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No-Notice Evacuations, Transport Security, and Environmental Injustice: An Exploratory Study

By

Lisa Schweitzer[1]
Pamela Murray-Tuite[2]
Claudia Avendano[1]
Daniel Inloes, Jr.[1]
Yasaman Deghani[3]
Mary Kuhn[1]
Jianping Zhou[1]
Carina Lieu[1]
Hoda Assadian[3]
Mohja Rhoades[1]
Fynnwin Prager[1]

[1]Sol Price School of Public Policy, University of Southern California
[2]Civil and Environmental Engineering, Virginia Tech
[3]Daniel J. Epstein Department of Industrial and System,

Corresponding Author:
Lisa Schweitzer
Associate Professor
University of Southern California
Los Angeles, CA 90089-0626
lschweit@usc.edu

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Project Abstract

The project objectives are three-fold. The first objective is to examine the geography of evacuations, injuries, and deaths caused by hazardous and toxic materials releases from 1998 to 2010. All of the hazardous materials releases from transport on all modes will be integrated into a geographic information data system, along with socio-demographic information from the U.S. Census. Distinctions will be made between minor and serious releases. Distinctions will also be made between spills that happen on intermodal or shipping sites and those that happen off-site and in-transit. This first level of analysis describes the national geography of where major events and evacuations have occurred, and whether those past events are useful proxies for understanding future events.

The second objective of the study is to examine the socio-economic make-up of the groups and individuals who live next to those release and evacuation locations. In this way, it will be possible to compare whether evacuations have occurred in areas occupied primarily by groups with lower socioeconomic status than elsewhere.

The final objective of the study is to examine the relationships between infrastructure, land use, and the likelihood of evacuation from a hazardous materials release. Previous research on hazardous materials has established that in addition to routing variables, land use is also a strong predictor of where spills will occur. This part of the study will contribute substantially to important contemporary debates about the safety and security of proposed new infrastructure, urban development, and intermodal facilities.

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Chapter 1: Overview of the Studies

No-notice (post-impact) evacuations can be a major challenge for transport policy given contemporary concerns about terrorist activities. Even so, comparatively little is known about them. This research examines the sociodemographic and spatial distribution of previous no-notice evacuations that have resulted from hazardous materials spills. It also part of building up a larger research project on understanding household evacuation decisions under extreme time constraints.

Previous transportation evacuation models have largely overlooked non-driving behavior [1], household decisions (other than when to evacuate [2, 3]), and geospatial variables. As a result, these models lead to overly optimistic evacuation time prediction and fail to capture complex travel patterns. While extensive research is available on hurricane evacuations, short- and no-notice evacuations have received little attention. This is a major problem for evacuation studies because, unlike hurricane evacuations, no-notice evacuations have greater space-time uncertainties associated with the events. Because evacuation time models can influence whether and when officials decide to give evacuation orders, these models affect how many people leave the area. The result can be overly optimistic evacuation time predictions, which portend potentially devastating consequences.

1. 1 Prior Research

No prior studies have attempted to do what is proposed here: to capture the combination of socioeconomic, infrastructure, and land use variables that a) contributed to elevated risks for evacuation and concurrently b) restricted or enabled individuals' planned evacuation behaviors. Most studies of hazardous materials spills focus on risk-minimizing algorithms without validating those against the empirical data record on where hazardous materials incidents occur [4-8]. The proposed research takes the opposite approach: it evaluates where accidents have occurred and attempts to describe the geographic conditions that increase the need for evacuation preparation.

The two previous studies of the geographic distribution of hazardous materials incidents examined only two regions: the Los Angeles region of southern California and two counties in New York. The New York research used modeled plumes to examine potential accident exposures among vulnerable populations [9]. The Los Angeles study looks only at geographic frequency of hazardous materials incidents, not the severity of the spills or the consequences that spills have had in prompting road closings and evacuations [10].

Neither modeling nor geographic approaches alone can address the complex interactions between land uses, populations, infrastructure supply, and evacuation options. Engineering has expended significant effort to model evacuations, particularly with respect to hurricanes, but no studies have examined the influence of geography and population on the risks and results no-notice evacuations [11, 12]. Engineering simulation models, such as NETVACl[13], MASSVAC [14, 15], REMS [16], and OREMS [17, 18], have focused on the traffic modeling aspects of evacuations. Other simulation tools included the spread of information [19, 20], and still others integrated geographical information systems [21, 22]. But all of these omitted social considerations.

Additional engineering studies have investigated methods with which to improve network performance through network modifications [23-29] and traffic control [30, 31] and demand management, such as staged evacuation [32-36]. While engineering studies are concerned with the quantities of evacuees and departure times [2, 3, 37-41], social network studies focus on characteristics that are associated with those who evacuate and those who choose to stay [42-52]. Neither approach integrates the complex geographic and social interactions between land use, urban populations, and chemical accidents that mark no-notice events.

The proposed research examines evacuations due to hazardous materials (HazMat) releases, which are known to cause mass evacuations [53] of significant distance 7+ miles[54]. They are a comparatively rare phenomenon. The US Commodity Flow Survey reports that in 2002, there were 326,727,000 ton-miles of hazardous materials shipped. The number of incidents reported that year was 15,114; so the incident rate per ton-mile is 0.000004625. Of those 15,114 incidents, only 222 caused a fatality, injury, or a serious evacuation (defined as six or more evacuees). Fatalities are a small percentage even among serious incidents; injury incidents and evacuations are prevalent compared to fatalities, but they are still very rare when compared to the volumes and mileage of hazardous materials shipping that occurs nationally. As a source of danger, acute exposure to hazardous materials spills is statistically just not very likely. In 10 years of data, 142 people have died. This scarcity affects the statistical analysis.

