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BUSINESS DISRUPTION DUE TO
EARTHQUAKE-INDUCED
LIFELINE INTERRUPTION

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ABSTRACT

The importance of continuity in the provision of lifeline services has been long recognized with respect to facilitating emergency response to a major earthquake, but little attention has been directed toward the importance of lifeline continuity for minimizing economic disruption. This paper focuses on the indirect economic impacts of lifeline disruption on businesses. A study was conducted with a random sample of businesses in Memphis, Tennessee to determine their dependence on various lifeline systems and what level of economic impacts businesses would experience if those systems failed. Findings point to the need to address this problem with a collective approach by integrating lifeline service providers into community recovery planning and by involving business associations in educational programs for their members.

INTRODUCTION

One of the major problems in anticipating the magnitude of economic losses that can be caused by a destructive earthquake is understanding the various, complex ways in which the economic sector—including both large and small businesses—can be effected. This information is extremely important to communities that are trying to develop both emergency response plans as well as community recovery plans. While engineers have been working on loss estimation methodologies for the last 15 years (cf, NAS, 1989) the losses they have principally been concerned about were those due to direct (or primary) effects of earthquakes; that is, the structural and non-structural damage to buildings and their systems due to ground motion.

In contrast, the approach taken in this paper will focus on the indirect (or secondary) effects of an earthquake that prohibit businesses without primary damage from operating in a normal way. One of the primary ways in which undamaged businesses' activities could be restricted is through the loss of lifeline services. Tierney (1994), in a recent analysis of the

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impacts of the 1993 Midwest Floods on Des Moines, Iowa, concluded that damage to lifelines and resultant service interruptions were a more important cause of business disruption than was the physical flooding itself.

As recently illustrated by both the Northridge and Kobe earthquakes, the effects of lifeline failures go far beyond the immediate impact area, creating problems for the economic health of an entire metropolitan area and, perhaps, beyond. However, no research has ever addressed this question of the relationship between lifeline failures due to an earthquake and economic consequences for the affected area. This paper begins to address this neglected area of research.

LITERATURE ON BUSINESS DISRUPTION

As significant as the economic sector obviously is in the recovery process for any community, it has received almost no attention from social scientists involved in disaster research. In his extensive review of disaster research findings, Drabek (1986) does not even mention the economic sector. After an exhaustive review of the literature on business recovery following a disaster, Dahlhamer (1992) found only three studies (Durkin 1984; French *et al.* 1984; Nigg and Tierney 1990) that specifically addressed this issue.

However, sprinkled throughout the disaster literature are indications of the disruption of community life due to the disruption of the business community. For example, one of the first events that documented the impacts of disaster on business communities was the Xenia tornado of April 3, 1974. The entire downtown area, housing the city business district, was devastated. Approximately 155 commercial and four industrial businesses in 121 structures were destroyed, including eight supermarkets. One hundred other businesses suffered major or minor damage (DRC 1976).

More recently, the downtown business district of Santa Cruz, California was devastated by the October 17, 1989 Loma Prieta earthquake. It was estimated that 60% (approximately 650) of the downtown businesses were destroyed or sufficiently damaged to require at least temporary closure (DRC 1993).

There are two compelling reasons why social scientists should study the business recovery process. First, businesses as units of analysis have many of the same characteristics as households: they vary in size, they have incomes, they age, they have socioeconomic locations in the social structure, they are physically housed in structures that are more or less vulnerable, they may be embedded in a network of community organizations, and the types and amount of resources they have access to varies. On the basis of these characteristics, some businesses are obviously going to be less vulnerable to a disaster agent and more capable of recovering from disaster impacts.

THE MEMPHIS BUSINESS STUDY: RESEARCH DESIGN

This study was conducted with businesses in Memphis and Shelby County, Tennessee in June, 1993. Memphis resides in one of the highest Modified Mercalli Intensity zones projected from the 1811-1812 great earthquakes that occurred within the New Madrid Fault zone (see Map, next page). The area around Memphis has not had any significant, large magnitude earthquakes in the recent century; however, earth scientists are anticipating that this area could experience an earthquake of magnitude 6 within the next 20 years.

Until recently, neither the building code for the state of Tennessee nor the city of Memphis required seismic design in engineered structures; and none of the lifeline companies in the area had taken seismic ground forces into consideration in the design of their systems. Because of the seismic hazard and vulnerability and because Memphis plays such a prominent role in the economic health of the region (including northeastern Arkansas), Shelby County was an excellent candidate site for this study.

