THE LAW AND POLICY OF EARTHQUAKE HAZARD IN THE CENTRAL UNITED STATES

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I. INTRODUCTION

For most people living in the Central United States, earthquakes are not seen to pose a significant risk. While “everyone knows” there are likely to be earthquakes in California, people dwelling in the Midwest are more likely to fear tornadoes, ice-storms, floods, and other weather-related catastrophes than seismic activity. Yet there is significant evidence that earthquake risk in the Midwest is significantly higher than is generally believed, and may in some ways be comparable to that in California.

This article examines earthquake risk in the Midwest with particular emphasis on the New Madrid Seismic Zone, which suffered three large earthquakes in 1811-1812 near New Madrid, Missouri. The article considers the appropriate legal and policy response for seismic preparedness in the Midwest, discussing legislative schemes that have been developed in recent years. The responses to date, however, have been uneven across states and in some places have been woefully inadequate. We propose a regulatory regime for the state of Illinois, which

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heretofore has only minimal legislation to mitigate the risk of damage caused by the well-documented seismic hazard of the New Madrid Seismic Zone.

One reason that regulation has been inadequate in some states is that the risk of earthquakes in the Midwest is under-appreciated. While the probability of high magnitude quakes may be lower in the Midwest than on the West Coast, the *projected damage* from a high-magnitude quake is potentially much higher in the Midwest. In part this is because public authorities and private actors in California, perceiving the risk, have taken steps to retrofit bridges, freeways, buildings, and other structures so as to minimize property damage and loss of life. The effectiveness of this strategy was illustrated in the 1989 Loma Prieta earthquake (magnitude 7.1) when only 62 people died with the majority of these deaths (42) occurring in the collapse of the Cypress Street Viaduct, a double-decked highway structure near Oakland that had not been properly constructed. The total damage caused by the Loma Prieta earthquake reached as high as $10 billion with direct damage estimated at $6.8 billion.[1] In contrast, an earthquake of similar magnitude (6.9) and similar fault rupture mode,[2] killed 5300 people near Kobe, Japan in 1995. The earthquake-induced losses in the Kobe area were estimated to be as high as $200 billion.[3] Thus, risk perception has led to public policy responses that have lowered the absolute level of earthquake risk in California.[4]

We argue that the opposite dynamic has shaped earthquake policy in the Midwest. Because the risk is not perceived to be high, public authorities and private actors have been relatively slow in responding to the threat of earthquakes. The expected damage from a major earthquake event in the Midwest may therefore be higher than in California because of the large number of vulnerable structures.

The article proceeds as follows. Part II outlines the history of earthquakes in the Midwest and shows that while the probability of a major quake is lower than in California, it is hardly negligible. It also considers the types of hazards that would result in the Midwest should the risk of a major quake be realized. Part III explores why it is that perceptions of the risk differ from the actual risk, and demonstrates that there is potential tort liability for property owners should they fail to take certain steps to mitigate potential damage. Part IV examines existing regulatory schemes in the region as well as in California. Finally, Part V proposes a legislative scheme for Illinois to reduce the risk.

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[1] EQE International, Inc., "The October 17, 1989 Loma Prieta Earthquake," Report on Local Effects of Loma Prieta Earthquake, summarized at www.eqe.com/publications/lomaprie/introduc.htm.

[2] A fault rupture mode describes the manner in which a fault ruptures which creates the ground shaking. For example, a strike slip rupture mode means that one side of the fault is sliding horizontally past the other side of the fault which corresponds to the San Andreas Fault. A thrust rupture mode corresponds to one side of the fault being pushed vertically past the other side of the fault, which corresponds to the Northridge Fault. Both the Hyogoken-Nambu (Kobe) earthquake and the Loma Prieta earthquake were strike-slip quakes, so a direct comparison of earthquake magnitude, ground shaking, and damage is appropriate. M. Kimura, ed., SPECIAL ISSUE OF JOURNAL OF SOIL MECHANICS AND FOUNDATIONS 1 (1995).

[3] Earthquake Engineering Research Institute (EERI), Hokkaido-Nansei-Oki Earthquake and Tsunami of July 12, 1993 – Reconnaissance Report, EARTHQUAKE SPECTRA, Vol. 11 supplement, April, 165 pp. (1995).

[4] One area of California that may still be subject to a high level of risk is the East San Francisco Bay area, underlain by the Hayward fault. This fault runs through the densely populated areas of Fremont, Hayward, Oakland, Berkeley and Albany.

II. EARTHQUAKE RISK IN THE MIDWEST

A. The New Madrid Seismic Zone

The New Madrid Seismic Zone (NMSZ) of the central United States encompasses a multi-state region from northern Mississippi to Central Missouri and from eastern Missouri to western Indiana and includes the major cities of Memphis and St. Louis. The NMSZ is named for the epicenter of three large earthquakes (estimated earthquake magnitudes of 8.1, 7.8, and 8.0) that occurred during the winter months of 1811-1812.[5] Historic accounts suggest that these earthquakes are among the largest, if not the largest, earthquakes ever experienced in the United States.[6] The earthquakes reportedly rang church bells 1,000 miles away in Boston[7] and changed the topography of the region. Some of the geomorphic features that resulted from these earthquakes include the displacement and rerouting of the Mississippi River, subsidence that created Reelfoot Lake in Tennessee,[8] and extensive soil liquefaction features, such as sand blows or sand volcanoes, throughout the NMSZ.[9]

The first comprehensive study of the New Madrid earthquakes was published by the United States Geological Survey (USGS) approximately 100 years after the earthquakes.[10] Interest in the seismicity of the Mississippi River Valley increased significantly in the 1970s when proposals for construction of nuclear power plants in the mid-continent were being considered.[11] Since the 1970s, extensive research has been conducted and numerous technical papers written on the seismic hazard.[12]

While most people associate the New Madrid fault with the great earthquakes of 1811-12, the central Mississippi Valley is the most earthquake prone area of the United States east of the

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[5] R. Van Arsdale, *Hazard in the Heartland: The New Madrid Seismic Zone*, 4 GEOTIMES, 16-19 (1997).

[6] The quakes occurred on 16 December 1811, 23 January 1812, and 7 February 1812. *See* A.C. Johnston*, Seismic Moment Assessment of Earthquakes in Stable Continental Regions – III. New Madrid 1811-1812, Charleston 1886, and Lisbon 1755*, 126 GEOPHYSICS JOURNAL INTERNATIONAL 314-344 (1996).

[7] E.S. Schweig, et. al *The Mississippi Valley – Whole Lotta Shakin' Goin' On*, *U.S. Geological Survey Fact Sheet,* No. 168-95, 2 p. (1995).

[8] Tennessee Code §11-14-108 - Designation of areas (Reelfoot Lake a "natural, earthquake-formed lake, consisting of approximately eighteen thousand (18,000) acres of land and water in Lake and Obion counties").

[9] R. Van Arsdale, *Seismic Hazards of the Upper Mississippi Embayment*, U.S. Army Corps of Engineers, Waterways Experiment Station, Contract Report GL-98-1 (January 1998).

[10] M.L. Fuller, *New Madrid Earthquake*, U.S. Geological Survey Bulletin 494, 120 p. (1912).

[11] R. Van Arsdale, Hazard in the Heartland supra n. 5

[12] *See, e.g.,* A.C. Johnston and E.S. Schweig, The Enigma of the New Madrid Earthquakes of 1811-1812, 24 ANNUAL REVIEW OF EARTH AND PLANETARY SCIENCES, 339-384 (1996); E.S. Schweig, and R. Van Arsdale, *Neotectonics of the Upper Mississippi Embayment*, ENGINEERING GEOLOGY*,* 620-636 (1996); and A.C. Johnston, supra n. 6.

Rocky Mountains.[13] The Arkansas General Assembly determined that the "1811-1812 earthquake swarm" includes fifty-five (55) of the approximate two thousand ten (2,010) earthquakes occurring during the three-month period in the NMSZ having magnitudes of 6.0 - 8.7 on the Richter scale and affecting in excess of eight hundred thousand (800,000) square miles, and that recurrences remain a possibility in the region.[14] Table 1 presents a list of the earthquakes with a magnitude greater than or equal to 5.0 in the NMSZ since 1838. Earthquakes with estimated magnitudes of 6.4 and 6.8 occurred in 1843 and 1895, respectively.[15] More recent earthquakes in the NMSZ have exhibited an earthquake magnitude less than 5.0. For example, the magnitudes of the 26 September 1990 and 3 May 1991 earthquakes in Southeastern Missouri were 4.8 and 4.6, respectively.[16] The 6 December 1996 earthquake near Blytheville, Arkansas, which is just south of the Missouri border, had a magnitude of 4.3. On 4 May 2001 a magnitude 4.4 earthquake occurred near Little Rock, Arkansas, which is a little farther west than Blytheville.[17] These four earthquakes did not cause any significant damage but illustrate that strain energy continues to accumulate in the NMSZ, which attests to the ongoing seismic hazard that the area poses.

Table 1. History of Earthquakes with a magnitude greater than 5.0 in the Central United States[18]

Date	Magnitude	Location
1838/06/09	5.1	Southern Illinois
1843/01/04	6.4	Marked Tree, AR
1857/10/08	5.1	Southern Illinois
1865/08/17	5.2	Southern Missouri
1891/09/27	5.5	Southern Illinois
1895/10/31	6.8	Charleston, MO
1903/11/04	5.0	Southeastern MO
1909/05/26	5.2	Illinois
1968/11/09	5.4	South-central Illinois
1987/06/10	5.0	Southeastern Illinois
2002/06/18	5.0	Evansville, Indiana

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[13] T. G. Hildenbrand, V.E. Langenheim, E.S. Schweig, P.H. Stauffer, and J.W. Hendley II "Uncovering Hidden Hazards in the Mississippi Valley," *U.S. Geological Survey Fact Sheet,* No. 200-96, 2 (1996).

[14] Arkansas Code Annotated §12-77-102 (Earthquake Preparedness Act).

[15] The earthquake magnitude corresponds to the Richter earthquake magnitude and provides an estimate of the energy of the earthquake at its source. The higher the magnitude the greater the amount of energy released and the greater the potential for damage.

[16] Central U.S. Earthquake Consortium (CUSEC), *Earthquake Vulnerability of Transportation Systems in the Central United States*, September 1996 at 7.

[17] Center for Earthquake Research and Information (CERI), University of Memphis, Memphis, TN, http://folkworm.ceri.memphis.edu/recenteqs/Quakes/quakes.big.html.

[18] CUSEC, *supra* note 16, at 7.

Most people associate earthquakes more with California than the Midwest. However, there are at least three significant differences between earthquakes in California and the Midwest that suggest that residents of the NMSZ should not be complacent. First, California earthquakes have a higher recurrence rate and thus people are reminded more frequently of earthquakes in California than in the Midwest. As explained in Section III below, this can lead to distorted risk perceptions that hinder appropriate policy responses.

Second, the NMSZ is underlain by hundreds of feet of loose or soft sediments deposited by the Mississippi River, which can transmit the earthquake vibrations over greater distances than in California. For example, the great San Francisco earthquake of 1906 (magnitude 8.0) was felt only as far as 350 miles away in central Nevada whereas the New Madrid earthquake of December 1811 (magnitude 8.0) was reportedly felt in Boston.[19] Figure 1 presents the zones of impact of the 1994 Northridge earthquake near Los Angeles (magnitude 6.7) and the 1895 Charleston, Missouri earthquake (magnitude 6.8). The red (darker) enclosed area in the figure denotes areas of minor to major damage to buildings and their contents and the yellow (lighter) enclosed areas indicate areas in which shaking was felt but little or no damage occurred.[20] Figure 1 illustrates that the Charleston, Missouri earthquake influenced a much large area and many more states than the Northridge earthquake even though the magnitudes are similar.

Third, the large depth of loose or soft sediments may amplify the earthquake shaking. In other words, the shaking at the ground surface can be greater than the earthquake shaking at the bedrock where the earthquake originates. In the 1985 Mexico City earthquake the ground surface shaking was 1.5 to 2 times greater than the bedrock shaking, which contributed to the significant damage caused by the earthquake.[21] Mexico City is located on 100 to 200 feet thick soft clay deposits filling of an old lakebed.[22] The Mississippi River floodplain has similar sediments, but with a maximum depth of sediments of approximately 1000 feet. This suggests the potential for great amplification of earthquake shaking in the NMSZ for a given earthquake magnitude.

The potential losses from a future earthquake of magnitude 8 or greater in the NMSZ are expected to range from $60 to $100 billion dollars.[23] This is several times the damage of the 1989 Loma Prieta quake.[24] There are at least four reasons for these high damage estimates for the NMSZ: first, the area is now inhabited by approximately 100 million people; second, the population centers, notably Memphis and St. Louis, have many structures that are not constructed to withstand the effects of earthquake shaking; third, the Mississippi floodplain region is underlain by loose sandy soils that are susceptible to earthquake-induced liquefaction, a

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[19] Schweig et al., supra note 7 at 1.

[20] *Id.* at 2.