Nonetheless, the data also show that while the numbers are low, serious hazardous materials releases can have severe consequences at the community level, such as the evacuation of 10,000 people in Cincinnati in

2006 or the evacuation of 25,000 people in Greenville, South Carolina in 2002. Greenville's population is estimated to be around 56,000 people, so the evacuation cleared almost half of the city's population.

When combined with the nuisance, air quality problems, traffic safety and congestion, and noise issues associated with freight traffic more generally, hazmat events are disruptive and frightening when they occur. From 1997 to 2006, over 170,000 people have been evacuated because hazardous material releases during transport, while 2,752 people have been injured during this same time period. As with the consequences of many infrequent events like tornadoes or spree killings, aggregate numbers can mask the impact on a family or a given community of major accidents and evacuations, like Greenville. The proposed research uses spatial analysis to examine for geographic factors that correlate with high risks for major chemical releases in order to understand these impacts.

1.2. Data sources

This project used data from five major datasets: the Hazardous Materials Information System (HMIRS), the Hazardous Substances and Emergency Events Surveillance (HSEES) project, the Pipeline Hazardous Materials Safety Administration (PSMA) data, the US Census of Population, and local archives. These data are described in turn.

Hazardous Materials Information Reporting System (HMIRS). The HMIRS data are compiled from reports made by transporters and first responders. The data include many variables regarding the incident: the time of day, materials spilled, amounts, the carriers, what triggered the incident (e.g., human error, container failure), and the general roadway conditions. The data also include information on the consequences of the spills, including the number of people killed, injured, or evacuated. The data are collected, maintained, and distributed by the U.S. Department of Transportation's Office of Hazardous Materials Safety (OHMS).

Hazardous Substances Emergency Events Surveillance (HSEES). The HSEES data system is collected by the U.S. Department of Health and Human Services Agency for the Toxic Substances and Disease Registry. The program includes cooperative reporting agreements with the state health departments of 14 states, including New York, Florida, New Jersey, Texas, and Louisiana. The HSEES is a public database that collects information on acute hazardous materials releases and their consequences. It has been in existence since 1990. The HSEES collects data from both stationary chemical releases (65 to 75 percent of the yearly releases) and transport releases. The state departments of health report the geographic location, timing, substances and volumes of the release, and release consequences, such as evacuations, injuries and fatalities.

Pipeline Hazardous Materials Safety Data System. These data are collected in several data files by the U.S. Department of Transportation Pipeline and Hazardous Materials Safety Administration (PHMS) data. The PHMS contains data on both annual mileage and incident summaries for all hazardous liquids and gas pipeline releases. The data also include information on release consequences. These data are more difficult to model as pipeline locations are classified by Homeland Security, and access is limited to agency and company researchers. However, incident and evacuation locations are not.

Population data from the US Census. A large body of geographic research in environmental justice uses the spatial location of hazards, like spills, assigned to geographic units of analysis containing socio-demographic information from the US Census. This analysis follows the convention of previous environmental justice studies and uses Census data reported at the tract level to represent the population of individuals living next to hazmat routes, stationary sources, and chemical incidents.

Archival data. In addition to the existing data records, I will retrieve information on major evacuations from Lexus-Nexus, local newspapers, and agency reports.

1.3 Research hypotheses

Each of these datasets come from a different source; they will be reconciled using a geographic information system and deployed in multiple analyses designed to address specific hypotheses. Figure 2 is a summary graphic that shows how the data and the analyses fit together to answer four major hypotheses:

H1: Chemical releases from transport cluster together and cluster jointly with multi-modal facilities across space.

Because the previous research examined spill frequency in two regions without controlling for consequences, one of the gaps in the literature concerns whether the existing data record demonstrates a discernible geographic pattern for spills and evacuations across the US as a whole as well as within regions.

Hotspot analysis and co-clustering methods can help sort through some of these questions by creating local estimates of the measure of intensity λ. This process is also called kernel smoothing. Hotspots count the frequency of points within a given distance of each point, relative to a symmetric distribution. If $N(s,w)$ represents the number of events per unit area in a $w \times w$ square centered at *s*, then from another other point *u* from *s:*

$$\lambda_w(s) \equiv \frac{1}{p_d(s)} \left\{ \sum_{i=1}^{n} \mathrm{K}_d\left(s-u\right) \right\},\ w \in W \qquad \text{(eq. 1)}$$

Where *K* can represent any number of distributional functions.

H2: Spills causing evacuations occur disproportionately in high-frequency accident locations.

Severe releases may overlap with incident hotspot locations. Hazardous materials freight gathers on a comparatively small number of freeway and multi-modal links. Combined with human error in handling, the small number of routes would work to geographically concentrate spills in select locations. The same reasons may also work to spatially concentrate severe spills. Alternatively, there are several reasons why severe spills might not occur in the same general locations as the spill hotspots. First, the causes of the non-severe spills and severe spills differ; most routine spills occur from human error in transferring loads from one mode to another or in original shipment loading. But container breaches resulting from derailments and crashes are more common among severe incidents than among spills overall. These spills, unlike those caused by packing error, could occur anywhere along the route.

