

Modeling of Fire Following Earthquakes

Selina W. Lee

Civil Infrastructure Systems
School of Civil & Environmental Engineering, Cornell University



ABSTRACT

Within a simulation framework, this model will incorporate all three phases of fire following earthquake (FFE), which are fire ignition, spread, and suppression. Using cellular automaton, the fire spread module will provide probabilistic estimates of the total burnt area. Fire spread due to radiation, convection, conduction and branding, represented by transition rules, determine a cell's neighborhood function. By representing a fire department's emergency response procedure with discrete event simulation, a department's explicit decision variables are considered. This new method will incorporate recent MCEER models of post-earthquake water supply and electric power restoration and transportation system risk to provide a more realistic simulation of actual events.

BACKGROUND

The 1906 San Francisco earthquake (M8.3) destroyed approximately 28,000 buildings, and out of a population of 340,000, left 200,000 homeless and 700 dead (NFPA 1991). In the 1994 Northridge earthquake (M6.7), 110 earthquake related-fires were reported in the time between 4:31 am (time of main shock) and midnight (Scawthorn et al. 1998). An estimated 400 deaths and damage to 6,900 buildings within an area of approximately 0.25 square miles were attributed to fires following the Kobe earthquake (NFPA 1995). As demonstrated by history, social and economic damages due to fires following earthquakes have caused tremendous harm to seismically-active cities with large inventories of wooden structures all over the world. They pose a serious problem because many fires occur simultaneously at a time when fire suppression capabilities are diminished. Fire engines may be less able to maneuver on a damaged transportation network, and fire fighters may be less able to coordinate due to damaged communications systems and less able to fight fires with a damaged water supply system.



1906 San Francisco EQ
(Museum of the City of SF)



1923 Tokyo EQ
(J. B. Macelwane Archives,
Saint Louis University)



1995 Kobe EQ (EERI)

OBJECTIVES

The objectives of this research are to:

- **Develop an FFE computer simulation model.**
Programmed in C++, this simulation incorporates the three main phases of FFE—fire ignition, spread and suppression. The model will use cellular automata to model spread, discrete event simulation to model suppression, and GIS for data compilation and display. It will incorporate uncertainty and output from MCEER water supply, electric power, and transportation models. The anticipated output of the FFE model is the area burned by general usage category (e.g., single-family residential, commercial), including estimates of uncertainty, and information about fire fighting resources used.
- **Apply this FFE model to Los Angeles, California.**
This includes calibrating the model with Northridge earthquake data, conducting sensitivity analyses to evaluate the model's robustness given data uncertainty, assessing the FFE risk for Los Angeles by applying the model for a suite of earthquakes selected by MCEER investigators to represent the regional seismicity of Los Angeles, and using the model to evaluate the effectiveness of various FFE loss reduction strategies.

REFERENCES

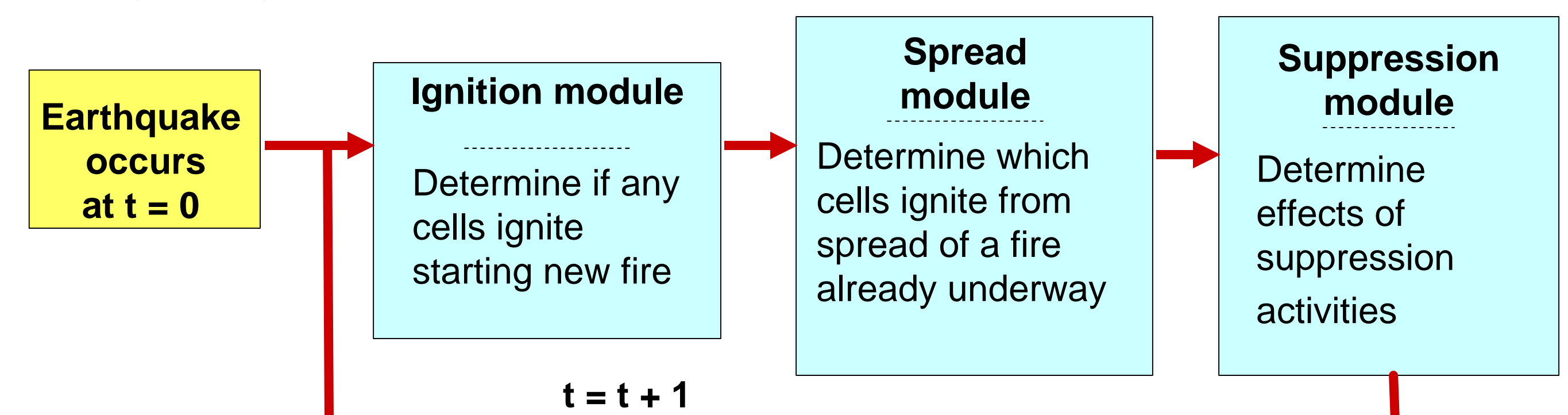
- National Fire Protection Agency (NFPA), 1991. *The Loma Prieta (San Francisco/Monterey Bay) Earthquake Emergency Response and Stabilization Study*, Quincy, Massachusetts.
- National Fire Protection Agency (NFPA), 1995. *Earthquake Fire, Kobe, Japan, January 17, 1995*, Quincy, Massachusetts.
- Scawthorn, C., Cowell, A.D., and F. Borden, 1998. *Fire-related aspects of the Northridge earthquake*, National Institute of Standards and Technology, Gaithersburg, Maryland

