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TRANSITORY TROUBLE: INTER- AND INTRA-STATE HAZARDOUS MATERIALS FLOW IN SOUTH CAROLINA

Jerry T. Mitchell
Department of Geography and Geosciences
Bloomsburg University

Arleen A. Hill
Department of Geography
Bucknell University

Melanie Baker, Steven Jones, and Susan Cutter
Department of Geography
University of South Carolina

ABSTRACT: *This paper details the purpose, method, and results of a hazardous materials commodity flow analysis commissioned by the South Carolina Emergency Management Division for the state's interstate highways. A three-year hazardous materials placard and vehicle manifest survey was conducted to provide emergency management officials and other emergency responders with a baseline assessment of South Carolina's highways. The implications of this study for preparedness and response capabilities to handle hazardous materials incidents are discussed.*

INTRODUCTION

The use of environmental resources produces individual and societal benefits. At the same time, however, humans also create negative externalities, the unintended by-products and consequences of their interaction with the natural world. Such is the legacy of coal in Pennsylvania – the useful extraction of years past burdens society with acid mine drainage and other ills today. In addition to these waste products, our consumer society has created a wide array of products that while useful in one venue are toxic in another. The far-flung distribution of the American population and its increasing mobility means that many of these human-created threats are rarely stationary. This creates problems for emergency management. While hurricanes largely affect coastlines and avalanches equally specific regions, hazardous materials spills can occur virtually anywhere. Many earthquake faults have been mapped and those same faults will be there tomorrow, but a 12,500 gallon tanker truck identified in place 'X' today may be in another state within a few hours. Without a reliable tracking mechanism for this environmental threat (cargo information is usually proprietary and not accurately reported), emergency responders typically have no idea what or when transitory threats exist within their jurisdiction.

The frequency of hazardous materials spills underscores the importance of identifying the type, quantity, volume, and spatial distribution of hazardous materials in transit. Many accidents are 'minor,' sometimes involving a small spill or, unfortunately, the death of the driver. In relative terms these particular losses are small, but the potential risk of damage to people, property, and the environment may be much greater depending upon the type and quantity of the material carried, and the time and location of the incident (Cutter and Ji, 1997).

A hazardous materials commodity flow analysis was commissioned in 1999 by the South Carolina Emergency Management Division (EMD) for the state's interstate highways to address some of these difficulties. Studies documenting the risk from hazardous materials transport are few (Belardo et al., 1985; Quarantelli, 1991; Mills and Neuhauser, 1998; Pine et al., 1998; Cutter and Ji, 1997; Mitchelson et al., 1995). As little is currently known about the patterns of hazardous materials flows within South Carolina, this study represents a crucial first step for EMD by providing empirical estimates of hazardous materials flows within the state.

The specific goal of this project is to provide emergency management officials and other responders with a methodology for better understanding the risk associated with the transient nature of hazardous materials (hazmat) in their environment. Within this goal, the objectives are to develop a comprehensive database that details the substance and flow of hazardous materials that travel interstates and highways, to create a methodology for hazmat analysis that is transferable to other locations, and to investigate the spatial and temporal dimensions of hazmat transport to suggest response solutions that might mitigate future accident occurrences.

SOUTH CAROLINA STUDY AREA

The South Carolina study areas consist of interstate and U. S. highways in three regions, the Upstate, the Midlands, and the Low Country. Interstates 26, 85, and 385 comprise the Upstate and pass through counties with a total population in excess 700,000 people. The Midlands region of South Carolina includes I-77, I-20, I-26, and I-126. Columbia, Rock Hill, Florence, and North Augusta are the primary population centers (in excess of 1 million total). The Low Country includes I-26, I-526, Hwy 17 and 17A, Hwy 501, Hwy 521, Hwy 701, and Hwy 17 Business. U.S. highways are included here because they traverse more densely populated areas than do the interstates in this portion of the state. The