[21] I.M. Idriss, *Response of Soft Soil Sites During Earthquakes*, PROCEEDINGS H. BOLTON SEED MEMORIAL SYMPOSIUM, 273, 285 (1990).

[22] H.B. Seed, M.P. Romo, J. Sun, A. Jaime, and J. Lysmer, *Relationships Between Soil Conditions and Earthquake Ground Motions in Mexico City in the Earthquake of Sept. 19, 1985*, Report No. UCB/EERC-87/15, Earthquake Engineering Research Center, University of California, Berkeley, October, 112 p. (1987).

[23] CUSEC, *supra* note 16, at 6

[24] *supra* note 1.

phenomenon which can result in a loss of foundation support; and fourth, a New Madrid earthquake would impact a large multi-state region as illustrated in Figure 1, which is about 10 times larger than the area impacted by a California earthquake of comparable size. In comparison to the loss estimate of $60 to $100 billion dollars, the 1994 Northridge earthquake resulted in $20 billion of damage over a smaller, albeit more heavily populated, area that had implemented significant seismic design and construction techniques.[25]

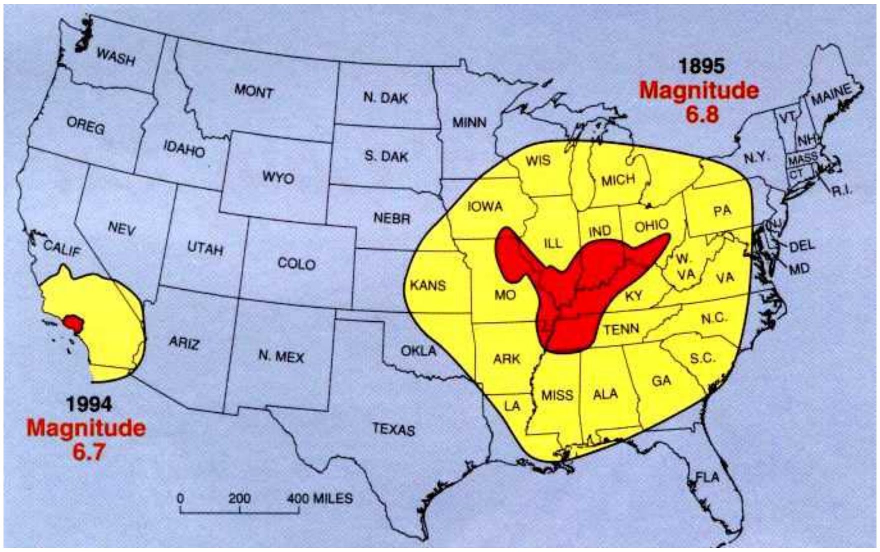

Figure 1. Comparison of Zones of Impact Between California and NMSZ Earthquakes [red (darker) enclosed area indicates major damage and yellow (lighter) enclosed area indicates shaking felt][26]

B. Historical Setting of the New Madrid Seismic Zone

An examination of the historical setting of the NMSZ shows that the three large earthquakes of 1811 and 1812 are not isolated events. In fact, the geologic data described briefly in this section suggests that as few as two and as many as four large earthquakes occurred in the 2000 years prior to 1811.[27] This reinforces the possibility that future large earthquakes will occur in the NMSZ because the earthquakes prior to 1811 and 1812 prove that this area is subject to a strain buildup over time that eventually results in large earthquakes. If large earthquakes had not occurred prior to 1811 and 1812, it could be argued that the large strain or energy release in 1811 and 1812 was an isolated event and thus seismic retrofitting techniques would not have

[25] Schweig et al., supra note 7 at 1.

[26] Schweig et al., supra note 7 at 1.

[27] A.C. Johnston, *The Enigma of the New Madrid Earthquakes of 1811-1812*, 24 ANNUAL REVIEW OF EARTH AND PLANETARY SCIENCES, 339, 372 (1996).

to be implemented today. The finding of recurring large earthquakes is significant because it implies that the more frequent low-magnitude earthquakes that continue to occur in the NMSZ are not releasing all of the strain energy, so the hazard is not eliminated.

The two most convincing pieces of evidence that suggest the occurrence of large earthquakes prior to 1811 are the dating of soil liquefaction features and the rapid subsidence that formed Big Lake and St. Francis Lake in northeastern Arkansas.[28] Studies of soil liquefaction features, termed paleoliquefaction features, have enabled researchers to determine when earthquakes large enough to cause soil liquefaction occurred. Soil liquefaction is the transformation of a saturated (below the natural groundwater table) granular material (sandy soil) from a solid to a liquid.[29] This transformation is caused by an increase in the water pressure in the soil caused by the rapid earthquake shaking.[30] The greater the earthquake magnitude, the greater the likelihood that soil liquefaction will occur. The date of a liquefaction feature is obtained by radio-carbon dating a piece of organic matter that is excavated from the liquefaction feature. Backhoe trenching in the southern NMSZ, between Blytheville, Arkansas and Caruthersville, Missouri, has shown soil liquefaction features that occurred around AD 800-1000 and AD 1200-1400.[31] The dating of the liquefaction features found in the trenches suggests that two different earthquakes large enough to cause soil liquefaction occurred prior to 1811 and 1812.

Another piece of evidence is the formation of Big Lake, which suggests that the lake formed by subsidence during at least two seismic events.[32] This is inferred from soil borings that reveal two distinct organic layers that reflect the subsidence caused by the 1811-1812 earthquakes and a prehistoric subsidence event.[33] The presence of a distinct organic layer suggests a rapid subsidence of the ground surface and quick deposition of soil above the existing organic material.[34] At the St. Francis Lake, similar soil borings indicate four separate subsidence and ponding events that preserved four distinct organic layers in the last 8000 years.[35] In summary, paleoliquefaction and geologic studies indicate a recurrence interval of 550 to 1,000 years for large (magnitude 8) earthquakes in the NMSZ.[36] This data also suggests a recurrence

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[28] *Id.* at 367.

[29] H.B. Seed, and I. M. Idriss, *A Simplified Procedure for Evaluating Soil Liquefaction Potential*, JOURNAL OF SOIL MECHANICS AND FOUNDATION ENGINEERING, 1249, 1251 (1971).

[30] *Id.* at 65. The earthquake applies rapid shear stresses to the granular soil causing a breakdown of the soil structure resulting in an increase in water pressure above the naturally occurring groundwater table induced water pressure. The water pressure increases until the soil becomes a liquid. This water pressure cannot drain or dissipate sufficiently because of the rapid nature of earthquake loading even though the soil is sandy.

[31] Johnston, supra n. 27 at 369.

[32] *Id.* at 370.

[33] *Id.*

[34] *Id.*

[35] *Id.*

[36] R. Van Arsdale, supra n. 5 at 18.

interval of only 450 years for earthquakes large enough to produce soil liquefaction (magnitude 6.5 – 7.5).[37]

Dating of soil liquefaction features and rapid subsidence events thus suggest that the 1811-12 quakes are not isolated events. Even if low-magnitude quakes occur, they are not likely to completely release the strain energy in the NMSZ. The next section discusses estimates of the probability of a large-magnitude event occurring in the NMSZ.

C. Probability of Future Damaging Earthquakes

The probability of moderate to large earthquakes occurring in the NMSZ in the near future was estimated in 1985[38] and updated in 1997.[39] Table 2 presents the probabilities of earthquake magnitudes of greater than 6.0, 7.5, and 8.0 in the NMSZ in the next fifteen or fifty years. It can be seen that the probability of a magnitude 8.0 earthquake in the next 50 years is less than 4%. However, the probability of a moderate earthquake, between 6.0 and 7.5, in the next fifteen years is 45 to 70% and within the next 50 years is approximately 90 percent. This is significant because even a moderate earthquake, between 6.0 and 7.5, is likely to cause damage in the NMSZ given the widespread presence of liquefiable soils and the large extent over which shaking will be felt (see Figure 1).

Table 2. Earthquake Probability Estimates for the New Madrid Seismic Zone[40]

Earthquake Magnitude, M	Probability of recurrence (percent) next 15 years	next 50 years
$6.0 \leq M \leq 7.5$	45-70	88-98
$7.5 \leq M \leq 8.0$	6-10	21-33
$M \geq 8.0$	0-1	2-4

This and other seismological information has been used by the United States Geological Survey (USGS)[41] to develop seismic hazard maps that are used for seismic design. These maps

[37] *Id.* at 18

[38] A.C. Johnston and S. J. Nava, *Recurrence Rates and Probability Estimates for the New Madrid Seismic Zone*, 90 JOURNAL GEOPHYSICAL RESEARCH, 6737-6753.

[39] A.C. Johnston, *Earthquake Probabilities in the New Madrid Seismic Zone: An Update for the Year 2000*, in ADDRESSING THE EARTHQUAKE RISK IN THE CENTRAL U.S., A FORUM FOR INSURANCE AND EARTHQUAKE HAZARDS PROFESSIONALS (Memphis, TN, December 3, 1997).

[40] *Id.*

[41] S.T. Algermissen,, et. al, "Probabilistic Earthquake Acceleration and Velocity Maps for the United States and Puerto Rico." Open-File Report 97-131, U.S. Geological Survey, Open-File Services Section, Denver, CO., (1997).

present another measure of earthquake strength, peak horizontal bedrock acceleration, for different probabilities of exceedance and return periods. The USGS seismic hazard map for a 2% probability of exceedance in 50 years predicts a peak horizontal bedrock acceleration greater than 1.6 times gravity in the NMSZ. For comparison purposes, the highest peak horizontal bedrock acceleration for the same probability of exceedance and return period in California is only 0.8 times gravity and is located near Los Angeles. Therefore, the predicted peak horizontal bedrock acceleration in the NMSZ is approximately twice as high as California according to the USGS. This coupled with the lack of seismic preparedness suggests potentially extensive damage.

D. Types of Hazards

This section details some of the hazards that are expected to occur if another large earthquake strikes the NMSZ. Earthquakes can affect the constructed environment in a number of ways, four of which are discussed in this section. First, the shaking can damage buildings by causing components of the supporting structure to fail. This could result in full or partial collapse especially when structures have not been designed to resist seismic loads. Without earthquake design provisions, structures are designed primarily to support vertical loads induced by gravity. Earthquake shaking results in horizontal forces that can be devastating to a building that is only designed for vertical loads. One such type of structure is made of unreinforced masonry or brick. Historically, masonry has been a popular building material because it is very strong for supporting vertical loads and is fire resistant. However, horizontal earthquake loads can cause the masonry to separate and fall off the building, which can injure people and lead to collapse of the structure.

Second, ground or foundation failures caused by the foundation soils losing strength via liquefaction during earthquake shaking also can have a detrimental impact on a structure. The loss of soil strength due to liquefaction can cause subsidence or overturning of the structure that can make the structure unusable or result in structural collapse. Prior earthquakes have shown that loose, saturated sandy soils are the most susceptible to liquefaction and strength loss and this behavior is usually observed in moderate to large earthquakes. This is a significant problem because the NMSZ is a large area that is underlain by loose, saturated sandy soils deposited by the Mississippi River.[42] In comparison, the areas of San Francisco Bay that are susceptible to liquefaction and strength loss are limited to areas in which sandy soil was used to fill in portions of the Bay for development purposes.

Third, surface faulting can damage structures by causing distortion or displacement of the structure. Damage to structures such as pipelines, highways, or lifelines can occur due to surface faulting, which could result in fires or release of hazardous materials.

Fourth, Mississippi River flooding could be induced by a dam or levee failure either caused by surface faulting or liquefaction under the dam or levee, which could affect the constructed environment. Even if the shaking does not damage buildings directly, it could have an indirect impact through such flooding.

Any of these hazards would likely impact the nation’s economy because the Midwest is an important link in the nation’s transportation system. The Midwest transportation network includes substantial portions of the nation’s highway and railroad systems, major waterways and

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[42] *See* Section II.C. *supra*.

shipping facilities on the Mississippi, Missouri, and Ohio Rivers, and airports that serve as hubs for the nation's airline (St. Louis) and air freight operations (Memphis). For example, the Memphis airport is ranked number 1 in the world in the volume of air freight and the St. Louis airport is ranked number 17 in the world for passenger volume.[43] Thus, extensive damage to any of these systems or facilities may have severe national economic and security ramifications, and also would seriously impact emergency response and recovery operations.

These potential hazards, combined with the high probability of a future moderate earthquake in the NMSZ, suggest that the risk is significant. One would expect that such significant levels of risk would induce policymakers and the public to respond aggressively. Although some states in the NMSZ have adopted significant legislation to reduce potential damages from an earthquake,[44] the response has been far from uniform. We believe that distortions in risk perception may deserve part of the blame for a still incomplete policy response. The next section lays out our claim and discusses earthquake awareness in the region.

III. EARTHQUAKE AWARENESS AND POLICY RESPONSE

A. Risk Perception and Earthquake

Although economic methodology assumes that individuals are rational with respect to the calculation of risks,[45] a growing body of evidence suggests that there are systematic distortions in the way risks are perceived. In other words, people will not fear all risks equally, even if the objective level of expected harm is identical. This section discusses two different branches of psychological research that illuminate these distortions: risk perception analysis in social psychology, and behavioral psychology. While these literatures both draw on psychology to examine related questions, their approaches are slightly different and lead to different implications for our analysis.