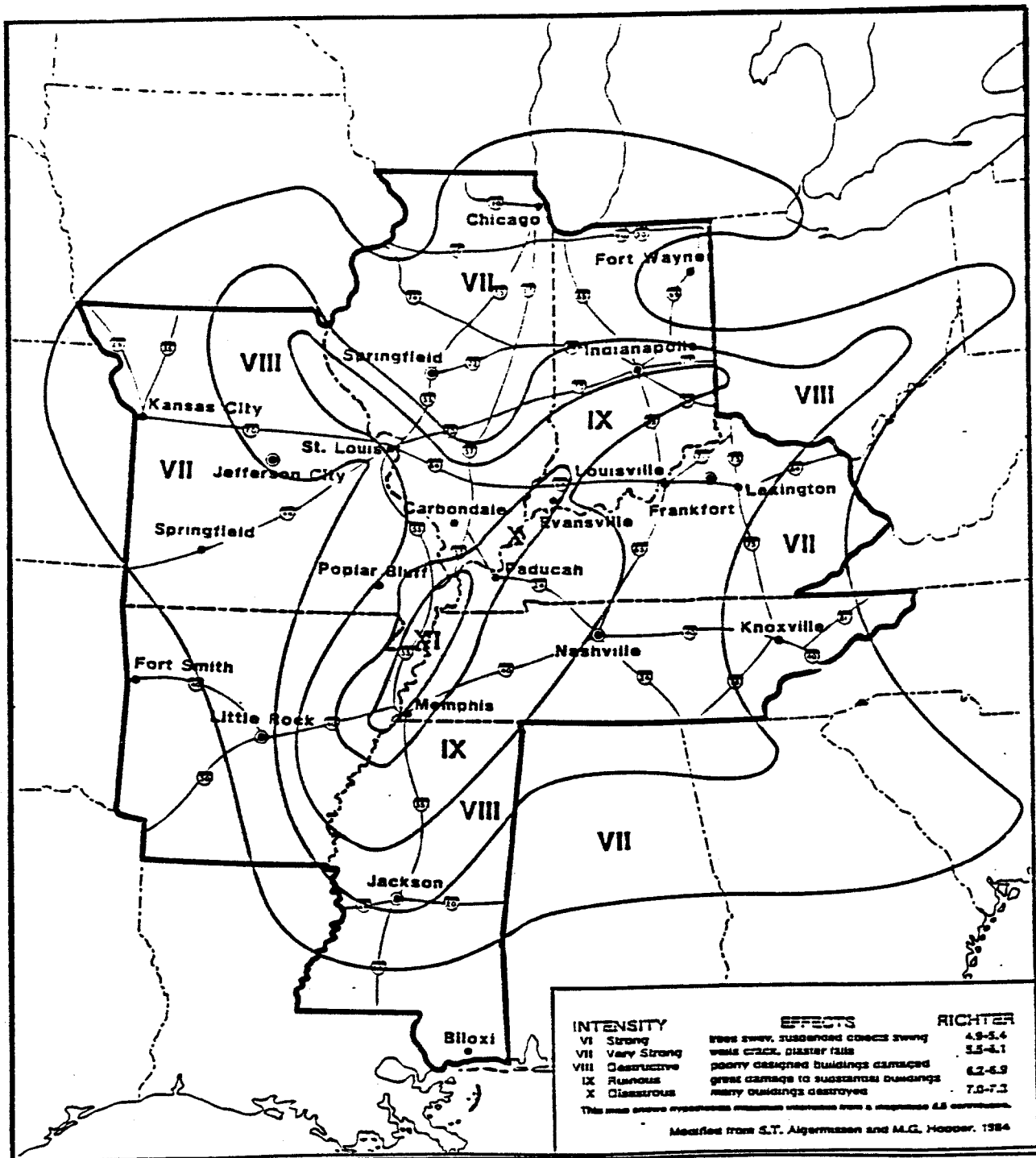
Shelby County has 34,106 businesses, which was the sampling frame for the study. These businesses were stratified on two criteria. First, because we hypothesized that different types of businesses might have different needs for lifeline services, businesses were classified into five sectors. Those sectors were: wholesale and retail trade; manufacturing and construction; business and professional services; financial, real estate, and insurance; and a residual category of other businesses (including agriculture, fishing, mining, forestry, and transportation).

Second, we hypothesized that large businesses (that is, those that employ more workers), if they could not function, could have a potentially larger negative impact on the economics of the region. We therefore divided businesses into two categories: small businesses having 19 or fewer employees, and large businesses with 20 or more.