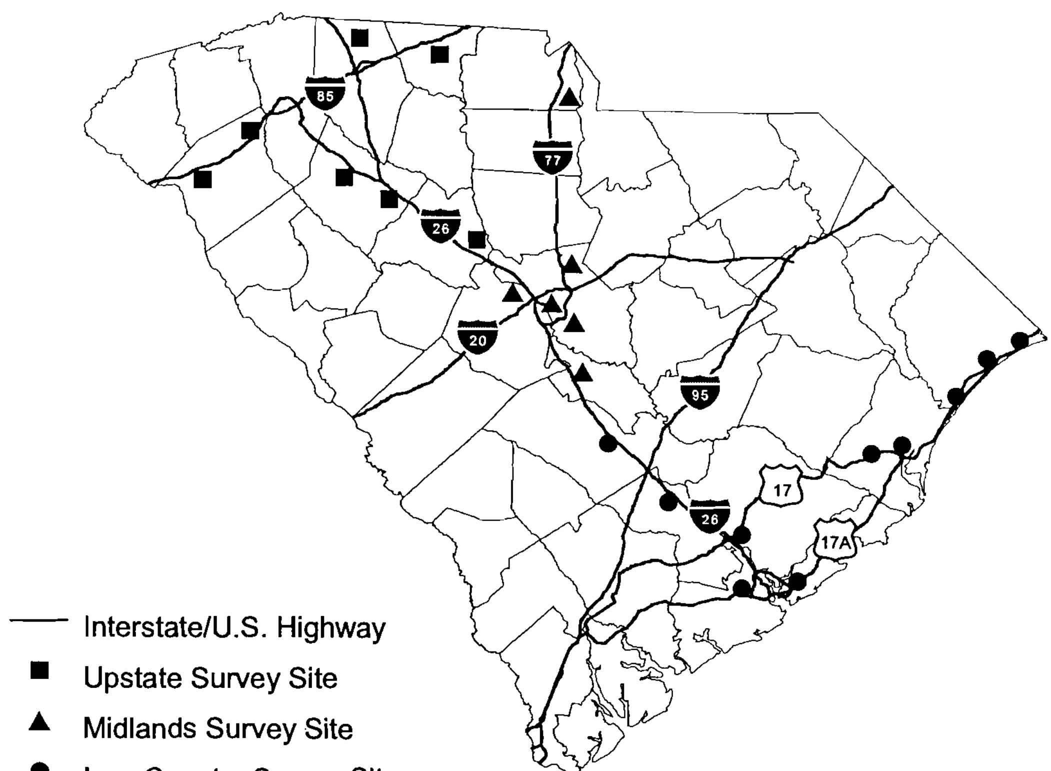

Figure 1. South Carolina study area.

Figure 2. Recording HazMat data along interstate highways.

main population centers include Charleston and Myrtle Beach (approximately 700,000 people total). Interstate 95 was excluded due to a concurrent study by another researcher.

METHODS

The data for this study were collected using two different methods: a placard survey of trucks and a vehicle manifest survey of hazardous materials haulers. The survey was conducted at various sites from January 1999 through August 2001 (Figure 1).

Placard Survey

A field survey instrument (loosely based on Belardo et al., 1985 and Mitchelson et al., 1995) was developed to monitor all 5-axle vehicle traffic (Figure 2). Throughout the study period, a total of 1,347 observation hours were recorded. Five two-member teams worked back-to-back, six-hour shifts. We were restricted to daylight hours only, so the shifts ran from 6 a.m. to 6 p.m. After the first six hour shift, the teams moved to observe the opposite traffic direction. The sites were surveyed at different days of the week to ensure that we had both peak and off-peak traffic. Every team kept track of each 5-axle (18-wheel) vehicle by hand-held counter to get an overall count of vehicular traffic. Smaller vehicles were included in the overall count if they had a placard. Table 1 provides a description of the data collected. For further verification of the truck traffic totals, the South Carolina Department of Transportation (SCDOT) laid count strips for a period of 24 hours before and after each site visit. No statistically significant differences (*t*-tests) were found between our traffic counts and those of SCDOT for any of the study sites or for any of the time periods.

