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AFTER THE TERRORIST EVENTS OF SEPTEMBER 11, 2001, there has been renewed interest among firms to protect economic assets against unforeseen disruptions. In particular, the potential effects of disruptions on supply chain management are of importance to practitioners and academics. In this article, Professors Sang Lee and Marijane Hancock of University of Nebraska-Lincoln report the findings from a survey of managers from a variety of industries on whether their supply chains were affected by the event of September 11, 2001. They also found that some firms chose to be proactive immediately after the event by stockpiling additional inventory, while others chose not to do so. Reasons for this pattern are offered. We hope that this important study will stimulate additional interest on the topic amongst our members and generate further debate and possible future articles on supply chain risk assessment and risk management.

Disruption in Supply Chain Due to September 11, 2001

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Agility of the supply chain has become a focus of organizations faced with today's highly discontinuous business environment characterized by rapid technological change, global competition, and demanding customers. Many believe that agility is fundamental to maintaining a leadership position in the global market. However, the terrorist attack on September 11, 2001 (9/11), on the U.S. set off a chain of events that raised concerns about the agility of the supply chain in the case of unforeseeable disaster. There has been little empirical research published on the relationship between the aftermath of 9/11 and changes in the supply chain to adjust to the circumstances. This study presents findings on the length of disruption due to 9/11 and changes in days of supply and the primary mode of transportation and distribution. Data were collected from a sample of members of the Institute for Supply Management. The results indicate that while 34 percent of the respondents experienced a disruption in supply, there was no major change in days of supply or the pri-

mary mode of transportation used for distribution.

The effects of the terrorist strikes on September 11, 2001, against the World Trade Center in New York and the Pentagon in Washington, D.C., are still reverberating worldwide. The long-term effects of the 9/11 attacks on business should be left to historians to analyze years or decades from now. However, by late afternoon on September 11, the U.S. was on full alert. An estimated quarter-million federal employees, except for essential personnel, were sent home. The White House, the U.S. Capitol, and other potential at-risk buildings were evacuated. Military jets patrolled the skies over the country's major cities scanning for possible terrorism. President George W. Bush was moved to a secure location and prepared to address the country about the terrorist attacks that took the world by surprise.

Impact of 9/11 on Transportation

Immediately after the attack, the U.S. Customs Service moved to Alert Level

One, which called for intensive antiterrorism operations at all borders and points of entry. The U.S.-Mexico and U.S.-Canada borders were closed down entirely. For 36 to 48 hours post-attack, no trucks were allowed to cross the borders. Trucks were eventually allowed to proceed, but had to endure an average wait of 15 to 20 hours to cross the border, compared to a normal time of 30 minutes (Smith, 2001). After the initial closedown, customs checks became an eight- to nine-hour process as customs agents searched each truck and checked the manifest, plus driver's license, passports, and birth certificates (Smith, 2001).

The shut down of the U.S.-Canada border, with over 200 million crossings per year, had the most repercussions. Canada was the U.S.'s largest trading partner, with trade in goods in 2000 amounting to approximately \$411 billion, marking the largest trade relationship that had ever existed between two nations. The U.S.-Mexico border, spanning 1,951 miles, had approximately 300 million people, 90 million cars, and 4.3 million trucks crossing annually. By 2000, Mexico had become the second most important U.S. trading partner with trade in goods amounting to \$112 billion—more than the U.S.'s third and fourth trading partners, Japan and the U.K. combined (Shuman, 2002).

Railroads faced speed and service restrictions in the northeast U.S. immediately after the attacks. Some shipments were delayed 24 to 48 hours. However, all rail companies were operating almost normally three days after the attacks. Security was heightened as inspections increased along main lines, bridges and tunnels, and other infrastructure (Seewald, 2001). U.S. seaports also experienced minimal delays, even though additional procedures to ensure safety and security were implemented. Vessels were escorted in and out of ports, and vehicle and ID checks were performed (Mortan et al., 2001).

Out of all modes of transportation, airlines were the most adversely affected. All commercial air service was shut down, airports were emptied, and the Federal Aviation Administration

(FAA) prohibited passenger planes from carrying cargo. A week after the attacks, most airlines were offering full services again, and the ban by FAA was lifted. The only contingency on carrying international cargo was that it had to be off-loaded at the first U.S. city at which the plane arrived, where it then had to be moved to its final destination by surface transportation (Mortan et al., 2001). The grounding of all planes after the terrorist attacks caused the airlines a loss of approximately \$650 million (Economist, 2001).

Soon after the incidents, reports appeared in the popular press about the effects of the September 11 terrorist attacks on business, in particular on the disruption of supply and distribution. Many manufacturers were forced to close down their plants because parts needed to keep lines running could not be delivered. One industry with extreme sensitivity to border disruptions is automobile manufacturing.

