure (CCI), Council on Disaster Risk Management (CDRM), and Technical Council on Lifeline Earthquake Engineering (TCLEE). The IRD charter was formally approved by the ASCE Board of Direction at its January 2015 meeting. In 2018, Congress re-authorized NEHRP, with a new emphasis on functional recovery of the built environment to support community resilience. As part of the re-authorization, Congress asked FEMA and NIST to develop options to improve the built environment for post-earthquake functional recovery times. Several ASCE IRD members contributed to the development of recommendations that were included in a report titled Recommended Options for Improving the

Built Environment for Post-Earthquake Reoccupancy and Functional Recovery Time. In January 2021, one month before the 50th Anniversary of the 1971 San Fernando Earthquake, FEMA and NIST submitted the report to Congress.

Over the past fifty years, we have made significant progress in improving the seismic performance of the lifeline infrastructure systems. However, there remains a lot of work to do to realize the long-term goal set by the late Professor Duke in 1975. The 50th Anniversary of the San Fernando Earthquake is an opportunity to reflect on the need to increase the resilience of our critical infrastructure systems to earthquakes and other hazards. As a result, the theme for the Lifelines 2021-2022 is **Understanding, Improving, and Operationalizing Hazard Resilience for Lifelines**. The conference goals are to:

- provide a retrospective of where we are today and how we got here
- help define a global vision for where we are going to create resilient infrastructure systems within interdisciplinary and multi-hazard environments which support community and regional resilience.

As such, the technical program of the conference was organized with seven topics, including (1) The 1971 San Fernando Earthquake, (2) Hazards, (3) Lifeline Infrastructure Systems, (4) Post-event Investigations and Longitudinal Studies, (5) Community Resilience, (6) Emerging and Advanced Technologies, and (7) Policy and Governance.

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