Fricker [55] developed a useful spatial methodology for detecting the spatial distribution of a unique location among other points. His method would be useful here, with a few adaptations. If we allow R_i to represent the count of spills in census tract *i,* we can assume R_i uses the Poisson distribution again with intensity (I_i). Severe spills S_i are a subset of all spills, so that S_i Ã R_i and $S_i \mid R_i$: binomial $\left(R_i, a\right)$. If S_i is simply a random subset of R_i, then there should be no discernible correlation between the counts of the entire set and the subset; that is, the number of severe incidents that occurs in any given I_i (the intensity per unit of space) should not systematically vary with the intensity of all spills, severe and not. If so, $S_i \mid R_i$: binomial $\left(R_i, a\right)$ describes a thinned Poisson point process, with some rate of thinning, a. The expected number of spills in any given zone, $\hat{e}$, will then be $R_i\hat{a}$, and we can test the expected value against the observed values. These tests will pinpoint high-frequency, high-consequence geographic zones.

H3: Spills and evacuations occur disproportionately in low-income communities and communities of color (environmental justice hypothesis).

We will use a buffer analysis surrounding each high-frequency, high-consequence location to gather nearby population data according to the U.S. Census of Population. From these, I plan to estimate two models for the data at the tract level. A log-linear generalized model with spatial lags will estimate the count of spills in a tract, testing particularly for socio-demographic variables. This model shows spatial correlation rather than causality, and this method is commonly used in geographic research on environmental justice [56-60]. In order to use the generalized linear model, the relationship between the dependent variable and its covariates should be linear.

These results of this analysis will allow me to locate places where there have been evacuations and places where there are vulnerable populations who have been evacuated. This step is an important part of the analysis because it will provide a basis for spatial sampling these populations for future research.

H4: Evacuations demonstrate a random routing effect and a urban-form/socio-spatial effect.

Based on the first three hypotheses and archival research on major evacuation events (over 1,000 people) over the past 18 years, I will test my hypothesis there is both a predictable spatial aspect to where evacuations occur and a random component unassociated with error.

The proposed research will examine the spatial characteristics between evacuation locations and specific infrastructure and land uses.

Figure 1 summarizes the global methodology that guides the remaining chapters.

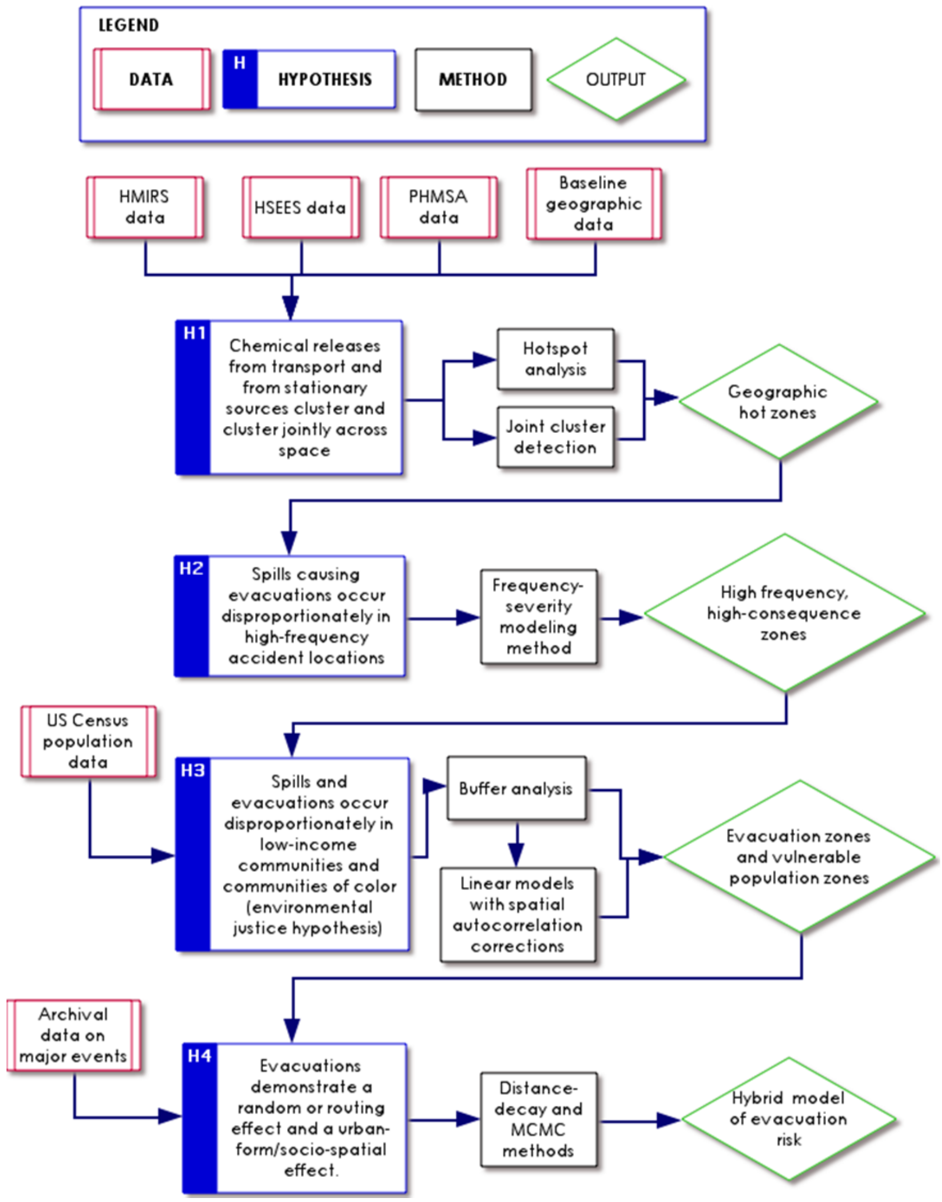


Figure 1. Global Methodology Guiding the Studies

Chapter 2. Geocoding and Data Preparation

For this research the first step was to construct an inventory of hazmat spills into an enhanced database containing the most comprehensive spills information available. The database has been assembled and geocoded for records reported from 1998 to 2010 from the data from the four major (HMIRS) and PMSA data. More details about the enhanced database is given in appendix A.