Scholars of risk perception in social psychology have noted that risks vary in terms of their perceived dreadfulness and the degree of familiarity with the hazard.[46] Risk perception reflects general psychological features that can lead to systematic distortions in the perception of risk. For example, cancer is a disease that leads to special dread even though other diseases kill

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[43] T.D. Stark, et al, *Seismic Bridge Research in Transportation Networks Program of Mid-America Earthquake Center*, paper presented at Transportation Research Board (TRB) Session on Seismic Design of Bridges, TRB Annual Meeting, Washington, D.C., January, at 1 (2000).

[44] See Section V.B. *infra*.

[45] *See, e.g.*, GARY BECKER, AN ECONOMIC APPROACH TO HUMAN BEHAVIOR 14 (1976) (people "maximize their utility from a stable set of preferences and accumulate an optimal amount of information and other important inputs in a variety of markets.")

[46] Ortwin Rehn & Bernd Rohrmann, eds., CROSS-CULTURAL RISK PERCEPTION: A SURVEY OF EMPIRICAL RESEARCH 29 (2000).

more people.[47] This is in part because compared with other diseases, cancer is seen to be uncontrollable; is caused by involuntary exposure to unknown risks; has delayed effects; and is generally uncertain.[48] Uncertainty creates further dread.

While this approach illustrates general distortions in risk perception, it leads to a question with regard to earthquakes. Earthquakes would seem to have the characteristics that would cause over-estimation of their actual risk. As unknown and uncontrollable risks, they would seem to cause special dread in people.[49] Cross-national studies show that people in a number of countries perceive earthquake risks as higher than many other kinds of risks.[50] The question that arises is why has the public in the Midwest not demanded greater attention to earthquake risk?

We believe the answer may lie in some of the recent developments in behavioral psychology. Much of this literature from behavioral psychology has made inroads into legal scholarship.[51] Behavioral psychology has shown, convincingly, that people do not conform to the rational actor model of economic theory. Behavior varies from the model, however, in systematic ways. People have certain mental biases and tricks that lead them to distort evidence, to weigh it poorly, and to make irrational judgments. Many believe that a greater understanding of these mental heuristics and biases can inform legal policymaking.

Recently legal scholars have begun to consider the implications of systematic errors in risk perception to risk regulation.[52] We focus on two key findings. One of the early findings of behavioral psychology concerned the "availability heuristic." This means that people rely on "a pervasive mental shortcut whereby the perceived likelihood of any given event is tied to the ease with which its occurrence can be brought to mind."[53] The availability heuristic means that recently-occurring or well-publicized events are given special weight in our mental process of evaluating probabilities. For example, people asked about the possibility of a hijacking immediately after September 11, 2001 would likely rate the risk higher than they would have the day before. This is true even though the heightened security after the event would likely *reduce* the objective risk of a hijacking.

A second key finding is that risk perceptions are in part interpersonal.[54] One's awareness of a risk depends not only on one's own analysis of the objective likelihood of its occurrence, but

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[47] BARRY GLASSNER, THE CULTURE OF FEAR (1999).

[48] Howard Margolis, *What's So Special About Cancer*? in CULTURE MATTERS (MICHAEL THOMPSON & RICHARD J. ELLIS, EDS., 1997)

[49] Kirk Johnson, *The Things People Choose to Fear: Usually They Are Unknown and Uncontrolled, Not Near and Dangerous*, N.Y. Times, July 30, 2000, at 27.

[50] See Bernd Rohrmann, *Cross Cultural Studies on the Perception and Evaluation of Hazards*, in Renn and Rohrmann 101, 126-28 (respondents rate earthquake risk higher than mean of other forms of risk exposure).

[51] *See, e.g.,* Russell B. Korobkin and Thomas S. Ulen, *Law and Behavioral Science: Removing the Rationality Assumption from Law and Economics,* 88 CAL. L. REV. 1051 (2000) Cass Sunstein, ed., BEHAVORIAL LAW & ECONOMICS (1999).

[52] Timur Kuran & Cass R. Sunstein, *Availability Cascades and Risk Regulation*, 51 STAN. L. REV. 683, 685 (1999).

[53] *Id.*

[54] *Id.*

also on the perception of other people's assessment. The more others believe that a risk is significant, the more likely we are to hold the same beliefs. Together these two findings suggest that actors and incidents can create "availability cascades" that can make people more aware of risks. For example, environmental groups are credited with raising awareness of the risk of toxics after the Love Canal incident.[55]

These two features may explain the differing reactions to earthquakes in the United States. Why have California policymakers responded with comprehensive legislation while responses in the Midwest have been more uneven? First, nearly two centuries have passed since the great earthquakes of 1811 –12 in the Midwest. The area was not heavily populated when they did occur. These earthquakes also occurred before the development of modern media such as television and radio, and hence were not likely to create vivid images in the minds of those who were not directly affected. In contrast, California has experienced twelve earthquakes over 6.5 magnitude since the Fort Tejon earthquake in 1857.[56] The 1906 earthquake that destroyed much of San Francisco was well-publicized at the time and remains the stuff of urban lore in the Bay Area. The Loma Prieta Quake in 1989 was experienced by many people and the effects well documented because of the World Series telecast and subsequent coverage.[57] In California, a host of governmental and other studies sought to draw lessons from the Loma Prieta quake for future events.[58]

Second, despite growing attention paid to earthquake risk on the part of policymakers in the Midwest, the public has not responded with large-scale efforts to retrofit buildings and otherwise take precautions. This may be due to the interpersonal nature of risk perception. Survey data has shown that the belief that one's neighbors are prepared for an earthquake is a strong predictor of one's own level or preparedness.[59]

Without a recent high-profile earthquake event, policymakers have been unable to create an "availability cascade" to expand public awareness in the Midwest. In part this may be because long-term, uncertain risks are not attractive issues for politicians or the business community to focus on.[60] The more recent occurrence of the California quake, the number of

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[55] *Id.* at 691-92.

[56] USGS website at http://neic.usgs.gov/neis/states/california/california.html

[57] *See, e.g.,* VICTORIA SHERROW, SAN FRANCISCO EARTHQUAKE 1989: DEATH AND DESTRUCTION (1998).

[58] *See, e.g.*, *The Loma Prieta Earthquake: Lessons Learned: Hearing before the House Subcommittee on Science, Research, and Technology of the Committee on Science, Space, and Technology*, 101st Cong. 1st Sess. (1989); U.S. GEOLOGICAL SURVEY, LESSONS LEARNED FROM THE LOMA PRIETA, CALIFORNIA, EARTHQUAKE OF OCTOBER 17, 1989 (GEORGE PLAFKER AND JOHN P. GALLOWAY, EDS., 1989); JANET A MCDONNELL, RESPONSE TO THE LOMA PRIETA EARTHQUAKE (U. .S. Army Corps of Engineers, 1993); PATRICIA A. BOLTON, ED., THE LOMA PRIETA, CALIFORNIA, EARTHQUAKE OF OCTOBER 17, 1989: PUBLIC RESPONSE (1993); SUSAN K. TUBBESING, ED., THE LOMA PRIETA, CALIFORNIA, EARTHQUAKE OF OCTOBER 17, 1989: LOSS ESTIMATION AND PROCEDURES (1994). KARL V. STEINBRUGGE AND RICHARD J. ROTH, JR., DWELLING AND MOBILE HOME MONETARY LOSSES DUE TO THE 1989 LOMA PRIETA, CALIFORNIA, EARTHQUAKE (U.S. Geological Survey, 1994); PRACTICAL LESSONS FROM THE LOMA PRIETA EARTHQUAKE: REPORT FROM A SYMPOSIUM SPONSORED BY THE GEOTECHNICAL BOARD AND THE BOARD ON NATURAL DISASTERS OF THE NATIONAL RESEARCH COUNCIL (1994).

[59] JOHN E. FARLEY, EARTHQUAKE FEARS, PREDICTIONS AND PREPARATIONS IN MID-AMERICA 164 (1998) (belief one's friends and neighbors are well prepared is one of the best predictors of earthquake preparedness).

[60] ROBERT A. STALLINGS, PROMOTING RISK: CONSTRUCTING THE EARTHQUAKE THREAT 3-5 (1995).

people who experienced it first-hand, the wide publicity through various media, and the attention of the policy community all contribute to the greater perception of earthquake risk in California than in the Midwest. "Everyone knows" of the earthquake hazards in California, but differences in risk perception are not the same as differences in objective levels of risk. Objective levels of risk may in fact be similar in California and the Midwest, but perceptions of risk differ dramatically.

B. Earthquake Awareness in the Midwest

This is not to say that there has been no awareness of earthquake hazard in the Midwest. The single largest event that increased the awareness of midwestern residents was the prediction by Iben Browning, a meteorologist that another great earthquake would occur near New Madrid, Missouri on 3 December 1990.[61] Of course, a great earthquake did not occur but the small town of New Madrid was inundated with news media (see Figure 2) and tourists who lined the levee that parallels the Mississippi River in New Madrid to witness the predicted earthquake. Although the quake never materialized, the widespread coverage of the event at least initiated a discussion about earthquakes in the Central United States. Since 1990 many more news stories have documented the hazard. Today, visitors to New Madrid can tour the earthquake museum that is located adjacent the Mississippi River levee and dine on a quake burger at a local restaurant.

More recently, the news media has returned to the subject of earthquakes in the Midwest via a news story presented on the morning news program Good Morning America on ABC.[62] The news story was filmed primarily on a shake table to illustrate the effects of earthquakes on single family residences and the simple retrofit techniques that homeowners in the Midwest can implement to reduce earthquake-induced damage. In particular, a model family den was constructed on a shake table and subjected to earthquake magnitudes of 5.5 and 6.5. In the magnitude 5.5 simulated event, no damage occurred. However, in the 6.5 magnitude simulation, bookcases fell over onto the test dummies sitting on the sofa, the TV set slid out of the entertainment center, and loose objects were thrown onto the floor. The news segment suggested some simple retrofit techniques that homeowners can implement, such as anchoring bookshelves to walls and using an adhesive to secure the television set, lamps, and other loose objects, to reduce the potential damage. The NMSZ has also been the subject of national newspaper stories.[63] In summary, there has been some national television news and newspaper coverage of the seismic hazard in the NMSZ. In addition, local newspapers[64] and television news have covered the hazard so the residents and property owners of the Midwest should be aware of the seismic hazard.

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[61] See JOHN E. FARLEY, EARTHQUAKE FEARS, PREDICTIONS AND PREPARATIONS IN MID-AMERICA 1-20 (1998) (analyzing the Browning episode).

[62] The four minute news story was aired on 28 April 2000 and can be viewed at http://www.abcnews.go.com/onair/GoodMorningAmerica/gma000428_shake_guillen_feat.html.

[63] USA Today, April 23, 1999 at 6A; St. Louis Post-Dispatch, December 8, 1999 at A1

[64] The News Gazette, Champaign-Urbana, Illinois, August 31, 2001 at B1.

Figure 2. News Media in New Madrid, Missouri on 3 December 1990 awaiting the earthquake predicted by Iben Browning [Postcard Photo from The Gallery; 302 Powell St., New Madrid, MO 63869]

Recognizing the potential for large earthquakes in the Midwest, a number of organizations have been formed and existing agencies re-focused to address the estimated loss of life and property from future earthquakes in the NMSZ.[65] In 1983 seven states (Arkansas, Illinois, Indiana, Kentucky, Mississippi, Missouri, and Tennessee) formed the Central United States Earthquake Consortium (CUSEC) to improve public awareness and education. CUSEC is located in Memphis, Tennessee and is active in a number of earthquake related programs, such as coordinating the emergency response of the Departments of Transportation in the seven states, coordinating the studies of the State Geological Surveys in the seven states, and continuing earthquake awareness and education activities in the NMSZ.

In 1990, the USGS intensified study of the NMSZ culminating in Memphis being named as one of three cities (along with Seattle and Oakland) that would be foci for long-term earthquake related research in 1999. In addition, the Kentucky State legislature has mandated earthquake education in schools.[66] Missouri has passed legislation, described subsequently in detail, establishing a Seismic Safety Commission that prepared a strategic plan for earthquake safety in 1997.

The increased earthquake awareness has resulted in retrofit of some existing critical structures, such as highway bridges and dams. In particular, the Interstate 40, 57, and 55 Mississippi River bridges in Memphis, St. Louis, and Cairo, Illinois, respectively, are undergoing seismic retrofit techniques. New bridges, such as those near Cape Girardeau and St. Louis, Missouri are being designed and constructed using modern earthquake design standards. Some

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[65] Schweig et al., supra note 7 at 1.