The parts shortage that occurred as a result of border delays held the auto industry hostage. The Big Three auto companies, General Motors, Ford, and DaimlerChrysler, keep as little as 24-hour supply of parts in inventory and all other automakers as little as two days supply (Lynn, 2001). Auto production was halted at more than 60 plants in the U.S. and Canada on 9/11 as manufacturers were unable to get critical inventory (Ward's Auto World, 2001).

Ford closed all Canadian and U.S. manufacturing facilities, as did DaimlerChrysler Corp., Toyota Motor Mfg., and Mitsubishi Motor Mfg. Ford cut production 13 percent the week following the attacks because of blocked parts delivery and still ended up losing more than 16,000 units of production by the end of that same week. General Motors initially lost about 100 total hours of production at eight plants—six in the U.S. and two in Canada—and a week after the attacks reported 10,000 lost units of production (Bryce, 2001). BMW reported 750 units of production were lost when it ceased production at its Spartanburg, S.C., plant, and Toyota and Honda had to shut down plants

for a few days after the attacks. All automakers with North American facilities were affected, resulting in an estimated 52,636 units of production lost in the first week (Ward's Auto World, 2001).

A Survey

Initial reports in the popular press and then editorials speculated that there would be a significant change in how industry managed inventory in the post 9/11 period. There was speculation that businesses would need to build up an additional inventory to be prepared for future incidents. The purpose of this study was to answer three basic questions: Was there a disruption in supply? Did businesses change their level of supply? Did businesses change their mode of transportation?

A 10-item questionnaire was developed to collect data on the extent of the disruption of 9/11 on supply. The Institute of Supply Management (ISM), an association of purchasing and supply chain managers, granted access to their membership. Eighteen of the twenty general categories of economic activities classified by the 1997 National American Industry Classification System (NAICS) were identified that could potentially be affected by a disruption in supply. ISM provided mailing labels for a stratified sample of 1,000 individuals randomized across the 18 NAICS categories. A mailing was sent to individuals that included a printed survey and a postage-paid return envelope. Fifty of the addresses were invalid. Of the 950 surveys delivered, 134 valid responses were received for a return rate of 14 percent.

Summary of Responses

The distribution of survey respondents across NAICS categories was not representative of the initial sample provided by ISM. Therefore, only frequency distributions are reported here. The distribution of the responses by NAICS category (industry) and by response to the question "Did you experience a disruption in supply due to the September 11 terrorist attacks?" is described in Table 1.

Responses from four industries made up 77.4 percent of the total. Those categories and percent responses were: Manufacturing, 56 percent; Utilities, 10.4 percent; Construction, 9 percent; and Wholesale Trades, 6 percent; respectively. Responses from industries in the other 14 NAICS codes and those listed as Other totaled less than 5 percent. Of the respondents, 34 percent reported they had experienced a disruption due to 9/11; 66 percent reported no disruption.

Frequencies were also calculated within industry by disruption in supply cells for the other 4 variables collected. These variables include: (1) days of supply prior to 9/11, (2) change in supply post 9/11, (3) change in mode of transportation; and (4) size of industry.

Respondents were asked to categorize days of supply prior to 9/11 by 0-3 days, 4-7 days, 1-2 weeks, or over 2 weeks (see Table 2). Over half of all respondents, 53.5 percent, indicated they had on hand over 2 weeks of supply. The response was consistent across industry with the exception of Wholesale Trade reporting 85.7 percent with over 2 weeks of supply. Response was similar between those answering that they had a disruption due to 9/11 and those responding in the negative. The days of supply for those experiencing a disruption were 0-3 days, 11 percent; 4-7 days, 13 percent; over 1 week, 27 percent; and over 2 weeks, 49 percent. For those not experiencing a disruption, days of supply were 0-3 days, 8 percent; 4-7 days, 15 percent; over 1 week, 20 percent; and over 2 weeks, 56 percent.

The response to the question "Did you adjust your days of supply after 9/11?" was 79.1 percent *no adjustment*, 11.2 percent responded *yes, they increased the days of supply*, and 9.7 percent responded *yes, they decreased the days of supply*. Manufacturing, Utilities and Other had a response pattern similar to the aggregate response. However, Construction reported no, 76.9 percent; yes increased, 0 percent; and yes decreased 23.1 percent. Wholesale Trade reported no, 50 percent; yes increased, 37.5 percent; and yes decreased 12.5 percent. Be-

NAICS Category	Disruption in Supply Chain				Total Response	% of Response
	Yes	% Yes	No	% No		
Manufacturing	26	35	49	65	75	56.0
Utilities	4	29	10	71	14	10.4
Construction	4	33	8	67	12	9.0
Wholesale Trade	4	50	4	50	8	6.0
Other	8	32	17	68	25	18.7
All industries	46	34	88	66	134	100

Table 1: Responses to the question: "Did you experience a disruption in supply due to the September 11 terrorist attacks?"