2.1 Geo-databases

The enhanced data have addresses matched to street data so that the information is geocoded. Every spill is treated as a separated incident and plotted over continental US to build the first basic visualization model. The geolocations are reported in North American geographic.

2.2 Data problems

There are several important data problems and limitations that had to be addressed when constructing the data.

Consistency. Consistency in the database over a 12 year period. The content in the databases changes in response to legislation that could affect all bases for comparisons. For just one example, in 1990 EPA added 25 more chemicals to the list of hazardous materials.. As a result, more waste is considered hazardous, and the facilities to legislate as well as the spills to be reported were almost duplicated from one year to the next. EPA records report that definition of HAZMATS had changed in 1990, 1992, and 1995. Although the data are available from 1990 onward, we go from 1998 onward in order to get the most consistent dataset.

Geographic extent. Although mostly of the databases dealing with HAZMATS report at the national level, not all the databases do. Databases such as the HSEES are an effort sustained by only 14 states. The ERNS data are an expansion on the basic material contained in the HMIRS. The result for the enhanced data is that we have fairly extensive information on serious spills in the 14 participating states, but only baseline information for the remaining states.

Continuity over time. With changes in legislation, agency structure and budgetary constraints, some agencies discontinue data collection for the HSEES. The HMIRS data had policy-level changes in what the agencies decided to treat as “serious” in 1996

Other issues arise when data collection methods change. The HMIRS reporting shifted from a paper-based to an online reporting system. The new method of data reporting means that some spills report over two lines, while the paper reports generally read into one line of database. And not all agencies reported online, so that one-line and two-line incidents appear in the data and have to specially handled.

Availability. Changes in technology, media and right-to-know changes over time depending on the agency hosting the data.

Completeness: Data can be affected by the enforcement or the lack of enforcement exercised by the agency in control of the reporting requirements. Databases for which reporting is voluntary may seriously undercount. Polluting industries under-reported by as much as 48% in one survey *[61]*.

Accuracy: Common mistakes while entering the data manually, for both online and paper reporting, need to be considered, and the data need to be standardized previously to begin any analysis. The original HMIRS data contain wide variation in the spelling of common names.

Table 1. The variations on one address form

10661 EITWANDA AVENUE
10661 EIT WANDA
10661 EITWANDA AVENUE
10661 ETI WANDA AVENUE
10661 ETIWANDA
10661 ETIWANDA AVE
10661 EITIWANDA AVE
10661 ETIWANDA AVE
10661 ETIWANDA AVE
10661 ETIWANDA AVE
10661 ETIWANDA AVE

Each of these data sets have been edited to manage these problems, and the street addresses reconciled to Google

2.3 Data Processing and Spatial Merge

The SQL code use to compile the database and set data types is shown in Appendix C. All data bases then had been depurated and compiled in .dbf and .csv formats. A QA/QC analysis of the database checked for completeness and accuracy in the compilation process to ensure no truncation or data corruption problems.

The research team also checked the data for:

a) extreme or missing values;
b) abnormalities specially related with the geographic extend or
c) incongruencies with the dimensions of the data.

One identified anomaly occurred in 2006 resulted fromwith changes in legislation occurred in the wake of a major oil spills on Alaska. The Pipeline and Hazardous Materials Safety Administration (PHMSA) issued a proposed rule to expand oversight to cover rural low-stress lines in "unusually sensitive" areas, such as those, like BP's Prudhoe Bay pipeline in Alaska, that traverse environmentally sensitive areas or contain endangered species. Then, the US House Energy and Commerce Committee, passed legislation September 27 to require federal regulation of virtually all "low-stress" oil lines, while previously only high pressure and low stress lines that run under heavily populated areas were monitored.

When the Pipeline Inspection Protection Enforcement and Safety (PIPES) Act of 2006 passed, the PIPES Act broadened the scope of the systems-based approach to assessing and managing safety related risks. The additional initiatives included. Since the PIPES Act, PHMSA has doubled its enforcement and toughened proposed pipeline safety civil penalties. The average per case has more than tripled since 2006 *[62].*

Chapter 3. Past HazMats Events as Proxies of the Future

After nearly a decade of freight policy focused on security and expansion, recent US Federal policy under the Obama administration has begun to stress an entirely new direction: livability. Livability attempts to balance the needs that nearby residents have for environmental quality with the building, operations, and maintenance of nearby freight facilities. This chapter examines the consequences for nearby communities of hazardous freight, both from accidental and, by extension, terrorist events.

Freight shippers manage over 323 billion ton-miles of toxic and hazardous materials every year, and that volume has grown over time along with the US economy. Serious incidents, though, are rare. From 2000 to 2010, the US had over 120,000 spills recorded from around the country, with roughly 5,000 listed as serious over that time. Loss of human life or injuries are infrequent: only 136 people have died from hazardous or toxic material exposure, while only 1,587 have been injured in the last decade. Nonetheless, when accidents do become serious, they can cause considerable economic damage. The total economic damage associated with no-notice hazardous materials spill events exceed $550 million with very serious single events that cost in excess of $20 million.