[66] *Id.*

corporations are also starting to implement seismic design in new construction, such as the AutoZone corporate headquarters in Memphis, which is the first building in the NMSZ to utilize a base isolation system to reduce the level of shaking, transferred to the structure. However, the majority of the structures in St. Louis and Memphis consist of unreinforced masonry or brick and remain unretrofitted. Previous earthquakes, e.g., 1906 and 1989 earthquakes near San Francisco, have shown the vulnerability of unreinforced masonry or brick buildings to damage during earthquakes. Until the mid 1980's, the primary building material in St. Louis was brick and thus St. Louis is especially vulnerable to earthquake-induced damage. In particular, the area of St. Louis known as Soulard consists of beautiful brick buildings and houses dating back to the 1800's that have not been seismically retrofitted and thus is susceptible to earthquake-induced damage.[67]

The increased earthquake awareness has also resulted in a number of cities in the NMSZ being selected to participate in Project Impact. These cities include Cape Girardeau, Missouri, Carbondale, Illinois, Rector, Arkansas, Evansville, Indiana, Henderson, Kentucky, and Jackson, Tennessee. Project Impact is a Federal Emergency Management Agency (FEMA) program that is supplying federal funding to cities to help them better prepare for natural disasters such as earthquakes and floods.[68] FEMA is helping these cities and local officials in recruiting volunteers, assessing the potential for various disasters and developing site specific techniques to develop disaster resistant communities. The main reason these cities are participating in Project Impact is the threat of a NMSZ earthquake and Mississippi River flooding.

C. Earthquake Retrofit Techniques

This section describes some of the techniques property owners can utilize to reduce the potential of structural collapse and damage in existing or new structures in the NMSZ. These measures not only provide resistance against earthquakes but also other natural hazards, such as tornados, ice storms, and fires ignited by an earthquake or other means.[69] This is an important point, since it may help encourage public support for retrofits that convey collateral benefits in mitigating damages from other, higher frequency natural disasters. The retrofit techniques most relevant to a low frequency earthquake region are emphasized and it will be shown that property owners could implement these techniques to reduce the structural hazards imposed by a New Madrid earthquake.

California Government Code 8894.2[70] defines seismic retrofitting to encompass three categories or levels of strengthening. The first and least encompassing is retrofitting or reconstruction to significantly reduce structural collapse and falling hazards from structural or nonstructural components including, but not limited to, parapets, appendages, cornices, hanging

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[67] Beer drinkers will be happy to learn that the large Anheuser-Busch Brewery in this area of St. Louis has undergone seismic retrofitting.

[68] Arkansas Democrat Gazette, June 4 at B1 (1998).

[69] *Compare* Robert B. Olshansky, *Seismic Hazard Mitigation in the Central United States: The Role of the States*, U.S. Geological Survey Professional Paper 1538-G (1994) at G-10, ("there appears to be no other existing issue that could help carry seismic regulations in the Midwest").

[70] California Government Code §8894.2 – Seismic Retrofit.

objects, and building cladding that poses serious danger to the occupants or adjacent areas. The second technique is structural strengthening to modify the seismic response that would otherwise be expected by an existing structure so as to significantly reduce hazards to life and safety while also providing for the safe ingress and egress of the building occupants immediately after an earthquake. The third and most protective technique is retrofitting or strengthening of a structure to allow the structure to remain functional immediately after an earthquake. The technologies discussed in this section can be used individually or together to achieve any of these levels of strengthening. Thus, the priorities for strengthening, should be determined initially and then the appropriate strengthening measures can be implemented. For example, public buildings that must remain functional after an earthquake should receive the highest level of care.

The most common technique of seismic retrofitting is strengthening of the structure. Strengthening measures have developed from damage studies after previous earthquakes and can decrease the amount of damage to existing structures. These studies show that the type of failure, and thus optimal retrofit technique is a function of the building type, e.g., wood, masonry, or steel. For example, the common failure mechanism for one or two story wood residential-type structures caused by earthquake forces is the structure sliding off the top of the foundation or the structure collapsing. The foundation deficiency can be remedied by drilling through the wood sill plate on the top of the foundation walls and grouting new anchor bolts into the foundation wall. This strengthening technique can be readily implemented in new construction and can be implemented in existing homes without great difficulty. The common failure mechanisms for masonry type structures are brick walls falling away from the rest of the structure or bricks simply collapsing resulting in failure of the structure. The falling away of the bricks can be avoided by installing an anchoring system that ties the brick walls to the floor and roof framing of the building. The potential for structural collapse can be reduced by installing a floor to ceiling solid masonry wall, or walls, to prevent structural collapse. These techniques are relatively straightforward.

There are a number of more advanced techniques for retrofitting structures that have been implemented in Japan and California. One category of advanced retrofit techniques involves the installation of structural control measures to reduce the effect of earthquake shaking on structures.[71] These measures can be used to retrofit existing structures or protect new structures and basically respond to external forces applied to the structure. In other words, this extra structural resistance is waiting patiently for an earthquake to arrive and when it arrives the devices provide additional strength to the areas of the structure that need to be reinforced. The main premise of structural control measures is that the cost of retrofit can be reduced by not retrofitting the entire structure because the entire structure may not be challenged during its service life. Structural control allows the structure to be built with less resistance and then applying additional reinforcement to areas that may need it during the service life.

The structural control measures can be separated into five major categories: active control, semiactive control, hybrid control (combined use of active and passive control), passive control, and structural health monitoring.[72] The first four control mechanisms can add and

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[71] T.T. Soong and M.C. Constantinou, eds., PASSIVE AND ACTIVE STRUCTURAL VIBRATION CONTROL IN CIVIL ENGINEERING, (1994).

[72] G.W. Housner, et al., *Structural Control: Past, Present, and Future*, 123 JOURNAL OF ENGINEERING MECHANICS, 897, 899 (1997).

dissipate energy induced in a structure so the structure is not severely damaged by an earthquake or wind loading.[73] Therefore, property owners that implement seismic retrofit techniques in the NMSZ will also reduce the potential for wind, ice, or tornado damage. Active, semiactive, and hybrid control measures require external energy to be continuously provided to the sensors and the control devices that apply forces to the structure to resist the earthquake forces. If the sensing devices detect an external force being applied to the structure the sensors send signals to the control actuators that apply the necessary forces to resist or damp the external force and thus reduce or eliminate its impact on the structure. Therefore, the sensing devices must continually sense the forces being applied to the structures. This requires a constant energy source to operate the sensing devices even though no earthquake or wind forces are being applied and results in significant cost and are usually only justified in a high frequency earthquake zone.

Because the NMSZ is a low frequency earthquake zone, passive control measures are more appropriate for the region. Passive control devices do not require constant monitoring and thus do not require a constant external power source.[74] Passive control devices impart forces that are induced in response to the motion of the structure not a sensing device.[75] Therefore, the devices can be installed in a structure and will remain dormant until activated by an earthquake or tornado. This dormant nature reduces energy and maintenance costs for the active control devices.

Structural health monitoring systems can be used to detect the current seismic capacity and subsequent changes in the structural characteristics and structural response.[76] On-site nondestructive tests are used to detect the structural response of a structure, which may indicate damage or degradation of the structure. In a low frequency earthquake area it is important to assess the structural response as a function of time because structures may become more vulnerable to shaking as the structure ages.[77] Examples of structural degradation include cracking of building materials, corrosion of structural steel or concrete reinforcing bars, and weakening of welded connections with time.[78] Monitoring systems can assess the current structural capacity of older structures in the NMSZ and identify which structures need to be retrofit and in particular which portion(s) of a structure are most vulnerable and thus should be retrofitted either via passive control or strengthening measures. Health monitoring uses a number of techniques such as acoustics, fiber-optic sensors, hardness testing, magnetic perturbation, ultrasonics, x-rays, pulse-echo, and visual inspection to detect current structural

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[73] *Id.* at 899.

[74] *Id.* Passive control systems include a variety of materials and devices for increasing the damping, stiffness, and strength of a structure. The most common dampers are metallic yield, friction, viscoelastic, viscous fluid, tuned mass, and tuned liquid. *Id.* at 906. Each damper possesses advantages and disadvantages but is installed to dissipate external forces that are applied to a structure by any external force. These devices are installed in walls between each floor to dissipate the external energy applied to the columns supporting each floor. *Id.* at 902.

[75] *Id.* at 899.

[76] *Id.* at 899.

[77] *Id.* at 899.

[78] *Id.* at 945.

response, which can be used to assess current seismic vulnerability and locate and quantify any structural weakness.[79]

In summary, property owners in the NMSZ can implement passive control or structure strengthening techniques that reduce the potential for damage and collapse. The implementation of passive control devices may be less costly and less intrusive depending on the structure and do not require significant maintenance costs. Property owners can assess the need for seismic retrofitting by using a health monitoring system and assess the degradation, if any, over time of the seismic resistance.

Retrofitting techniques are now well developed and could easily be expanded in the NMSZ. It should be noted that special complications arise in retrofitting historic buildings because local Landmark Preservation Codes, for example that in California,[80] do not allow a structural alteration or exterior change that has a significant impact upon the landmark. This usually results in limited and costly alternatives for seismically retrofitting a structure. For example, a structure with a tower could be rebuilt at a lower cost to increase seismic resistance than undergoing a strengthening procedure described previously but the rebuilding may not be allowed under a Landmark Preservation Code.[81] However, churches or other religious structures may be exempt from local Landmark Preservation Code because of their religious affiliation and non-profit status.[82] In any case, the existence of this special category of buildings does not reduce the need for retrofitting most structures potentially vulnerable to earthquakes.

D. Tort Liability for Earthquake-Induced Damages

Given the availability of retrofit techniques described in the previous section, the question arises as to what are property owners' responsibilities to mitigate earthquake hazards. Traditionally, earthquakes present the quintessential "act of God" for which there is no tort liability. Although it is possible to induce earthquakes that might lead to tort liability,[83] these are not the norm. Very few firms or government agencies are involved in the type of activities that might risk inducing an earthquake. The more salient question is what liability might lie for choosing to ignore a risk of earthquakes that is ultimately realized? This question implicates virtually every firm and individual that owns or operates real property in the midwestern region and in particular the New Madrid Seismic Zone. Because public entities are usually shielded through statutory immunity,[84] we focus on private property owners.[85] Much of the relevant case law comes from California.

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[79] *Id.* at 945.

[80] Cal. Gov. Code §37361.

[81] *East Bay Asian Local Development Corp. v. State of California*, 102 Cal. Rptr.2d 280 at 293 (2000).

[82] *Id.* at 702.

[83] Darlene A. Cypser & Scott D. Davis, *Liability For Induced Earthquakes*, 9 J. ENVTL. L. & LITIG. 551 (1994).

[84] *See, e.g.,* Arkansas Code Annotated §21-9-301 – Tort Liability – Immunity Declared; Illinois Statute Chapter 745, Act 10, Section 1-101 – Civil Immunities Act, Local Government and Government Employees Tort Immunity; Missouri Statute 537.600 - Torts and Actions for Damages - Sovereign Immunity, Tennessee Statute 29-20-201 – General Rule of Immunity from Suit. See also *Mikkelsen v. State of California,* 130 Cal. Rptr. 780, at 780 (1976)

In determining when an actor is negligent, the paradigm approach is the rule developed by Judge Learned Hand in *United States v. Carroll Towing.*[86] The Hand Rule, which has produced a voluminous academic literature,[87] provides that an actor will be liable for negligence when she fails to undertake a burden that costs less than the expected harm of the accident without the burden. The expected harm is the product of the probability of a harm occurring multiplied by the severity of the harm should it occur. Thus if an actor could prevent a significant harm with a minor preventative measure, the actor will be liable. This formula has obvious implications for private property owners confronting earthquake risk. Property owners might be liable for failing to undertake seismic retrofitting or other forms of risk mitigation, or for negligently designing and constructing seismic retrofits.[88] For example, the burden or cost of a retrofit scheme to prevent building collapse may be less than the probability of the harm multiplied by the severity of the harm, e.g., personal injury or dearth.

Scholars have criticized the Hand formula on a number of grounds, including the impracticability of determining the values at issue. But these criticisms are less salient in the context of earthquake research. For example, in response to the charge that it is difficult to determine what the values are in the formula, it is important to note that scientists have made great advances in risk estimation models.[89] So whereas it may be difficult to determine the marginal benefit of looking both ways twice before crossing the street, sophisticated econometric tools are available for determining both earthquake probability and magnitude of expected harm. These tools provided the basis for the earthquake probability estimates given in Table 2 above.

There are at least two possible theories under which a plaintiff could recover from a property owner for earthquake damage. The first is for negligent initial construction that results

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(design immunity precludes state liability in wrongful death action when a concrete overpass collapsed over the Golden State Freeway in the Sylmar area during the 1971 San Fernando Earthquake); *Stevenson v. San Francisco Housing Authority*, 29 Cal.Rptr.2d 398 (1994 (state immunity shields public housing authority from claim that negligent inspections or breach of oral contract to routinely monitor tenant's health and safety caused earthquake related death); *Haggis v. City of Los Angeles*, 78 Cal.Rptr.2d 826 at 826 (1998) (affirmed by *Haggis v. City of Los Angeles*, 93 Cal.Rptr.2d 327 (2000) (claims of negligence in recording of certificate of substandard condition, issuance of building and grading permits, and failure to exercise its authority to stop construction work did not concern a mandatory duty and hence were dismissed).