NAICS Category	Days of Supply Prior to 9/11	Disruption in Supply Chain	
		Yes	No
Manufacturing	0-3 Days	8	10
	4-7 Days	12	15
	1-2 Weeks	32	17
	Over 2 Weeks	48	58
Utilities	0-3 Days	50	10
	4-7 Days	25	20
	1-2 Weeks	0	0
	Over 2 Weeks	25	70
Construction	0-3 Days	0	0
	4-7 Days	25	25
	1-2 Weeks	25	25
	Over 2 Weeks	50	50
Wholesale Trade	0-3 Days	0	0
	4-7 Days	0	0
	1-2 Weeks	0	33
	Over 2 Weeks	100	67
Other	0-3 Days	13	7
	4-7 Days	13	13
	1-2 Weeks	38	40
	Over 2 Weeks	38	40
All Industries	0-3 Days	11	8
	4-7 Days	13	15
	1-2 Weeks	27	20
	Over 2 Weeks	49	56

Table 2: Days of supply prior to 9/11 by disruption by industry.

cause of the response pattern it is not possible to draw conclusions regarding the difference in response patterns. There were only 18 responses that described the increase of supply. The answers were evenly split across 0-3 days and 4-7 days. Ten respondents from across all industries indicated that they would decrease their days of supply.

When asked if they had changed the primary mode of transportation, 96.9 percent of the respondents answered no. All but one of the yes answers had increased ground surface trucking. The one differing answer said they had increased the use of airfreight. Response was not uniform across size of the firm. The numbers of firms reporting by size were less than 100 employees, 15 percent; 100-500 employees, 39.1 percent; 500-1000 employees, 10.5 percent; and greater than 1000 employees, 35.3 percent.

Summary and Conclusions

Since the distribution of responses across industry categories was not representative of the distribution of industries in the original sample, only reporting of descriptive statistics is appropriate. The results, however, suggest some interesting patterns and future research questions. The majority of responses were from industries whose activities rely heavily on inventory and movement through the supply chain. Responses from Manufacturing, where continuous availability of supplies and materials are essential, comprised 56 percent of the total responses. Of the 18 industries polled, Utilities, Construction, and Wholesale Trade were the only other industry segments with a response above 5 percent of the total. Preliminary examination of the disruption of supply due to 9/11 indicates that future detailed studies should focus on manufacturing, utilities, construction, and wholesale trades. High volume retail trade might also be considered as a target.

A disruption of supply following 9/11 was reported by 33 percent of the respondent firms. Of those, however, only 21.1 percent reported a subsequent change in days of supply. An examination of the days of supply prior to 9/11

indicates that 22.5 percent had 1-2 week of supply and 53.5 percent held over 2 weeks of supply, for a total of 76 percent with over 1 week of supply. Since the immediate effect of 9/11 was under 2 weeks, those with over 2 weeks of inventory would expect to have experienced little to no effect. The literature and press articles reviewed indicated that several industries, most notable the automotive industry, suffered significant disruption and manufacturing shutdowns. Future research could identify the length of disruption in supply that might cause a company to reconsider inventory policies.

Although reports immediately after 9/11 cited disruption in ground and air transportation due to border closings and additional security for rail, ship, and air, the results of this study found no change in the mode of transportation (Mortan et al., 2001; Seewald, 2001; Smith, 2001). The response pattern of this survey precluded any comments on the interaction of size of industry with disruption or level of supply. Any future studies should insure all efforts are made to look at industries across size.

This study indicates that although some industries experienced an immediate disruption following 9/11, it is unlikely that there were any major changes in days of supply or mode of transportation as a result. Armbruster (2003) points out that in the two years following 9/11, supply chain managers have faced a series of events including the 2002 West Coast port shutdown, the 2003 SARS epidemic, the 2003 strike against East Coast ports, and the blackout in northeastern U.S. and Canada. In addition to Armbruster's list, the invasion of Iraq has caused heightened security alerts.

We believe there are several potential explanations for the lack of major changes in days of supply or mode of transportation in response to the events of 9/11. Of the respondents who indicated they had a disruption in supply, 89 percent indicated that they carried over 4 days of supply. By 9/11, the economy had already started an economic slowdown from the highs experienced in 1999 and 2000. In addition,

industry had put contingency plans in place in preparation for a potential Y2K disaster. Also, during the end of the 20th century, as firms developed their abilities to move goods domestically and internationally, some aspects of the supply chain had already started changing. The growth and development of the e-commerce infrastructure has moving companies in the direction of coordinating all aspects of the supply chain. The result is a system that is becoming simultaneously more efficient and more flexible.

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