The past decade of accident data suggests vulnerability to terrorism as well as accidents. Over 150,000 people were evacuated during the past decade because of accidental spills. The success of those evacuations hinges on the reliability of information and practitioners engaged in freight shipping—two factors that may be expected to break down under a planned, intentional strike such as a terrorist action. Under conditions where information placards cannot be trusted and where personnel or onlookers may be complicit and malicious, the consequences may be much higher.

Our past experiences with toxic and hazardous materials (hazmat) evacuations can yield insights into the consequences of terrorist strikes at or near large-scale multimodal facilities in the US. The results of evacuations conducted in “best-case” accidental conditions serve as a possible lower bound for damage estimates—the optimistic case—of terrorist acts against the hazmat system and suggest what the consequences of these events may be for communities surrounding large-scale freight facilities.

3.1 Background

Prior to the industrial revolution, goods movement occurred predominately by horse, barge, and foot *[63-64].* Workers and traders flocked to housing near freight facilities and ports out of economic advantage. Many of today's mega-regions began as port cities—entryways for trade activities—and, as a result, these locations have always been targets during armed conflicts and sources of environmental vulnerability. Just as people today worry about the global threat posed by viruses spread through global transportation networks, armies and goods movement spread diseases, perhaps most infamously the bubonic plagues of the 14th century *[65]*. Horse-powered cities were fetid places where pedestrians routinely risked typhus and other pathogen-related illnesses from sharing their streets with piles of manure and the rotting corpses of horses that had been worked to death on the city's streets *[65].*

With steam, rail, and streetcar technologies, workers and traders could cover more distance in less time, opening spatial opportunities for where they could live and work relative to factories, trade centers, and warehousing *[64]*. In addition to new transport technologies, nuisance laws and, eventually, zoning codes in the US instituted the social, economic, and geographic separation of urban housing, particularly for the affluent, from freight and industry *[66].* As regions have grown, so have calls to reverse the spread of urban populations through infill and higher density development and by doing away with single-use zoning that separates people from employment and trade *[67-68].*

Ultimately, the push and pull factors of policy, planning, and new technologies have had two major effects that interest us here. First, urban population growth (through natural increase and long-term, sustained outmigration from rural areas to urban centers) has placed more people than ever before into very high levels of population density within metropolitan centers. Just as an example, the Port of Los Angeles was established formally (after decades as a harbor) in 1906. The Los Angeles population was a little over 102,000 people then. Today, the city of Los Angeles has close to 4 million people, with the surrounding metropolitan area closer to 13 to 15 million, surrounding the US's two largest freight ports. Freight shipping as an industry has grown over the past century as well, particularly over the last decades of the 20th century, as global capital flows have increased, with logistics and industry practices moving towards greater scale and scope of goods movement facilities. Higher volumes of materials are being moved closer to higher numbers of urban residents as a result of these two growth effects.

Federal regulations have fostered both freight consolidation and scale, particularly in hazardous materials transport. The Resource Conservation and Recovery Act (RCRA) in 1980 mandated cradle-to-grave tracking of toxic and hazardous materials as they move through the US *[66]*. RCRA and subsequent laws requiring drivers and handlers to have additional credentials, standardized containers, and placarding have created barriers to entry in hazmat shipping. The regulatory environment yielded predictable results: the fewer shippers and facilities, the easier it is to monitor and enforce high industry safety standards.

Nonetheless, consolidation in the hazmat freight industry can have multiple—and unfortunately conflicting—effects on community vulnerability when populations have grown up around freight facilities. Consolidation can build up the volumes and diversity of materials at one geographic location. On one hand, the readily identifiable location helps first responders know where the likely problems are and, in the case of everyday incidents, allows companies to keep specialized equipment and professionals on site. The economies of scale and scope realized during everyday shipping activities also manifest for incident response. On the other hand, the consolidation of hazardous materials freight in one geographic location creates increased risks of accidental releases and a readily identifiable location for terrorist acts.

Toxic and hazardous materials shipping reflects the perennial tension between consolidating and distributing hazard in urban contexts: is it more secure (i.e., less likely to cause death, damage, and injury) to consolidate risks onto one location and one set of large-scale networks? Or is it more secure to disperse risks in small amounts, carried discretely through a highly disaggregated network of smaller-scale facilities and transport modes?

3.2 The consequences of land development and policy on network security

The concepts driving these questions are illustrated in Figure 2. Networks A and B illustrate the land use, infrastructure, and industrial organization that most similarly represents the arrangement of multi-modal facilities in the United States. Industrial consolidation can prompt companies to pursue very large operations, as in A. However, zoning and industrial agglomeration can cause the geographic clustering shown in scenario B, where multiple companies, and even multiple hazmat handling industries appear in a spatial area. In either A or B, vulnerability centers on one specific geographic location.

A key difference between A and B, however, concerns the highway network. In both A and B, the facilities are served by only one railway, which itself poses a potential target. The network in A reflects the current state of the practice in the US, which designates specific routes, while disallowing others, for highway movements of hazardous materials. In so doing, the requirement demonstrates the benefits of managing materials for accidents: routing is done according to the highway capacity and safety standard and isolates hazmat traffic to specific links. By disallowing other routes, however, hazmat route designation makes it easier for outsiders to figure out what highway segments are likely places for hazardous content to appear.