We then sampled proportionately from each of the 10 subsamples, selecting 1840 businesses to be included in the study. This produced a sampling error of +/- 4%. The self-completion questionnaires were mailed to the businesses, with a cover letter requesting that the instrument be completed by the owner or manager of the business. Two weeks after the initial mailing, respondents were sent a reminder postcard; and four weeks later a second mailing was sent to all businesses that had not yet responded. We then made a follow-up phone call to each non-respondent to encourage their participation in the study. After four months, 735 questionnaires had been returned, yielding a response rate of 40%.

CHARACTERISTICS OF BUSINESSES IN THE STUDY

Before looking at how these businesses evaluated their reliance on lifelines, it is important to know something about them--how old they were, what type of ownership the business had, whether they owned the building that housed their business, and how many employees that had.



Businesses ranged from new enterprises, open for only one year, to established companies, the oldest having been in business for 139 years. The average time they had been in operation was 22 years. Businesses in the service sector and smaller businesses were significantly newer than other types of businesses. Over two-thirds (69%) of the businesses were independent; that is, they were not a part of a franchise or a chain). Although the average number of employees was 60, the median number of employees was only 6, indicating the most businesses were small.

Only 37% of the sample owned the building which housed their business; others were renting or leasing their facility. In general, manufacturing operations were more likely to own their own buildings than were businesses in other sectors. Also, large businesses were more likely than small businesses to own their facilities.

IMPORTANCE OF LIFELINES TO BUSINESS OPERATIONS

Since we are interested in the effects of lifeline system interruptions or failures on business, we must first know which systems are most important to the businesses' operations during normal times. We asked owners to indicate, generally, the degree of importance each type of lifeline service had for the business under normal conditions. In Table 1, we see that electrical and telephone services are "very important" (82% and 78%, respectively) across all of the businesses. The availability of water and natural gas, and the ability to discharge wastewater were deemed to be much less important services on a day-to-day basis.

A similar pattern was seen when owners were asked how many hours their businesses could continue to operate if a particular lifeline service was not available (Table 2). Without electricity, the average company would have to close immediately; without phone or telecommunications service they would last for about 1/2 day. Without water or wastewater services, they would close after two days. Of those companies who used natural gas, they expected they could stay open for about one work week before having to close.

Influence of Sector and Size on Business Operations

We were interested in whether the type of business or its size would have any effect on dependence on lifeline services. As can be seen in Table 3, if water interruption were to occur, there is substantial variation across sectors and between large and small businesses in terms of the length of time they could continue to operate.

In order to investigate this variation empirically, we used the number of hours a business could remain open if a specific lifeline service were interrupted as our dependent variable. We used ANOVA techniques to look for consistency across the sectors and t-tests when we were comparing businesses on the basis of their size.

TABLE 1
IMPORTANCE OF LIFELINE SERVICE TO BUSINESS
OPERATIONS UNDER NORMAL CONDITIONS

IMPORTANCE	LIFELINE SERVICES				
	Electricity	Water	Natural Gas	Wastewater Treatment	Telephone
Very Important	82%	27%	18%	23%	78%
Important	14	34	29	32	17
Not Very Important	3	31	39	33	3
Not Important At All	1	8	13	13	2
TOTAL	100%	100%	99% ¹	101% ¹	100%

¹Does not total 100% due to rounding.

TABLE 2

MEDIAN NUMBER OF HOURS BUSINESSES COULD
OPERATE WITH LIFELINE LOSS

LIFELINE SERVICE	MEDIAN NUMBER OF HOURS
Electricity	0
Water	48
Natural Gas	120
Wastewater Treatment	48
Telephones	4

TABLE 3

MEDIAN NUMBER OF HOURS BUSINESSES COULD OPERATE
WITH LOSS OF WATER BY TYPE AND SIZE OF BUSINESS

TYPE AND SIZE OF BUSINESS	MEDIAN NUMBER OF HOURS
<u>Wholesale and Retail Trade:</u>	
Small ^a (N=124)	120.0
Large ^b (N=36)	24.0
<u>Manufacturing and Construction:</u>	
Small (N=64)	72.0
Large (N=26)	48.0
<u>Business and Professional Services:</u>	
Small (N=129)	24.0
Large (N=52)	23.5
<u>Finance, Insurance, and Real Estate:</u>	
Small (N=71)	120.0
Large (N=23)	8.0
<u>Other:^c</u>	
Small (N=61)	168.0
Large (N=29)	72.0
<u>All Businesses (N=627):</u>	<u>48.0</u>

^a Small businesses are those with 19 or less employees.

^b Large businesses are those with 20 or more employees.

^c "Other" consists of agricultural, fishing, forestry, mining, transportation, and public communications firms.

When electrical service was interrupted, 59% of the businesses reported they would have to shut down immediately; but 5% said they could operate indefinitely without the service. Neither sector nor size mattered (Table 4); the availability of electricity was critical to the functioning of all businesses, irrespective of type or size. While fewer than one-fifth (18%) of the natural gas users would have to shut down immediately, neither economic sector nor size of the business had any effect.