[85] Most of the case law in the following discussion is from California.

[86] 159 F. 2d 169 (2d Cir. 1947).

[87] *See, e.g.,* Richard Posner, *A Theory of Negligence*, 1 J. LEG. STUD 29 (1972); Mark Grady, *A New Positive Economic Theory Of Negligence,* 92 YALE L. J. 799 (1983);.WILLIAM LANDES AND RICHARD POSNER, THE ECONOMIC STRUCTURE OF TORT LAW (1987); STEVEN SHAVELL, ECONOMIC ANALYSIS OF ACCIDENT LAW 26-46 (1987); Barbara Ann White, *Risk-Utility Analysis And The Learned Hand Formula: A Hand That Helps Or A Hand That Hides?* 32 ARIZ. L. REV. 77 (1990); SYMPOSIUM, 54 VAND. L. REV. 813 (2001); Robert Cooter and Ariel Porat, *Does Risk To Oneself Increase The Care Owed To Others? Law And Economics in Conflict*, 19 J. LEG. STUD. 29 (2000).

[88] A separate question that we do not address concerns the failure to comply with state laws for earthquake preparedness.

[89] *See, e.g.,* table 2, infra.

in seismic vulnerability[90] and the second is for lack of or negligent seismic retrofitting so that the structure remains seismically deficient.[91]

A typical example of a claim of negligent construction in a commercial context is found in *London Guarantee & Accident Co. v. Industrial Accident Commission of California*.[92] In *London* a plaintiff was able to recover for the fatal injury of her spouse that resulted from the Santa Barbara earthquake of June 29, 1925 because of defective construction even though Mr. Mosteiro was covered by the Workmen's Compensation Act.[93] In this case, Segismundo Mosteiro was struck and killed by falling concrete walls of a Santa Barbara building while employed as a janitor. While the *London* court noted that earthquakes are considered *force majeure* and hence would be outside the ordinary scope of employer liability,[94] it still awarded damages to the plaintiff because it was shown that the building would not have collapsed had it been constructed of proper materials.[95] In particular, considerable evidence was introduced that showed the concrete used to construct the reinforced concrete building was defectively mixed, resulting in an improper bond between the cement and the gravel.[96]

London is of particular relevance to private property owners in the NMSZ, because it is likely that many buildings in the area will suffer damage from the horizontal earthquake loading even though they have successfully withstood gravity, i.e., vertical, loads for some time. In other words, earthquake shaking in the NMSZ could expose construction defects that have not manifested themselves in the absence of earthquake loading and thus cause property owners, insurers, contractors, engineers, and others to be liable for earthquake related damage and injuries. Courts might also find that buildings that are not designed to resist seismic forces are defective because the design process did not take into consideration a foreseeable force. This may allow courts to impose liability without having to show a specific defect in the building materials or construction.

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[90] *KPFF, Inc. v. California Union Ins. Co.*, 66 Cal.Rptr.2d 36 (1997).

[91] *Keru,* 63 Cal. App. 4th 1413, 1415 (Ct. App. 1998).

[92] *London Guarantee & Accident Co. v. Industrial Accident Commission of California***,** 259 P. 1096, at 1097 (1927). See also *Collins v. Industrial Acc. Commission,* 205 Cal. 727, 273 P. 33 (1928).

[93] "The responsibility of an employer for an injury sustained by his employee resulting from an earthquake or other like peril has frequently been the subject of judicial determination, and the rule applied by the courts almost universally is as follows: 'As a general principle, the employer is not responsible for damages caused to his workmen by lightning, storms, sunstroke, freezing, earthquake, floods, etc. These are considered as 'force majeure,' which human vigilance and industry can neither foresee nor prevent. The victim must bear alone such burden, inasmuch as human industry has nothing to do with it and inasmuch as the employee is no more subject thereto than any other person. Every human being is liable to suffer from events in which he has no share of responsibility." *Id.*

[94] *Id.*

[95] *Id.*

[96] *Id.* (noting that one witness testified that a drill would go through the concrete "like a piece of cheese.")

A typical defective residential construction case is *Aas v. Superior Court*[97] in which a homeowners' association and individual homeowners brought a claim for negligence against the developer, contractor, and subcontractors for failure to conform to building standards. In particular, the plaintiffs claimed that the absence of shear walls made the residences more susceptible to damage and personal injury from seismic and wind forces.[98] The negligence claim was denied because the property had not experienced any damage, but if damage had occurred due to seismic loading, the plaintiffs appeared to have a valid claim.[99] In stressing the importance of seismically resistant construction, the Court referred to a California Seismic Safety Commission recommendation that states:

> The greatest opportunity to ensure seismic safety is during a building's design and construction.... The Northridge earthquake and other past earthquakes have clearly and repeatedly demonstrated the remarkable effectiveness of paying attention to quality in reducing earthquake losses. Quality assurance is the single most important policy improvement needed to manage California's earthquake risk.[100]

There also have been several cases against contractors who failed to retrofit, based on claims of negligent construction. In the aftermath of the Northridge earthquake, in *Keru Investments, Inc. v. Cube Co*.[101] the California Court of Appeals denied a claim brought against the contractor by a noteholder who purchased an earthquake-damaged building. A man named Kaila was the owner of an apartment building in Hollywood; sometime prior to 1988, he sold it to the Moross Group. During that year, those owners hired an engineer and contractor to, respectively, design and effectuate a "seismic retrofit for the building."[102] In January 1994, the Northridge earthquake hit the area, and the building was badly damaged and ultimately "yellow-tagged" by the city.[103] The Moross Group then conveyed the building to Keru Investments (Keru), a company wholly owned by the original property owner, Kaila. Under their sales agreement, Keru assumed the loan obligations of the Moross Group, and the latter agreed that the property was being bought on an "as is" basis only, i.e., without any warranties. The agreement even specifically recited the building's "damages and need for repairs."[104] Sometime later, Keru concluded that both the seismic retrofit design and construction work were faulty, and sued both the engineer and contractor. However, the court held that there was no cause of action for the

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[97] *Aas v. Superior Court,* 101 Cal.Rptr.2d 718 (2000).

[98] *Id.* at 719.

[99] *Id.* at 718.

[100] *Id.* at 732 (quoting California Seismic Safety Commission, 'Northridge Earthquake: Turning Loss To Gain,' Dec. 1, 1994, at 22).

[101] 63 Cal.App.4th 1413, 74 Cal. Rptr. 2d 744 (Ct. App. 1998).

[102] *Keru,* 63 Cal. App. 4th at 1415.

[103] *Id.*

[104] *Id.*

noteholder because the Moross Group had been the owner at the time the damage occurred, as well as during the retrofit. In general, a cause of action for negligent design, engineering, or construction of buildings accrues in favor of owner of building at the time the damage occurs.[105] This means that a tort duty runs from an architect, designer, or contractor to not only the original owner for whom the real property improvement services are provided, but also to subsequent owners of the same property.[106]

The evidence showed that the retrofit had been partially successful, that is, greater damage would have occurred in the absence of retrofitting, but also negligent, in that a proper retrofit would have led to less damage than actually occurred.[107] *Keru* suggests, then, that had the plaintiff been properly situated, he could have brought a case.

Another category of claim involves insurance related claims.[108] A typical example of the many cases that appeared after the Great San Francisco Earthquake of 1906 involves fire insurance. Damage in this case was caused not by the earthquake directly but by the large fire that engulfed the city after the earthquake. The problem for property owners in such cases can result from exclusion clauses stating that if the building or any part thereof falls, except as a result of fire, all insurance on the building or contents shall cease because the remaining part of the building is subject to an increased fire risk.[109] Accompanying case law defined the "fallen building" clause of these fire insurance policies as "either the fall of the building as a structure, or of such a substantial and important part thereof as impairs its usefulness as such, and leaves the remaining part of the building subject to an increased risk of fire."[110] It is anticipated that if a large NMSZ earthquake occurs, substantial damage will occur to the large number of unreinforced masonry structures and the remaining issue may be whether or not the damaged portion of the building subjects the contents to an increased risk of fire. Of course, the main reason for the structural damage is that the vast majority of unreinforced masonry structures in the NMSZ were constructed with no seismic resistance and have not been retrofitted.

Existing California case law thus suggests that there is a duty to retrofit and that tort liability may accrue to owners who fail to do so or do so negligently. This duty to retrofit lies with the owner.[111] Even if the seismic retrofitting is required by ordinance or law, such as in

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[105] *Krusi v. S.J Amoroso Construction Co*., 97 Cal. Rptr. 2d 294 (2000).

[106] *Id.*

[107] *Id.* at note 2 (expert testimony that a proper retrofit would have led to one month's non-use of building rather than six as occurred.)

[108] These are not limited to claims based on property damage. *See, e.g,, Continental Cas. Co. v. Thompson*, 369 F.2d 157, at 157 (1966) (plaintiff recovers on insurance claim based on accidental death caused by mental shock from great Alaskan earthquake of 1964).

[109] *Fountain v. Connecticut Fire Ins. Co. of Hartford*, 117 P. 630, (1910).

[110] *Id.* at 634.

[111] *Prudential Ins. Co. of America v. L.A. Mart*, 68 F.3d 370 at 371 (1995) (private property owners cannot transfer retrofit liabilities to a lessee even though the property is secured by a long-term lease or sale-leaseback condition).

Hadian v. Schwartz,[112] courts have been reluctant to require the lessee to assume the costs of earthquake hazard reduction because the enhancements usually remain with the building.

Would such private liability exist in the Midwest? A simple application of the Hand Formula suggests that the objective risk may be as high as in California. Although the probability of a large-scale quake is lower, the potential loss may be as high because of inadequate preparation. Certain low-cost preventative measures, such as the seismic gas shut-off valves discussed below, almost certainly ought to be adopted in the Midwest under the Hand Formula. Larger scale retrofits would depend on the retrofit cost and the proximity of the structure to the NMSZ.

The existence of seismic safety commission recommendations in California is one factor that might lead courts to find that a reasonable property owner would engage in retrofits. Once such a duty exists, it must be done competently or lead to liability. It might be argued that the lack of earthquake awareness in the Midwest would lead courts to find that no such initial duty exists. However, growing awareness of earthquake hazard in the Midwest means that earthquake-related damages are becoming more foreseeable and hence recoverable. Private actors in the NMSZ ought to closely examine their potential liability and take preventative steps to mitigate their liability exposure, including constructing seismically safe buildings or seismically retrofitting existing buildings. Public agencies, e.g., State Departments of Transportation, are implementing seismic design in new structures, e.g., highway bridges. Private property owners will not enjoy the immunity that public entities and private lessees enjoy for seismic related injuries or seismic upgrade costs.

This potential source of private liability is related to public regulation in two ways. First, the development of legislative frameworks related to earthquakes may be seen as evidence that property owners are, or should be, becoming more aware of the risk. This could lead to an expansion of private liability, even if the statutes do not require specific steps, because the "reasonable" property owner should be aware of potential earthquake-related damage. Second, the legislative frameworks can ameliorate some of the hardship or cost incurred by private owners in retrofitting via loans or tax incentives. Indeed, such an approach has been adopted in California legislation, as will be described in the next section.

IV. PUBLIC REGULATION AND EARTHQUAKE-INDUCED DAMAGES

The discussion in Section III above shows that awareness of earthquake risk in the Midwest is increasing. Several states have enacted legislation promoting earthquake awareness.[113] It is not clear, however, that this response will be adequate to mitigate the damages that may result from a large quake. This section discusses existing regulatory schemes related to earthquakes. It then proposes enactment of regulation in one state, Illinois, which has not yet passed comprehensive legislation.

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[112] *Hadian v. Schwartz*, 35 Cal.Rptr.2d 589, at 589 (1994).

[113] See text at note 66, supra.

A. Federal Earthquake Related Legislation

This section summarizes federal earthquake related legislation, which emphasizes the need for increased public awareness, development of new building technologies, and implementation of model building codes. In 1977 the Earthquake Hazards Reduction Act[114] was passed. The Congressional Findings declare that all 50 states are vulnerable to earthquakes and at least 39 of them are subject to major or moderate seismic risk including Missouri and Illinois. One of the areas identified in the Act as being subject to a major earthquake risk is the NMSZ. The purpose of the Act is to reduce the risks of life and property from future earthquakes and to maintain an effective earthquake hazards reduction program via public education, development of feasible earthquake resistant design and construction methods for new and existing structures, and develop and promote model-building codes.[115] The Act gives primary responsibility for planning and coordinating a National Earthquake Hazards Reduction Program to the Federal Emergency Management Agency (FEMA).[116] FEMA responsibilities include providing grants and technical assistance to States to develop preparedness and response plans, executing a comprehensive earthquake education and public awareness program for schools and general public, developing building codes and practices for structures and lifelines, and coordinating interagency plans to respond to an earthquake.[117] The Act also mobilizes the US Geological Survey, National Science Foundation, National Institute of Standards and Technology to improve the understanding of the causes and behavior of earthquakes including the NMSZ.[118] The Act also requires the assessment and enhancement of existing buildings constructed for or leased by the Federal Government, which were designed and constructed without seismic design standards.[119]

In summary, not only has the NMSZ been recognized on the federal level, FEMA and other agencies have been charged with increasing public awareness of the earthquake risk in the NMSZ. Evidence of this includes the "ear-marking" of $450,000 to continue CUSEC's efforts "to reduce the unacceptable threat of earthquake damages in the New Madrid seismic region through efforts to enhance preparedness, response, recovery, and mitigation."[120] Nevertheless, the Act does not directly affect the standards of care for private actors concerned about potential tort liability.