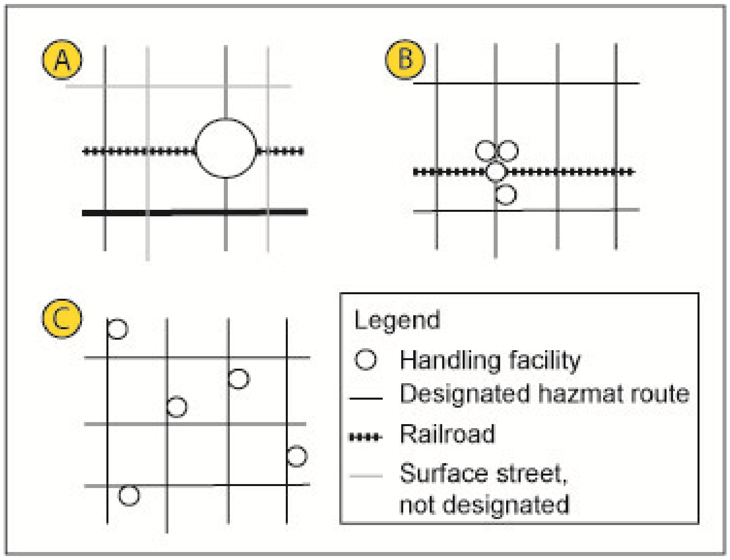


Figure 2. Different network, industrial organization, and land use

Scenario C shows the opposite of the three variables (land use, infrastructure, and industrial organization). The land use configuration and industrial organization separate the facilities across the geographic network. The disaggregated, gridded highway network allows for many routing combinations once past the limits of facility-access links. This routing flexibility allows shippers to vary routes for security purposes and/or avoid minor disruptions in the network. Scenario C lacks rail transport, which would allow hazmat shipments to be easily tracked and controlled, but rail has limited routing flexibility and the volume of materials carried at a given time has potentially disastrous effects if an accident or attack occurs.

Without information about the shipments and, more importantly, the population of the surrounding area, it is impossible to determine what type of arrangement carries the highest vulnerability for urban populations. However, the existing US conditions currently resemble A and B, and the

US is unlikely to shift land uses or hazardous materials management. The result is a geographic consolidation of hazmat risks at multi-modal facilities or facility clusters, and the designated routes that immediately serve those area facilities.

Theorizing about risks anchored by facilities and surrounding land uses redefines spatial risk away from the largely stochastic events—which can happen anywhere—towards more a tractable geography of risk. Most studies examine risks according to routes and attempt to derive the population-minimizing routes between origins and destinations *[7-8; 69-70]* or a combined objective of minimizing travel time and population exposure or other measures of risk (e.g. *71-76).* The population minimizing route may not always be the shortest route or the route that uses the highest-standard facilities; hence, researchers have often included dual objectives for hazmat routing. In addition, examinations of route-based risk functions tend to treat hazmat spill likelihood as a function of distance *[77],* but such conceptualizations of stochastic events become less useful in thinking about the likely geographic location of intentional strikes.

Analyses of the risks for terrorist events specifically at multi-modal facilities tend to be primarily focused on seaports and on the loss of economic productivity from shutting down freight facilities or critical infrastructure *[78].* For hazardous materials, the research contains mostly frameworks and many potential "how-tos." Strikes against freight facilities are unknown in the US; internationally, above-ground oil pipelines have been targeted, not to harm nearby populations but to disrupt production and send a message to corporate owners *[79-80]*. Thus the available empirical knowledge base and data for building vulnerability or consequences models of intentional strikes are sparse to nonexistent.

To give some indicator of the relationship between facilities and potential consequences, we can examine the past record of accidental incidents, their geographic locations, and their consequences on communities surrounding the multimodal facilities. In this way, it is possible to test empirically whether the industrial organization and infrastructure networks laid out conceptually in Figure 2 concentrate accidental hazardous materials shipping risks in ways that can help enlighten the potential consequences of terrorist strikes. Moreover, the consequences from accidental spills provide further information for future risk modeling efforts.

3.3. Data on consequences

There are comprehensive records available in the US for examining the spill records surrounding multi-modal facilities, although the data have some problems with geographic accuracy, particularly for data going back farther than 2000.

National Transportation Atlas Database 2010. We define multi-modal facilities as those listed in the Atlas database, published by the Bureau of Transportation Statistics (BTS). These data contain the name of the facility, city, state, zip code, list of businesses associated with the facility, and mode. According to the Atlas, there are 3,281 intermodal facilities in the US: 227 rail-and-truck-facilities, 744 port-rail-truck facilities, 408 air-and-truck facilities, 62 port-and-truck facilities, 10 rail-and-port, and one port-rail-truck-airport (Port of Little Rock).

Hazardous Materials Information Reporting System (HMIRS). As described in the first chapter, the HMIRS data are compiled from reports made by transporters and first responders. The data include many variables regarding the incident: the time of day, materials spilled, amounts, the carriers, and what triggered the incident (e.g., human error, container failure). HMIRS data contain information on the consequences of the spills, including the number of people killed, injured, or evacuated. The data are collected, maintained, and distributed by the U.S. Department of Transportation's Office of Hazardous Materials Safety (OHMS). The data used for our analysis in this project span from 2000 to 2010. The OHMS designates serious spills as those which cause death or injury, a major road, or prompt an evacuation of more than six people.