Economic sector was found to be important when considering both the loss of wastewater disposal and telephone services. Although one in five businesses reported that they would have to close immediately if wastewater or sewerage services were lost, those service-oriented businesses would have to close significantly sooner than other types of businesses. While 45% of all businesses reportedly would have to close immediately if telephone (or telecommunications) services were lost, those businesses in wholesale or retail trade could stay open significantly longer than businesses in other sectors.

Size of the business was found to be important only when water systems failed. Even though 1/4 of all business would have to cease operations immediately if water weren't available, small businesses could operate significantly longer than larger ones without water.

Effects of the Loss of Multiple Lifeline Systems

What we have learned from past earthquake disasters is that multiple lifeline systems are often disrupted in the same event. In the Northridge earthquake, for example, water, wastewater, and natural gas systems were disrupted over large parts of the San Fernando Valley for an extended period of time. Due to the Kobe earthquake, electrical service to large parts of the metropolitan area was not restored for nearly a week.

In order to investigate what the combined effects of the disruption of these systems would have on a business's ability to continue to operate, a composite measure of disruption was created by counting the number of times an owner indicated that a lifeline service was "very important" to the functioning of the business (as presented in Table 1).³ As indicated in Table 5, almost 2/3 of the businesses (65%) would be "very disrupted" if two to four of these systems were interrupted by an earthquake. For only two percent of the businesses were no lifeline systems very important, subsequently, they would experience little disruption.

IMPLICATIONS OF FINDINGS ON LIFELINE IMPORTANCE

These findings give us an important, and overlooked, perspective on the criticality of lifelines for business continuity in the immediate post-earthquake impact period. Even businesses that could function because their facilities and buildings sustained no structural damage would be

³ Because natural gas was not used by everyone, it was deleted from this measure. Disruption only refers to the loss of electricity, phone, water, and wastewater disposal services.

TABLE 4

EFFECTS OF SECTOR AND SIZE ON BUSINESSES' ABILITY TO CARRY ON
NORMAL OPERATIONS WHEN A LIFELINE SERVICE IS INTERRUPTED

LOST LIFELINE	% CLOSE IMMEDIATELY	% OPERATE INDEFINITELY	SECTOR EFFECTS (F)	SIZE EFFECTS (t)
Electricity	59%	5%	1.53	-.84
Water	25%	12%	.88	-2.31*
Natural Gas*	18%	12%	.21	.56
Wastewater/ Sewerage	20%	a	3.02*	1.12
Phone/ Telecommunications	45%	4%	3.40**	1.11

* Significant at the .05 level

** Significant at the .01 level

a Less than 1%

TABLE 5

INDEX OF TOTAL EXPECTED DISRUPTION OF LIFELINE SYSTEMS
ON ABILITY TO CARRY ON BUSINESS ACTIVITIES

SEVERITY OF EXPECTED DISRUPTION	PERCENTAGE
Extreme Disruption	28%
Major Disruption	37
Modest Disruption	33
Little Disruption	<u>2</u>
TOTAL %	100%
TOTAL N	(704)

disrupted if lifeline systems fail. We now have some indication of how vulnerable businesses, especially those of a certain size and in specific business sectors, are to economic disruption because of lifeline system failures. And, since we know that multiple lifelines are often severely interrupted during the same event, we have some assessment of the extent of possible business disruption due to the failure of multiple lifeline systems.

Even if business owners and managers had acted on the need to structurally reinforce their buildings or to lease only properties that were structurally sound, such investments may not protect them from economic disruption. If they lose lifeline services--especially electricity and phone services--they may have to close anyway until those services are restored.

This information on importance of lifeline services gives lifeline providers--both public and private--some indication how quickly they must be able to restore service before substantial secondary economic losses will begin to take place within the functional business community. We now have evidence to indicate that lifeline "hardening" and service restoration are not only important in assisting the community during the emergency response period, but in reducing post-impact economic losses within the larger area and in speeding the community's recovery.

These findings demonstrate the need for communities to incorporate lifeline service providers into their disaster response and recovery planning in order to decrease the secondary effects of an earthquake event. Clearly, the emergency management officials and leaders in the business community must become more active in making the economic sector aware of the potential problems they could face and develop strategies to deal with these problems.

However, it should not be assumed that business owners can resolve these problems on an individual basis. The potential economic disruption due to lifeline losses is a collective problem, beyond the capability of any individual owner to address. This issue is one that needs to be addressed from a collective basis, including lifelines service providers, emergency management and community officials, and business organizations.

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