Vehicle Manifest Survey

Vehicle manifest surveys were also conducted to acquire origin and destination information – and the volume of materials carried – for trucks displaying placards; these surveys were conducted at SCDOT weigh stations. With the assistance of the South Carolina State Transport Police, placarded trucks were waived over at the

Table 1 Survey Variables

All Surveys	Placard Surveys	Manifest Surveys
Time of Day	Hazardous Class Number	Hazardous Class Number
Day of Week	Material Guide Number	Material Guide Number
Survey Date	Carrier Name	Carrier Name
Interstate	Vehicle Type	Carrier Address (home base)
Location		Amount of Chemical Transported
Mile Marker		Vehicle Type
Direction		Vehicle (cargo) Origin
Survey Team		Vehicle Destination
		Basic Route Driven
		NAERG Safety Guide Possession

weigh station following their initial weigh-in. A 5-minute driver interview was conducted to collect data from the truck manifest. Table 1 provides a description of the data collected. All field data were added to a relational database for subsequent use in statistical and geographical analyses. Additional data added included evacuation distances for each chemical (NAERG, 1996), Chemical Abstracts Service (CAS) registry numbers, and the truck counts provided by the South Carolina Department of Transportation.

ANALYSIS AND RESULTS

Temporal Patterns

The first component of data analysis compared the volume of non-hazmat truck traffic (termed "regular truck") and the hazmat volume. These volume or frequency comparisons were made for hourly, daily, and seasonal time periods. Observations suggested that the volume of hazmats was low (4.4 to 7.1%) compared to regular truck traffic (Figure 3). Peak flow of regular truck traffic occurred on Wednesdays and Thursdays with

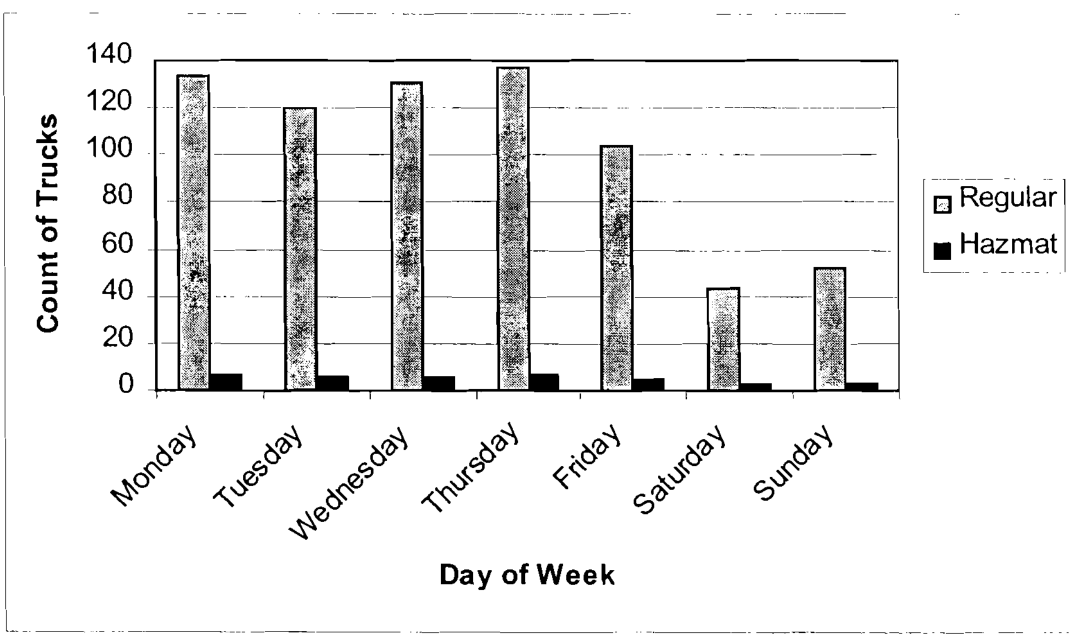

Figure 3. Weekly Truck Traffic.