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[114] 86 USC 7701 – 7706. The Act was amended in 1980, 1981, 1983, 1984, 1985, 1988, 1990, 1994, and expanded in 2000.

[115] 86 USC 7702 at 887.

[116] 86 USC 7704 at 890.

[117] 86 USC 7704(b)(2)(A) at 890.

[118] 86 USC 7704(b)(3) at 892.

[119] 86 USC 7705(b) at 903.

[120] 86 USC 7706 at 80.

B. State Earthquake Related Legislation in The Midwest

This section summarizes the state related legislation that has been promulgated in Missouri, Arkansas, Tennessee, and Illinois because these states immediately surround the NMSZ. Missouri and Arkansas, both west of the Mississippi River, have more stringent earthquake requirements than Illinois and Tennessee, east of the Mississippi River.

1. Missouri

Missouri has enacted four key pieces of earthquake related legislation since 1990. Section 319.200 of the Missouri Revised Statutes[121] provide building design and construction standards for buildings in each city, town, village, or county that can expect to experience an intensity of ground shaking equivalent to a magnitude 7.6 earthquake occurring along the New Madrid Fault. In particular, §319.200(1) requires each city, town, village or county to adopt an ordinance requiring new construction, additions, and alterations to comply with the standards for seismic design of the local business code or the national uniform building code. However, §319.200(2) does not require existing buildings to be retrofitted to comply with seismic design standards even if the existing building is being added on to or altered. If the addition or alternation adversely affects portions of the existing structure, it must be retrofitted such that the structure is at least as safe as it was prior to the addition or alteration. Section 319.200 is further limited because it does not apply to private structures with a total area less than ten thousand square feet, single family or duplex residences, and state or higher education buildings, or political subdivisions begun or finished before 28 August 1991. Any city, town, village or county not complying with §319.200 that can expect to experience a magnitude 7.6 earthquake is not eligible to receive any state aid, assistance, grant, loan, or reimbursement until compliance is proven.

Missouri Revised Statutes Section 160.451[122] requires the establishment of an Earthquake Emergency Procedure System in every school that can expect to experience an intensity of ground shaking equivalent to a magnitude 7.6-earthquake occurring along the New Madrid Fault. Under §160.453 this System shall include a disaster plan ready for implementation at any time and an earthquake emergency exercise to be conducted at least twice each school year to practice the disaster plan. Section 160.455 also requires each school district to distribute to each student materials on earthquake safety prepared by the Federal or State Emergency Management Agency or any other agency that is an authority in earthquake preparedness to develop public awareness of earthquakes, promote an understanding of the impact of earthquakes on natural features and manmade structures, and provide safety measures that individuals and households can implement.

Chapter 44 of the Missouri Revised Statutes describes civil defense procedures some of which pertain to the occurrence of New Madrid earthquakes. Section 44.023[123] establishes an Emergency Volunteer Program whereby architects, engineers, construction contractors, equipment dealers, and other owners and operators of construction equipment may volunteer

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[121] 1996 Missouri Senate Bill 826.

[122] 1990 Missouri Senate Bill 539 §2.

[123] 1991 Missouri Senate Bill 265 §1.

their services and/or equipment without personal liability except in the case of willful misconduct or gross negligence. Section 44.227 establishes a Seismic Safety Commission to, *inter alia*, develop a comprehensive program to prepare Missouri for responding to a major earthquake, set goals and priorities for the public and private sectors to mitigate the earthquake hazard, monitor the NMSZ, and assist in promoting earthquake and disaster safety.[124] Beginning 1 January 1993, insurers must provide information to original applications regarding the availability of insurance for loss caused by a NMSZ earthquake.[125]

2. Arkansas

Arkansas has the most comprehensive earthquake legislation addressing four major earthquake related issues: preparedness, seismic design of public buildings, earthquake insurance, and seismic monitoring. The section on seismic design divides the state into three earthquake damage zones (greatest, moderate, and low).

First, Arkansas Code requires the Arkansas Department of Emergency Management (ADEMA) to establish an Earthquake Preparedness Program to assess the seismic risk, train and educate state and local officials, and coordinate all government officials in preparation, guidance, and assistance for response to and recovery from earthquakes.[126] In addition, the Earthquake Preparedness Act must disseminate information to the public pertaining to the earthquake hazard, protective measures during and after an earthquake, and other matters the ADEMA determines necessary or appropriate to educate, inform, and equip Arkansas citizens.[127] The Earthquake Preparedness Act also amends the Interstate Civil Defense and Disaster Compact to be in concert with the Central United States Earthquake Consortium (CUSEC) to develop an Interstate Emergency Compact.[128]

Second, Arkansas Code[129] requires all public structures, i.e., any building intended, or adaptable, for public employment, assembly, or any other use open to the public,[130] to be designed and constructed to resist the earthquake forces of the NMSZ. An important provision of the requirement of seismic design for public buildings is that the Arkansas Legislature created three seismic damage zones in the state based on expected ground accelerations.[131] The three expected seismic damage zones include those of greatest risk (13 identified counties), moderate risk (12 identified counties), and low risk (all remaining counties), corresponding to ground accelerations of greater than or equal to 0.2, between 0.1 and 0.2, and less than 0.1,

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[124] 1995 Missouri Senate Bill 63.

[125] Missouri Statute 379 §975 – Earthquake Insurance.

[126] Arkansas Code Annotated §12-77-103- Earthquake Preparedness Act.

[127] *Id.*

[128] Arkansas Code Annotated §12-77-102 - Earthquake Preparedness Act.

[129] Arkansas Code Annotated §12-80-101 - Earthquake Resistant Design for Public Structures.

[130] Arkansas Code Annotated §12-80-102 - Earthquake Resistant Design for Public Structures.

[131] Arkansas Code Annotated §12-80-101 - Earthquake Resistant Design for Public Structures.

respectively.[132] These damage zones are used as notice to private property owners to assess their susceptibility to earthquakes.

Third, Arkansas Code[133] makes residential earthquake insurance available to homeowners via the Market Assistance Program (MAP).[134] If there is no approved insurer in the MAP or the MAP rates substantially exceed rates that could be offered by the Arkansas Earthquake Authority (AEA), the AEA can offer coverage to potential insured private parties. If so required, the AEA can offer a residential earthquake policy with dwelling coverage in amounts up to one hundred thousand dollars ($100,000).[135] Under this portion of the Arkansas Code, insurers must notify existing policyholders who do not maintain residential earthquake insurance or who maintain earthquake insurance at an amount less than one hundred percent of the value of the dwelling of the potential eligibility for residential earthquake insurance through the MAP or AEA.[136] Insurers writing new homeowner and farmowner policies must advise new applicants of the availability of earthquake insurance through the insurer or the MAP and the applicant must reject coverage in writing.[137]

Fourth, Arkansas Code[138] creates and charges the Arkansas Center for Earthquake Education and Technology Transfer at the University of Arkansas at Little Rock to establish the Arkansas Seismological Observatory to create a long-term, continuous monitoring of earthquake activity in Arkansas in order to provide reliable data for a realistic seismic hazard assessment and to collaborate with the existing seismic monitoring programs at St. Louis University and the University of Memphis.

3. Tennessee

Even though Tennessee is in close proximity to the NMSZ, this State has less stringent earthquake legislation than Arkansas and Missouri. The Tennessee legislation covers the same four earthquake related categories as the Arkansas Code, namely earthquake preparedness, seismic design of public buildings, earthquake insurance, and seismic monitoring, and is described in the following paragraphs. Under preparedness, Tennessee Code refers to mutual aid among states in meeting any emergency or disaster caused by earthquakes.[139] Like Missouri,

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[132] Arkansas Code Annotated §12-80-103 - Earthquake Resistant Design for Public Structures.

[133] Arkansas Code Annotated §23-102-110 - Arkansas Earthquake Authority Act.

[134] The stated purposes of these insurance safeguards are to address the threat of or actual occurrence of a major earthquake, the potential unavailability of earthquake insurance or inadequate coverage, lack of awareness of the consequences of a major earthquake, low percentage of Arkansans with earthquake insurance, and lack of awareness of residential homeowners and farmowners that earthquake is not a covered peril under a basic policy unless affirmatively added. Arkansas Code Annotated §23-102 - Arkansas Earthquake Authority Act.

[135] Arkansas Code Annotated §23-102-113 - Arkansas Earthquake Authority Act.

[136] Arkansas Code Annotated §23-102-114 - Arkansas Earthquake Authority Act.

[137] *Id.*

[138] Arkansas Code Annotated §15-21-601 - Earthquake Activity.

[139] Tennessee Statute 58-2-701 - Interstate Earthquake Compact of 1988.

Tennessee also provides immunity to an architect or engineer who voluntarily provides inspection services after a major earthquake if requested by a public safety officer or city or county building inspector.[140] Second, Tennessee does not have legislation pertaining to design and construction of public buildings but does require each local education agency within one hundred (100) miles of the New Madrid fault line to implement earthquake preparedness drills at least twice every school year in cooperation with the Tennessee Emergency Management Agency.[141] Third, Tennessee allows any empowered company to insure against earthquake related loss or damage but does not require notification as Arkansas does.[142] Fourth, Tennessee Code[143] creates and charges the Center for Earthquake Research and Information (CERI) at the University of Memphis to provide services such as accurate reports on the occurrence of earthquakes, background information for individuals, civic groups, schools, governmental agencies, the news media, and others, to conduct research on causes and effects of earthquakes, and to study the desirability of earthquake resistant design.

4. Illinois

Even though the NMSZ and the Wabash Valley Seismic Zone along the southeastern border of Illinois threaten Illinois,[144] the State has the least restrictive earthquake related legislation of the four states considered. The Ninety-Second General Assembly, 2001 expanded the Earthquake Awareness Program under the Illinois Emergency Management Agency (IEMA) to increase efforts to distribute earthquake preparedness materials to schools, political subdivisions community groups, civil organizations in areas most at risk, and the media and develop agreements with medical supply and construction equipment firms to supply resources necessary to respond to an earthquake.[145] The IEMA also determines which jurisdictions will be required to include earthquake preparedness in their local emergency operations plans.[146] At present, Illinois does not require seismic design of public buildings but allows the State Board of Education to loan or grant moneys for temporary relocation expenses by school districts as a result of earthquakes.[147] Illinois Code only requires insurance companies to provide information to homeowners applying for insurance on the availability of insurance for loss caused by earthquake in areas susceptible to a magnitude 7.6 or greater.[148] There is no provision for seismic monitoring in Illinois as there is in Missouri, Arkansas, and Tennessee.

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[140] Tennessee Statute 62-2-109 – Limitation of Liability.

[141] Tennessee Statute 49-1-302 – Dept. of Education - Powers and Duties.

[142] Tennessee Statute 56-2-202 – Kinds of Property Insurance.

[143] Tennessee Statute 49-8-602 - Center for Earthquake Research and Information.

[144] Illinois Statute Chapter 225, Act 745, Section 5 – Findings.

[145] Public Act 92-73, Senate Bill 860. Emergency Management Agency – Requirements.

[146] Illinois Statute Chapter 20, Act 3305, Section 10 - Emergency Services and Disaster Agencies.

[147] Illinois Statute Chapter 105, Act 5, Section 2-3.77 – Temporary Relocation Expenses.

[148] Illinois Statute Chapter 215, Act 5, Section 143.21c– Insurance.

5. Conclusion

In sum, states in the Midwest that lie within the NMSZ have responded to earthquake risk with a range of legislation. The most extensive legislation is in Arkansas, with Missouri and Tennessee enacting less comprehensive schemes. Finally, Illinois has only minimal legislation related to earthquakes which does not include provisions for seismic monitoring or seismic design of public buildings.

C. California Earthquake Related Legislation

This section summarizes California legislation related to earthquakes to illustrate how a state in a high earthquake frequency area has responded with much more comprehensive legislation than those states in low earthquake frequency areas such as the NMSZ.[149] Given the greater frequency of quakes and the resulting awareness of the risk, it is not surprising that California has promulgated significantly more earthquake related legislation, with at least one hundred (100) active statutes. This section summarizes the main features of these statutes and provides an insight to how legislation in the Missouri, Arkansas, Illinois, and Tennessee might be amended to better address the earthquake hazard that the NMSZ poses.

California legislation is more comprehensive than the legislation in Missouri, Arkansas, Tennessee, and Illinois. It covers five (instead of four) major earthquake related issues: preparedness, seismic design of public buildings, seismic design of private buildings, earthquake insurance, and seismic monitoring. It will also be seen that the California Legislature has granted substantial authority to a Seismic Safety Commission in an effort to increase preparedness and decrease earthquake-induced losses.