Lexis-Nexis and Newspaper Reporting on Serious Spill Incidents. In order to expand the information in the HMIRS and the HSEES, the research team used Lexis-Nexis to find newspaper coverage of the major spill incidents. A member of the research team cross-referenced Lexis-Nexis against serious spills in the HMIRS database by date, location, and substance (three separate searches). The match rate was disappointing. We found news coverage of only 22 percent of the serious spills that occurred across the US, and of those, only 15 percent related to spills occurring during transfer or storage at multi-modal facilities. However, the records were saved for what events did receive press coverage. In some respect, the lack of press coverage demonstrates how well hazmat materials incidents are managed; however, it also demonstrates how invisible hazardous materials shipping is to the general populace.

3.4 Data on consequences and California geography

We restrict the spatial analysis to the state of California because of the computational requirements of doing a spatial analysis on the entire country, given the 120,000 spills that occurred from 2000 to 2010 summarized in **Table 2**. Instead, 10,496 spills occurred in California, which makes for a much more tractable spatial analysis. The data were geocoded to a 91 percent match. All of the multimodal facility locations already had geographic location information. The California spills were mapped against facility location, with the results shown in **Figure 3** with map insets for the Los Angeles and Bay Area regions.

Table 2. Spills within 1 mile or 3 miles of multi-modal facilities, 2000 to 2010

	Total incidents		**Serious incidents**	
Total	10,486	100 %	1,109	100%
1-mile buffers	3,393	32%	314	28%
3-mile buffers	6,531	62%	631	57%

Source: HMIRS and National Transportation Atlas data, geocoded and analyzed by the authors.

Figure 3 only maps the serious spills against the multi-modal facility location: with all spills, there was too much overplotting to distinguish the relationships. In order to capture the geographic relationship between spill and multi-modal facility locations, one-mile and three-mile buffers were used to capture spills that occurred on highway and rail links proximate to the facilities.

Spatial analysis of the buffers shows that a third of all spills occur within one mile and more than half occur within 3 miles of multi-modal facilities. These percentages are mirrored among serious incidents as well. Based on the previous experience with spills, a spatial buffer surrounding multi-modal facilities that includes the facility-access link captures a fairly high portion of all of the toxic and hazardous materials spills. This finding tracks with previous research conducted from 2000 to 2004 only in southern California *[10].*

This simple geographic analysis suggests that facility locations are reasonable spatial proxies for predicting accident locations—and for serious spill locations. As a result of the geographic commonality, the spills that occur in the accident record are also good potential exemplar events for what the consequences might be for strikes against the multi-modal facilities. Further analysis will be required to see if the geographic relationship found in the state of California holds in other places around the US.