Table 2 Percentage of Hazardous Material by Frequency

DOT ID	Hazardous Material	DOT Class	% of Hazmats
1203	Gasoline	3	26.5
1993	Fuel Oil	3	26.5
1977	Liquid Nitrogen	2	8.2
3256	High Temperature Liquids	3	4.1
2187	Carbon Dioxide	2	2.45
1073	Liquid Oxygen	2	1.63
1075	Propane	2.1	3.0
3082	Hazardous Waste, liquid	9	2.8
3257	High Temperature Liquids	3	1.9
1824	Sodium Hydroxide	6	2.8
3264	Corrosive Liquids	8	1.8
1863	Aviation Fuel	3	1.7
2794	Batteries	8	4.4
-	Other	-	12.3

significantly less traffic on the weekends. However, a higher proportion of hazmat haulers to regular trucks were observed for weekend days.

Another indicator of the timing of traffic was the distribution throughout the course of a day. Observations were made for all daylight hours and peaks in hazmat transportation occurred in the morning hours between 08:00 and 10:00 with a secondary peak in the early afternoons between 14:00 and 16:00; these observations did not vary daily. These findings are consistent for each individual phase of the research project, for each sub region of South Carolina, and for the dataset taken as a whole.

The final temporal investigation was the seasonal variation in transport through the state. In these analyses regional variations were discovered. In the Upstate a steady increase in both regular truck and hazmat traffic was observed between January and June, with the peak in the summer months. In the Low Country the trend is markedly different. The peaks for regular and hazmat trucks occurred in September and February with a low in November. The Midlands seasonal variation in frequency of both regular and hazmat trucks peaks in February with a low in June, similar to the trend for the Low Country. In general, the winter months, specifically February, were associated with the greatest volume of hazmat transportation in South Carolina.

Commodity Pattern

Determining when hazardous materials were flowing through South Carolina was an important first step of this study. Next the types and amounts of materials were considered. When identifying the most frequently transported hazardous material (based on the frequency or count of each placard displayed on vehicles), gasoline and fuel oil account for a majority of the materials transported on South Carolina roadways (Table 2). Aggregating the

Table 3 Percentage of Hazmat Class by Volume

Hazmat Class	Amount (1000 lbs)	% of Total
1: Explosives	75	0.43
2: Gases	5573	32.01
3: Flammable/combustible	6877	39.50
4: Flammable Solids	451	2.59
5: Oxidizers and Organic Peroxides	208	1.19
6: Toxic or Infectious Materials	373	2.14
7: Radioactive	12	0.07
8: Corrosives	2904	16.69
9: Miscellaneous	935	5.37

frequencies by DOT Class shows that Classes 3 and 2, flammable and combustible liquids and gases respectively, followed by Class 8 corrosives were the most frequently hauled commodities. However, when incorporating the actual volume of material being carried, relying on the manifest survey data, an additional part of the story is observed (Table 3). The frequency of class 8 corrosives was low, 1.8%, however, by volume they account for 16.69% of the hazardous materials.

Transportation Pattern

The final component of this analysis addresses the question: what was the hazmat origin and what is its final destination? A majority of the materials traveling on South Carolina interstates and highways had both origins and destinations within the state. This is a significant finding as it suggests that South Carolina experiences the economic benefits of the commerce while also shouldering the burden of the potential risk associated with the traffic. Notable exceptions to the intra-state trend were materials with origins in South Carolina delivered to Charlotte, North Carolina traveling on I-77 and materials with origins at an *AutoZone* distribution center in Lavonia, GA with destinations throughout the Southeast via I-85.