EXPECTED SIGNIFICANCE

There are three main academic and societal contributions of this research:

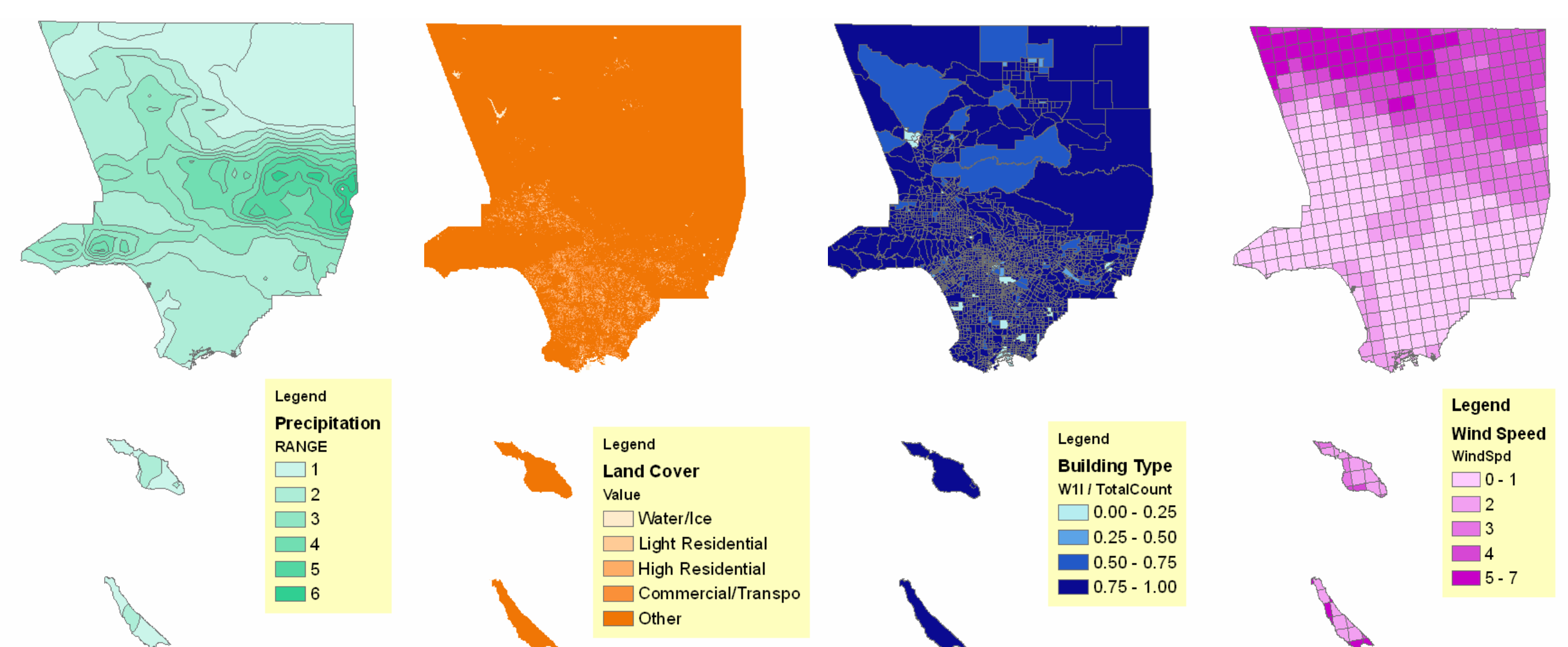
- **Advance the state-of-the-art in FFE modeling.**
The state-of-the-art will be advanced by the application of cellular automaton for modeling fire spread to produce probabilistic estimates of the total burnt area, application of discrete event simulation for modeling a fire department's emergency response procedure to explicitly representing their decision variables and incorporation of MCEER lifeline results of electric power restoration, water supply damage and transportation delays.
- **Improve estimation of FFE losses as part of a larger MCEER effort.**
By using MCEER results, which provide better estimates of actual lifeline damage after an earthquake in Los Angeles, improved estimates of FFE losses will result. This information will help city planners who need to design fire-resistant communities and insurance companies in re-evaluating relevant policies (since many property owners set their houses on fire after an earthquake to claim insurance from fire damage).
- **Support decision making to reduce future FFE losses.**
This model will allow evaluation of potential risk reduction efforts by key agencies able to plan in advance to or provide post-disaster relief to mitigate fire loss in a virtual care-free environment. Such agencies include the fire departments, utility companies and community planners.

FLOWCHART



METHODS

- **Cellular automaton**
Cell size: square cells measuring 3x3 meters, 30x30 meters, or by census track
Cell state: not burnt, mildly burnt, severely burnt, burnt out
Neighborhood: E, W, N, S, NE, NW, SE, SW cells
Transition rules: Probabilities based on physics of fire spread and branding
- **Discrete event simulation**
Entities (Attributes): Dispatch center (working or not), fire station (type of equipment), fire (size, status)
Resources: Fire engine, helicopter, fire boat
Events: Go to safe location, check-in, drive through, travel, fight fires
- **Geographic information systems (GIS)**
Data layers (i.e., building, environmental, lifelines, location of fire departments) for LA are compiled and converted to appropriate formats using GIS. Sample data below:



ACKNOWLEDGEMENTS

Principal investigator and/or faculty advisor: Rachel A. Davidson
Acknowledgements: Thomas O'Rourke, Charles Scawthorn, Anthony Ingraffea