1. Earthquake Preparedness

First, California Government Code 8870.5[150] created the Seismic Safety Commission to promote seismic safety in California, set goals and priorities for preparedness in the public and private sectors,[151] to enter into agreements to act cooperatively with private nonprofit scientific,

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[149] In California Government Code 8876.1, the California Legislature declares that during the 1990's the state endured a number of moderate earthquakes resulting in injuries, loss of life, and in excess of thirty billion dollars ($30,000,000,000) in property damage. The findings also state "moderate, potentially damaging earthquakes occur on the average of every couple of years somewhere in this state, and another great earthquake in southern California can be expected within the next 20 to 30 years." *Id.* "Projected losses in future earthquakes could exceed one hundred fifty billion dollars ($150,000,000,000) as was the case for the recent Kobe earthquake in Japan." *Id.* The legislature goes on to find that seismicity in this state may have been anomalously low in the recent past, and that a normal period of more frequent large earthquakes may be returning. *Id.* These findings illustrate some of the differences between California and the NMSZ, most notably the short recurrence between moderate earthquakes and the potential for a great earthquake in the next 20 to 30 years.

[150] California Government Code §8870.5 – Seismic Safety Commission – Powers and duties.

[151] California Government Code §8870.7 – Earthquake Preparedness.

educational, or professional associations or foundations engaged in promoting seismic safety in California, to develop a research plan to implement the hazard reduction plan,[152] and report annually to the Governor and Legislature on its findings, progress, and recommendations relating to earthquake hazard reduction.[153] The scope of the Commission is increased in California Government Code 8870.5,[154] which creates a coordinated program, titled California Earthquake Hazard Reduction Program, to implement new and expanded activities to significantly reduce the earthquake threat to citizens. This program is administered by the Seismic Safety Commission and has the following four main objectives, which might be used to develop a similar program in the NMSZ:

(1) *Mitigation*: The reduction of the earthquake hazard to acceptable levels through significant reduction in the number of hazardous buildings and the expansion of scientific and engineering studies.

(2) *Preparedness*: The increase in the level of preparedness statewide by appropriate measures to deal with special issues, such as earthquake prediction, hazardous materials, critical facilities, and disaster preparedness plans for all major population centers, and education, training, and public information.

(3) *Response*: The enhancement of the state's capability to respond to a major earthquake disaster by giving priority to increased coordination and integration of federal, state, and local plans and preparedness activities, improvements in the statewide communication system, creation of a state emergency coordination center or centers, and greater automation of emergency management data.

(4) *Recovery*: The development of management systems for major earthquake recovery, the enhancement of resources management, and the minimization of high unemployment, multiple business failures, tax base erosion, and associated monetary and financial issues critical to the restoration of California's economy and public services.[155]

The California legislation specifically targets private property owners. California Business and Professions Codes 10149 and 10147 specifically require the Seismic Safety Commission to develop and adopt a Homeowner's Guide to Earthquake Safety[156] and a Commercial Property Owner's Guide to Earthquake Safety[157] for distribution to reduce earthquake-induced losses on or before July 1, 1992 and January 1, 1993, respectively. California Public Resources Code 2807 empowers the Commission to establish a project for the implementation of a statewide program of earthquake safety education and preparedness entitled the California Earthquake Education Project (CALEEP). The Seismic Safety Commission may contract with the University of California to carry out the project and the project focuses on

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[152] California Government Code §8819.15 – Hazard Reduction Plan.

[153] California Government Code §8870.1 – Reporting.

[154] California Government Code §8870.5 – Earthquake Hazard Reduction Program.

[155] *Id.*

[156] California Business and Professions Code §10149 – Homeowner's Guide to Earthquake Safety.

[157] California Business and Professions Code §10147 – Commercial Owner's Guide to Earthquake Safety.

identifying state and local leadership interested in using the CALEEP materials, disseminating those materials, and utilizing the materials. Additional Commission tasks include:

> Developing and distributing an educational pamphlet for use by grades K-14 personnel to identify and mitigate the risks posed by nonstructural earthquake hazards.[158]

> Conducting a study to determine the feasibility of (i) establishing a comprehensive program of earthquake hazard reduction to save lives and mitigate damage to property including developing guidance for land use policy decisions and (ii) developing and implementing a system for predicting damaging earthquakes in California.[159]

To increase earthquake preparedness the California Legislature has also required the governing board of each private school to establish an earthquake emergency procedure system in every private school building under its jurisdiction having an occupant capacity of 50 or more pupils or more than one classroom.[160] To facilitate these preparedness provisions the Legislature requires the development of statewide seismic hazard mapping to assist cities and counties in protecting the public health and safety from the effects of strong ground shaking, soil liquefaction, landslides, or other ground failure and other seismic hazards.[161] This effort is complimented by a provision requiring delineation of earthquake fault zones and developing official fault zone maps.[162]

2. Seismic Design of Public Buildings and Structures

Second, California legislation related to the seismic design of public structures focuses on hospitals and highways, and in particular bridges because of the newsworthy collapses or failures that have occurred during past earthquakes. Prior to June 30, 1996 the Office of Statewide Health Planning and Development was required to define earthquake performance categories for both new and existing hospitals such that the hospitals are reasonably capable of providing services to the public after an earthquake[163] and in compliance with the requirements of the Alfred E. Alquist Hospital Facilities Seismic Safety Act.[164] Prior to December 31, 1996, the California Building Standards Commission also was charged with adopting earthquake performance criteria, seismic evaluation procedures, and standards for upgrading hospitals.[165]

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[158] California Government Code §8887.7 – Earthquake Education.

[159] California Government Code §8870.75 – Earthquake Prediction.

[160] California Education Code §35296 – Private Schools.

[161] California Public Resources Code §2692 – Seismic Hazard Mapping.

[162] California Public Resources Code §2621.5 – Fault Zone Mapping.

[163] California Health & Safety Code 130005 – Seismic Design for Hospitals.

[164] California Health & Safety Code 130000 – Alfred E. Alquist Hospital Facilities Seismic Safety Act.

[165] California Health & Safety Code 130020 – Seismic Design for Hospitals.

The Department of Highways is the lead agency for the seismic evaluation of publicly owned bridges, which includes pedestrian and railway bridges, throughout the state, except for those bridges not on the state highway system in the County of Los Angeles and in the unincorporated areas of the County of Santa Clara, in which cases the respective counties are the lead agency.[166] The Department must review the structural design and construction details of all publicly owned bridges for which it is the lead agency and assess the need for seismic retrofit work, taking into account the structural deficiencies that surfaced following the Sylmar, Whittier, and Loma Prieta earthquakes. For each bridge that is determined to be structural deficient, the lead agency shall identify a retrofit project to be funded from the account. This 1989 legislation, which is current through 2001, appropriates $60 million for the state retrofit program to meet matching requirements for any federal funds and $20 million for local agencies to retrofit deficient bridges.[167] The Department of Highways also must revise seismic standards for earthquake resistance to be utilized in the design and construction of new state highways and bridges, and for the retrofit of existing highways and bridges.[168]

California has given considerable authority to the State Architect to develop seismic retrofit guidelines and standards for buildings enclosing more than 20,000 square feet of floor area with concrete or reinforced masonry column or wall construction by January 1, 1996 and these guidelines were adopted and published by the State Building Standards Commission by July 1, 1997.[169]

The Building seismic retrofit guidelines include provisions for the strengthening of structures of buildings, or the means necessary to reduce the response of a building to ground shaking, so as to significantly reduce the hazards to life, while concomitantly providing for safe egress of occupants during and immediately after an earthquake.[170] For public and private buildings California defines earthquake hazard mitigation technologies to include, but not limited to, seismic isolation, energy dissipation, ductility, damping systems, and other technologies (some of these technologies are discussed in the Section III.C) that protect buildings and nonstructural components from earthquake damage.[171] In practice the State Architect must review and approve all design and building permit application involving schools.

California is more stringent than the states in the NMSZ in requiring all buildings open to the public to install earthquake sensitive gas shutoff devices.[172] These devices stop gas supply to the building in the event of an earthquake to reduce the potential for fire, which was the main cause of the damage caused by the 1906 earthquake near San Francisco. In addition, California requires seismic gas shut-off valves for individual public structures connecting to main gas

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[166] California Streets and Highways Code §179.3.

[167] California Streets and Highways Code §179.3.

[168] California Streets and Highways Code §162.5.

[169] California Government Code §8894.

[170] California Health & Safety Code §16100.

[171] California Health & Safety Code §16100.

[172] California Health & Safety Code §19181 – Seismic Gas Shut-Off Valves.

lines[173] and local governments are authorized to adopt ordinances requiring installation of earthquake sensitive gas shutoff devices in buildings.[174] The State Architect must certify operation and functionality of seismic gas shut-off valves before manufacturers can market the devices.[175]

3. Seismic Design of Private Buildings

Third, there is substantial legislation regarding the seismic design of private buildings. Local building departments must establish a mitigation program for potentially hazardous buildings, e.g., unreinforced masonry, to include notifying the legal owner and may include low-cost rehabilitation loans or tax incentives.[176] The Department of Housing and Community Development, with the review and advice of the Seismic Safety Commission, also promulgated rules and regulations to ensure that purchasers of all manufactured homes and mobile homes installed for human occupancy are offered earthquake resistant bracing systems that meet generally accepted seismic safety standards for the reduction of damage and for the protection of the health and safety of the occupants. [177]

In addition, any building owner who has received actual or constructive notice that a building located in seismic zone 4 is constructed of unreinforced masonry shall post in a conspicuous place at the entrance of the building, on a sign not less than 5" X 7" the following statement, printed in not less than 30-point bold type:

> "This is an unreinforced masonry building. Unreinforced masonry buildings may be unsafe in the event of a major earthquake."[178]

A similar requirement could be instituted for areas in the NMSZ that are expected to experience shaking equivalent to a magnitude 7.6 earthquake occurring along the New Madrid Fault. California provides direct and indirect assistance to private owners to facilitate seismic retrofitting in the form of public loans or funds for unreinforced or other buildings to facilitate compliance with seismic safety regulations or standards, because this strengthening results in a public benefit.[179] In addition, California provides a tax exemption for construction or installation of seismic retrofitting improvements or improvements utilizing earthquake hazard mitigation technologies that are required by local ordinance. Therefore, the county assessor's valuation of real property for tax purposes will not reflect improvements made for seismic retrofitting

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[173] California Health & Safety Code §19204 – Seismic Gas Shut-Off Devices – Application of article.

[174] California Health & Safety Code §19180 – Seismic Gas Shut-Off Valves.

[175] California Health & Safety Code §19202 – Seismic Gas Shut-Off Valves.

[176] California Government Code §8875.2.

[177] California Health & Safety Code 18613.5.

[178] California Government Code §8875.8 – Notice.

[179] California Health & Safety Code §10100.

purposes.[180] The California Revenue and Taxation Code[181] also clarifies that "newly constructed" and "new construction" does not include seismic retrofitting improvements and improvements utilizing earthquake hazard mitigation technologies to an existing building or structure. Therefore, seismic retrofitting activities receive a tax exclusion by not allowing the assessor to consider improvements to real property that are or are not required by ordinance as long as the activity improves seismic stability.

4. Residential Earthquake Insurance

California created the California Earthquake Authority (CEA) to provide California homeowners with a source of basic earthquake insurance.[182] Basic earthquake insurance covers residences and individual condominium unit properties and is available to any owner that has secured residential property insurance from a participating insurer.[183] The California Earthquake Authority consists of participating insurers but does not prohibit a participating or nonparticipating insurer from offering a condominium or residential earthquake loss assessment policy for different amounts of coverage other than those offered by the Authority.[184] No new residential property policy may issue or an existing policy renew without the insured being offered residential earthquake insurance as provided by the CEA.[185] The CEA is required to pay claims within one year of a major seismic event[186] however, the payment is limited to the available resources of the CEA and the remaining losses, if any, are not transferable to the owners' residential property insurance.[187] If resources are available, the CEA may also supply grants and loans or loan guarantees to dwelling owners who wish to retrofit their homes to protect against earthquake damage via an Earthquake Loss Mitigation Fund.[188]

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[180] California Construction Article 13A, §2.

[181] California Revenue and Taxation Code 74.5 – Definitions.

[182] California Insurance Code §10089.5 – California Earthquake Authority – Definitions.

[183] California Insurance Code §10089.26 – California Earthquake Authority – Issuance of Policies.

[184] Id.

[185] California Insurance Code §10081 – Residential property insurance; necessity to offer.

[186] California Insurance Code §10089.13 – Annual report.

[187] California Insurance Code §10086 – Offer of earthquake coverage accepted.