APPLICATION

The previous discussion highlights the general usefulness of the data collection – the establishment of a baseline for the hazardous materials traveling on interstate highways. The descriptive statistics provide emergency responders with an understanding of the spill potential in terms of type and quantity. Two possible mitigation approaches present themselves: 1) all responders in the state could be outfitted with protective gear and containment resources for all hazardous threats moving throughout the state; or 2) a subset of responders that is more likely to deal with a hazmat threat could be similarly supplied. Given the paucity of resources, the first option is problematic and diverts resources that may be used elsewhere. The second option appears more appropriate, but the issue of determining which responders to supply out of the total universe of fire and other responders remains.

Figure 4 highlights a solution. Within the North American Emergency Response Guide are recommended evacuation distances for each listed chemical (NAERG, 1996). For each interstate, in this case Interstate 85, the worst chemical (in terms of largest recommended evacuation distance) in transit may be identified. A buffer can be drawn around the location of a given accident, thus creating a 'risk-shed' for hazardous materials spills. In this example an accident has been "located" every one-tenth mile. A layer of responding fire stations has been included. The fire stations within the evacuation buffer reasonably are the best to equip with mitigation gear and procedures.

Another consideration applies to the likely affected population. Several "accident" sites in this example are far removed from population centers; others are not. In fact, several potential accident sites may lay proximate to more vulnerable populations – elementary schools, nursing homes, etc. It may be appropriate then to devise a ranking scheme to better allocate hazmat mitigation resources. The responders within the evacuation buffer near vulnerable populations would receive priority for resources, then responders in the buffer zone, and so on.

Problems, of course, remain. For example, the circular evacuation buffer does not match real world environmental conditions related to slope or wind dispersal of the spill. This example also keeps the vehicles on the interstate; at some point the vehicle will exit and create new zones of risk. Care must also be taken not to model simply because one can. For many emergency managers, it may be enough to tell them that a certain chemical exists within their area. Given that the risk of a spill is small, they may decide to allocate resources elsewhere. But they are at least armed with the knowledge of the potential problem.

CONCLUSIONS

While this study looks at a specific location (South Carolina) within a specific time frame (1999-2001), it does present a method of analysis which can be used anywhere by anyone to systematically quantify a largely unquantified risk. This study of hazardous material commodities flowing through South Carolina used two survey types to collect data regarding the nature of the risk associated with the transportation. Patterns in the frequency, amount, type, and timing of materials flowing though the state was observed and analyzed. Prior to this analysis little was known about the patterns of hazardous materials flows within the South Carolina. Importantly, the findings suggest that hazmats are a small proportion of the total 5-axle traffic on South Carolina's road network. Incidents involving hazmats are low probability events, but the consequence of the event could vary widely as attested to by the variety of materials carried. Additionally, the mid-day hazmat traffic peaking and regional variation in seasonality indicates that opportunities exist to re-orient mitigation and response resources to the times and locations that demand them. In addition to a more thorough analysis at the local level, other future avenues of inquiry include:

- When matching hazmat data with demographic data are some communities differentially more

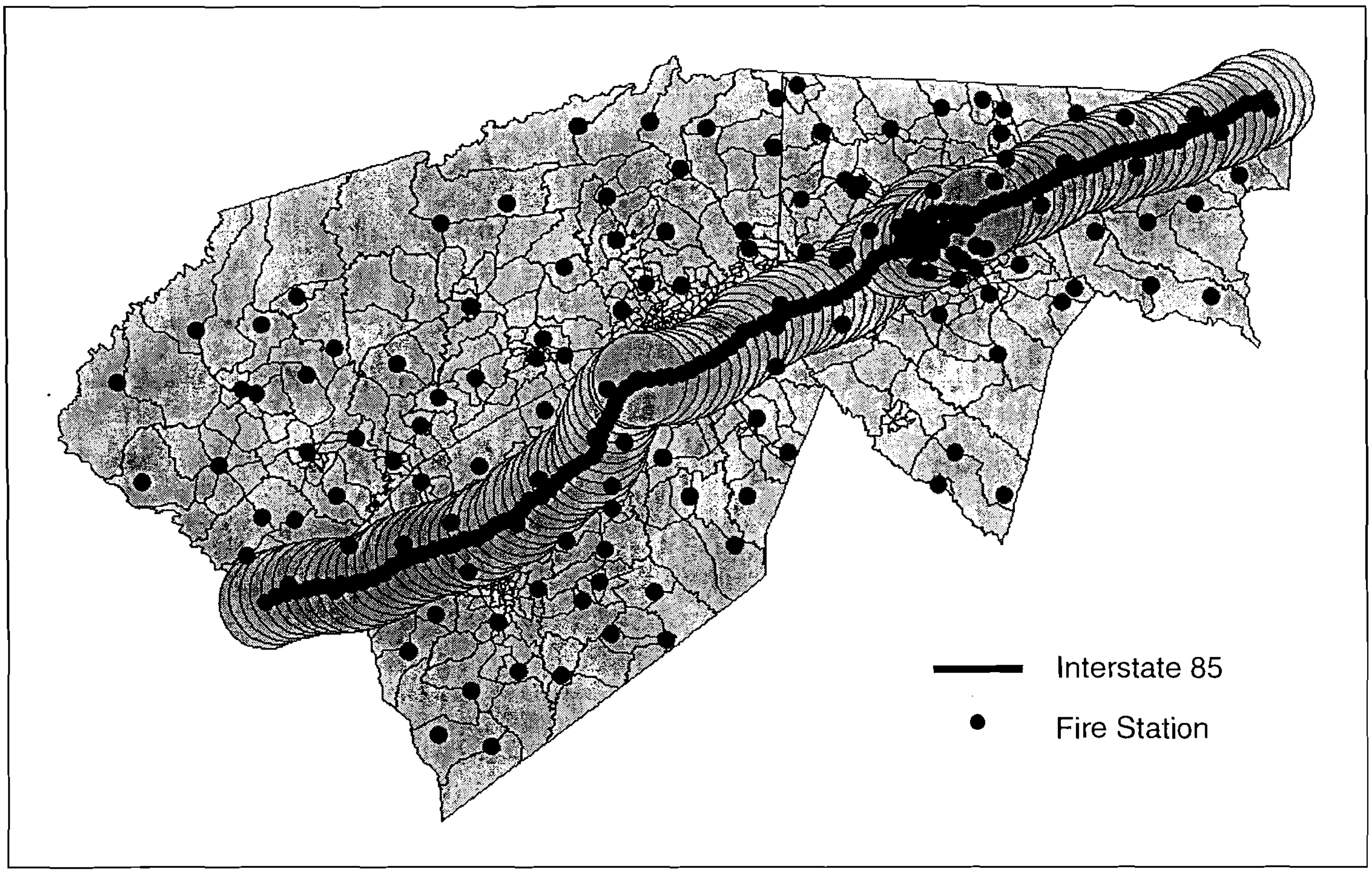

Figure 4. Creating a "Risk-shed" for HazMat spills.

vulnerable to hazmat spills than others? (e.g.: low-income housing is often co-located with transportation corridors or industrial land uses)

- Does the data collection methodology constructed suggest other opportunities to collect data and monitor this threat more effectively?

This study is a crucial first step in providing empirical estimates of hazardous materials flows within the state. These results should provide emergency officials and other responders with a baseline assessment of South Carolina's highways to improve preparedness and response capabilities to handle these events when they do occur.

NOTES AND ACKNOWLEDGEMENTS

More detailed information about the method and results of this study can be found in Cutter, Mitchell and Baker, 1999; Cutter and Baker, 2000; and Cutter, Hill, and Jones, 2001. Previous versions of this paper were presented at the Association of American Geographers annual meeting (New York City, March 2001) and the annual meeting of the Middle States Division of the AAG (Upper Montclair, NJ, October 2002).

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