[188] California Insurance Code §10089.38 – Grants and loans; Earthquake Loss Mitigation Fund. The Earthquake Loss Mitigation Fund is created by the supervising board of the CEA setting aside in each calendar year an amount equal to 5 percent of investment income accruing on the authority's invested funds, or five million dollars ($5,000,000), whichever is less, if deemed actuarially sound by a consulting actuary employed or hired by the CEA. California Insurance Code §10089.37 – Earthquake Loss Mitigation Fund

5. Seismic Monitoring

Fifth, California Legislation authorizes the University of California to establish the California Center for Earthquake Engineering Research after July, 1996. The Center is headquartered at the University of California at Berkeley and involves all university members of the California Universities for Research in Earthquake Engineering. Establishment of the Center is one of the recommendations of the Seismic Safety Commission's plan for earthquake risk reduction.[189] The objective of the Center is to reduce casualties, property losses, and economic or other disruptive consequences of earthquakes in areas of high seismicity through the advancement of knowledge and technology in the earthquake-engineering field. The Center shall develop methods for identifying and quantifying the risks of great urban earthquakes, including seismic monitoring, and shall develop cost-effective strategies for reducing those risks to reasonable levels.[190]

Legislation under this category empowers the State Geologist to continually review new geologic and seismic data and revise the earthquake fault zones or delineate additional earthquake fault zones or traces when warranted by new information.[191] Fault zone information is necessary because California Legislation requires that a structure cannot be situated upon a trace of an active fault.[192] California Legislation also provides funding for one of the largest seismic monitoring projects in the United States.[193] The Department of Geology, Mines, and Mining is tasked with developing and maintaining an earthquake prediction system, in cooperation with the U.S. Geological Survey, along the central San Andreas fault near the City of Parkfield. The system includes a dense cluster of seismic and crustal deformation instrumentation capable of monitoring geophysical and geochemical phenomena associated with earthquakes and analyzing the resulting data.[194] The monitoring system is still in operation near Parkfield.

In sum, California has an extensive set of legislation related to earthquake risk. This legislation includes a program of preparedness overseen by a state commission, seismic related regulation of the design of both public and private buildings, earthquake insurance, and a program of seismic monitoring. The key difference between legislation in California and the NMSZ is not only that California's earthquake regulations are more extensive, but also that they directly relate to public and private property owners.

As described in Section II, the expected damage from an earthquake in the NMSZ may be the same as or greater than that in California. Although probability of an earthquake is lower, the losses from an earthquake that occurs may be higher because of inadequate preparation. In many cases, the burden of retrofitting or installing gas shut-off valves may be less than the rather

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[189] California Government Code – §8876.2 – Earthquake Engineering Research Center.

[190] *Id.*

[191] California Public Resources Code §2622 – Earthquake Fault Zones; Official Maps.

[192] California Public Resources Code §2621.7 – Structures, developments and alterations.

[193] California Public Resources Code §2802 – Earthquake Prediction.

[194] *Id.*

substantial expected damage, and there may be private tort liability for failure to construct earthquake-resistant buildings or retrofit existing buildings. This suggests that public policymakers should consider encouraging private property owners to take steps to mitigate earthquake damage.

V. PROPOSED ILLINOIS EARTHQUAKE RELATED LEGISLATION

This section presents provisions that the Illinois legislature could adopt to reasonably protect Illinoisans from the adverse effects of a NMSZ earthquake. As discussed earlier in Section IV.B., Illinois has the least developed legislative scheme of all the states in the NMSZ. The provisions we suggest have analogous provisions in the Arkansas, California, Missouri, and Tennessee statutes previously described, but our suggestions are tailored to suit the seismic hazard in Illinois. After discussing potential earthquake damage zones, this section discusses the five major earthquake related issues discussed previously: preparedness, seismic design of public buildings, seismic design of private buildings (including seismic gas shut-off valves), earthquake insurance, and seismic monitoring.

A. Designation of Zones

An important aspect of the proposed legislation is describing the seismic hazard in Illinois and delineating the portions of Illinois that would be subject to the seismic requirements. The risk of earthquake hazard is not uniform across the State. We propose that Illinois be divided into three potential earthquake damage zones (greatest, moderate, and low) based on expected ground surface accelerations. This approach is similar to that adopted by the Arkansas Code.[195] As in Arkansas, we propose that the greatest, moderate, and low seismic damage zones correspond to ground surface accelerations of greater than or equal to 0.2, between 0.1 and 0.2, and less than 0.1, respectively. These ranges of peak ground surface acceleration are estimated from the bedrock accelerations obtained from the seismic hazard map for 2% probability of exceedance in 50 years prepared by the U.S. Geological Survey.[196]

Note that while the USGS hazard map presents the bedrock acceleration, our proposed statute uses ground surface acceleration because the structures that need to be protected are at the ground surface. If the structure is founded on rock, the bedrock acceleration is the same as the ground surface acceleration; but if the structure is founded on soil, the ground surface acceleration can be greater than, less than, or equal to the bedrock acceleration. Engineering analyses are readily available to predict the ground surface acceleration from the bedrock acceleration.

If the three ranges of ground surface acceleration are adopted, the greatest damage zone would extend from the southern boundary of Illinois to approximately Effingham, the moderate damage zone would extend from Effingham north to approximately Champaign-Urbana, and the low damage zone would extend from Champaign-Urbana to the northern boundary of Illinois, including the population center of the Chicago metropolitan area. Establishment of these damage

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[195] Arkansas Code Annotated §12-80-101 - Earthquake Resistant Design for Public Structures.

[196] Algermissen et al., supra note 7 and at the USGS website http://geohazards.cr.usgs.gov/eq/hazmaps/250pga.gif

zones could provide notice to private property owners to assess their susceptibility to earthquakes. It would also delineate the portions of the state where both public and private property owners should implement seismic retrofit techniques. Because of the low frequency of NMSZ earthquakes, the legislation could require that only the greatest damage zone (south of Effingham) undergo earthquake preparedness, a similar approach to that of the Missouri regulations that limit provision to areas that can expect to experience an intensity of ground shaking equivalent to a magnitude 7.6-earthquake occurring along the New Madrid Fault.[197] This approach will minimize the need for extensive retrofitting in the Chicago area, which is where the risk is least and the cost would be highest because of the large population and complexity of the structures.

B. Earthquake Preparedness

We propose that Illinois create a Seismic Safety Commission that would consist of policy makers, emergency management personnel, business representatives, transportation (highway, waterway, railway, and airway) officials, earthquake engineers, seismologists, and others deemed necessary to address the Illinois seismic hazard. The main task imposed on the Commission would be to set cost-effective goals and priorities for preparedness in the public and private sectors only for the greatest damage zone, coordinate the earthquake related activities of the Illinois Emergency Management Agency, enter into agreements with neighboring states to facilitate response and recovery operations including identifying common emergency routes between states in the NMSZ, develop a research plan to implement the Commission's hazard reduction plan, and report annually to the Governor and Legislature on its findings, progress, and recommendations relating to earthquake hazard reduction in Illinois.

The proposed statute would also expand the Earthquake Awareness Program under the Illinois Emergency Management Agency (IEMA) to train and educate state and local officials and volunteers on earthquake response and recovery activities, coordinate all government officials in preparation, guidance, and assistance for response to and recovery from an earthquake, establish agreements with contractors and construction equipment companies to utilize their equipment, expertise, and supplies in the event of an earthquake, and continue dissemination of information to the public pertaining to the earthquake hazard, protective measures during and after an earthquake, and other matters the IEMA or Seismic Safety Commission determine necessary or appropriate to educate, inform, and equip Illinois citizens.

C. Seismic Design of Public Buildings and Structures

We propose that legislation address the seismic design of public structures in the greatest earthquake damage zone, i.e., south of Effingham. In particular the legislation would require essential facilities, such as hospitals, fire stations, police departments, and highway bridges, to be strengthened to withstand the expected ground surface accelerations from a large NMSZ quake. The Illinois Department of Transportation has already started retrofit activities to the Interstate 57 Bridge over the Mississippi River near Cairo, Illinois. The proposed legislation could task the Seismic Safety Commission with developing the design NMSZ earthquake for these structures by adopting the appropriate level of risk or probability of an earthquake and the appropriate

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[197] 1996 Missouri Senate Bill 826.

return period. For example, Table 2 presents probabilities of recurrence of various earthquakes in the next 15 and 50 years. The Seismic Safety Commission could be tasked with determining whether or not all essential facilities should be designed to resist an earthquake with a magnitude between 7.5 and 8.0 given that the probabilities of recurrence are 6-10% and 21 –33% in the next 15 and 50 years, respectively. In addition, the Commission could be tasked with developing and adopting earthquake performance criteria for structural and non-structural components (bookshelves, light fixtures, shelving, hot water tanks, oxygen tanks), seismic evaluation procedures, and standards for retrofitting these essential facilities.

D. Seismic Gas Shut-Off Valves in Public and Private Structures

The proposed legislation could require the installation of emergency seismic gas shut-off valves in the greatest damage zone (south of Effingham) to reduce the potential for fire after an earthquake. Fire was the main cause of the damage from the 1906 earthquake near San Francisco because of the lack of water and the collapse of many firehouses. Therefore, measures that reduce the potential for fire should be implemented especially when the retrofit activities are implemented over a period of time, which is the case in the NMSZ because the threat is not imminent.

Proactive measures, such as seismic gas shut-off valves, could be installed to reduce the amount of other retrofit measures that need to be implemented.[198] These shut-off valves cost roughly $180 and one to two hours of a plumber's time to install, a relatively small expense for lifetime protection from gas-induced fires.[199] Installation of seismic gas shut-off valves could be required on new gas lines and gas lines that are repaired. Therefore, gas lines not in the greatest damage zone or not being repaired would not have to be retrofitted because of the low frequency of earthquakes in the NMSZ. Installation of seismic gas shut-off valves instead of current manual gas shut-off valves is a cost-effective means for controlling the aftermath of an earthquake and postponing the need to immediately retrofit all water lines and sprinkler systems to be operational after an earthquake to prevent a 1906 type fire. If a seismic gas shut-off valve is installed, the potential for a gas-induced fire occurring at or near the hot water heater or furnace is eliminated. However, a property may still desire to secure the hot water heater to a wall to reduce the potential for water damage caused by the heater leaking or overturning. Specifications for the seismic gas shut-off valves could be adopted from the California Office of the State Architect.[200]

E. Earthquake Insurance

In the initial earthquake related statute it is proposed that no provisions for earthquake insurance be promulgated until the insurance industry has had an opportunity to respond to the proposed division of Illinois into three damage zones. If suitable earthquake insurance is not

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[198] See text at note 172, *supra*.

[199] Information obtained from authors' inquiries, based on California prices. The valve works by having a metal ball perched/balanced above the open gas line inside the valve. If the gas line is jostled, the metal ball will fall off the perch that it is balanced on and close the gas line.

[200] California Health & Safety Code §19202 – Seismic Gas Shut-Off Valves.

available or the premiums cost prohibitive, Illinois could enact legislation similar to Arkansas Code,[201] which makes residential earthquake insurance available to homeowners via a Market Assistance Program (MAP) or a State entity like the Arkansas Earthquake Authority.[202] Such a program should only be initiated upon evidence that market forces are undersupplying earthquake insurance.

F. Seismic Monitoring

The proposed statute should establish the Illinois Center for Earthquake Engineering Research at the University of Illinois at Urbana-Champaign and involve all public universities situated in Illinois. Special attention should be given to cooperation and collaboration with Southern Illinois University at Carbondale (SIUC), because it is located in the greatest potential earthquake damage zone. For example, SIUC could coordinate the seismic monitoring and reconnaissance activities because of its proximity to the NMSZ. The objective of the Center is to reduce casualties, property losses, and economic or other disruptive consequences of earthquakes in areas of high seismicity through the advancement of knowledge and technology in the earthquake-engineering field. The center shall develop methods for identifying and quantifying the risks of large infrequent earthquakes and shall develop cost-effective strategies for reducing those risks to reasonable levels given the low frequency of occurrence. In addition, the reduction of earthquake risk should be coupled with the reduction of risk from other natural hazards encountered in Illinois, such as tornados, wind, flooding, fire, and ice storms.

VI. CONCLUSION

Risk of earthquake-related damage has historically been under-appreciated in the Midwest, even though the region has been the home of the largest earthquakes in modern American history.[203] This under-appreciation results in part from the "availability bias" that leads actors to overestimate the probability of recently occurring events. Although the probability of a major earthquake in the NMSZ is less than that in California, the expected damage from an earthquake if one occurs is much greater because of geological features and because policymakers and the public have not taken adequate steps to mitigate damages. A simple application of the Hand formula suggests that, given the significant risk, policymakers and the public should take reasonable steps to mitigate expected damages. In the case of private actors, this will shield them from tort liability that might otherwise accrue and possibly more expensive rebuilding costs.

Earthquakes cannot be avoided. Damage from earthquakes, however, can be minimized through prudent public policy and private care. The article has described the legislative regimes related to earthquakes in California and the states of the NMSZ. Illinois, in particular, has so far

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[201] Arkansas Code Annotated §23-102-110 - Arkansas Earthquake Authority Act.

[202] Arkansas Code Annotated §23-102-113 - Arkansas Earthquake Authority Act.

[203] Johnston, *supra* n. 5.

not developed an adequate legislative regime to minimize earthquake damage even though the risk to parts of the state are as great as in neighboring states with more developed legislation. The legislative regime for Illinois proposed herein would begin to redress this problem, and help ensure the safety of Illinois residents in the event of a major earthquake.