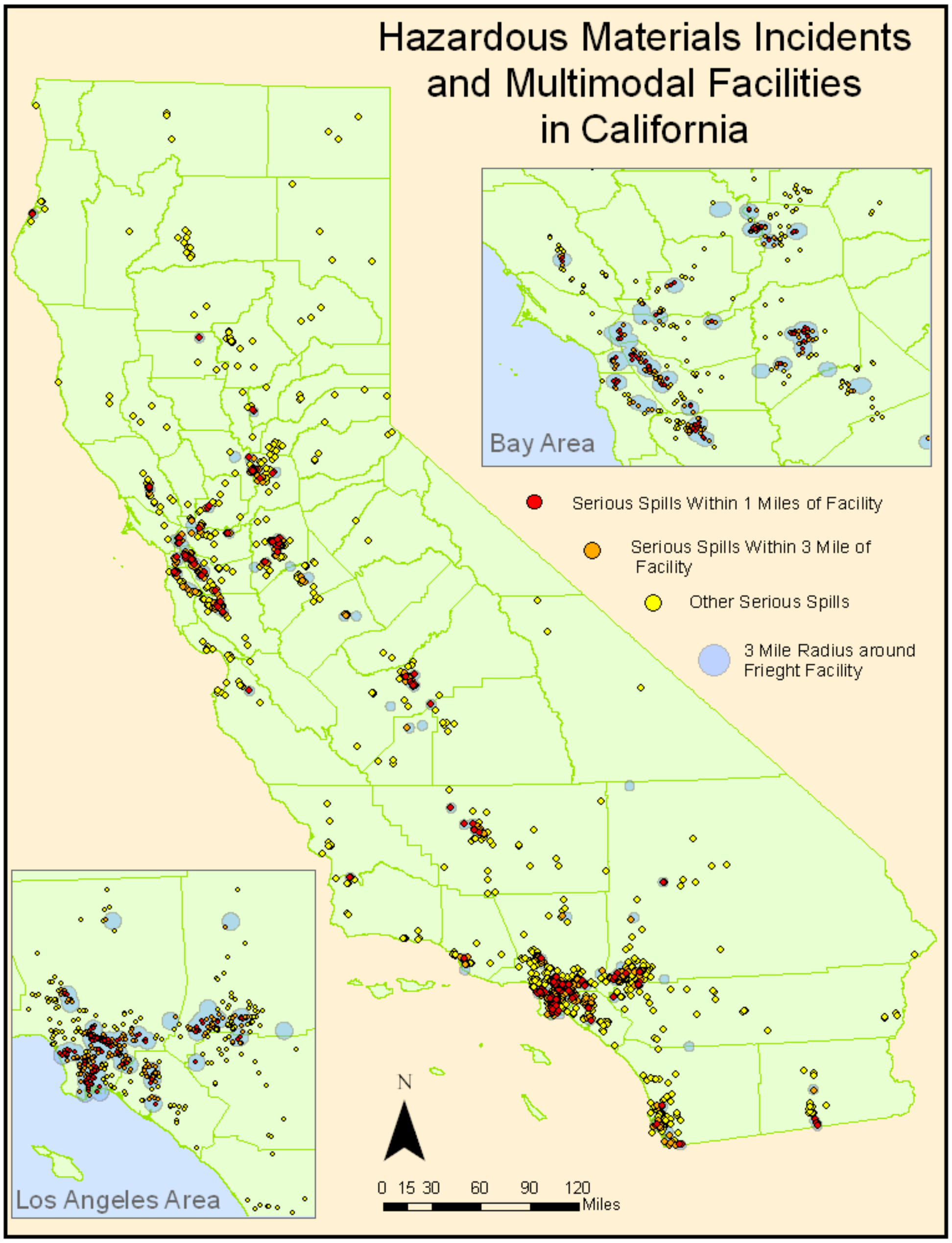


Figure 3. Spatial buffers around multi-modal facilities in California

3.5 Data on event consequences

The HMIRS data have multiple measures for event consequences which are summarized in

Table 3.

The first set of outcome variables is binary, and it indicates whether, once a spill has occurred, any subsequent event then occurred. Release measures whether, in case of a container breech, the material leaves the container and enters the environment. Just because a vehicle with hazardous materials derails or crashes does not mean that the container will breech, and just because the container breeches does not mean that the material will always release. Of the 5,196 serious spills in the US (and 120,000 total spills), 4,579 spills had a release occur.

The radioactive material (RAM) binary variable represents only one of a possible series of binary outcome variables based on the type of materials released. Radioactive material shipping is rare compared to other types of shipping, and the containers in which they are shipped are carefully constructed. Only four RAM events occurred from 2000 to 2010. The Hazardous Materials Information Systems data contain categories for all the standard classes of hazardous materials, and thus it is possible to create binary event outcomes for any type of material.

The next six binary outcome variables concern events that may occur subsequent to an incident and a release. Closure (n=1,204) measures whether the incident closed a major arterial (or higher level of service) roadway. Environmental damage (n= 606) indicates whether the spill caused any environmental damage, such as a petroleum spill. Unfortunately, the databases contain very little information about the nature of environmental damages. Evacuation (n=843), gas dispersion (n=687), fire (n=472), and explosion (n=145) represent progressively rarer events, so that the probability of any given outcome is related to the outcomes of previous events: $p(c|r)|p(r|e)$, where $p(r|e)$, the probability of a release *(r),* is conditional on a previous event *(e)* such as an intentional strike, crash, turnover, or cargo mishandle, and where the probably of any given consequence *(c)* is again conditioned on a release event.

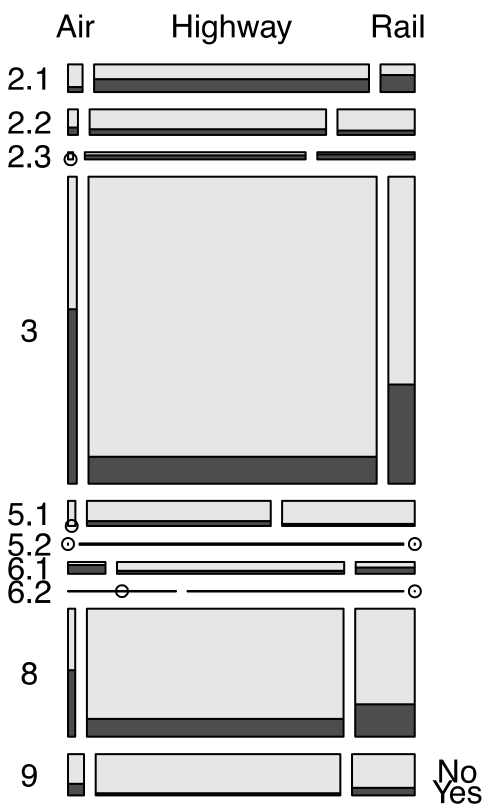
Table 3. Outcomes associated with toxic and hazardous events

Outcome	Data definition
Binary Variables (1=Yes, 0=No)	
Release (Spillage) *(r)*	Material is released due to incident (N=4579)
Radioactive material	Release of radioactive material (extremely rare)
Closure	Major artery was closed as a result of spill; Y=1204
Environmental damage	Release resulted in environmental damage; Y=606
Evacuation	Release resulted in an evacuation order; Y=843
Gas dispersion	Materials released in gaseous form; Y=687
Fire	Material caught on fire; Y=472
Explosion	Whether explosion occurred; Y=145
Cost variables ($US)	
Property damage	Damage to public or private property
Response costs	Costs of labor and equipment for responders
Remediation and cleanup	Remediation costs
Total damages	Total cost figure (sum of property, response, remediation and other costs)
Continuous or Count Variables (Persons, hours)	
Volume released	Volume of materials released
Fatalities	Fatalities associated with employees, the public, and first responders
Injuries	Injuries associated with employees, the public, and first responders
Total evacuated	Employees and public evacuated
Total evacuation hours	Duration of the evacuation
Duration of closure	Duration of major artery closure
Calculated Variables	
Value of life and injury	Deaths multiplied by the statistical value of life
Person-hours of evacuation	Duration of evacuation multiplied by members of the public evacuated.
Lost productivity	Value of time lost to evacuation: person-hours of evacuation multiplied by prevailing wage rate

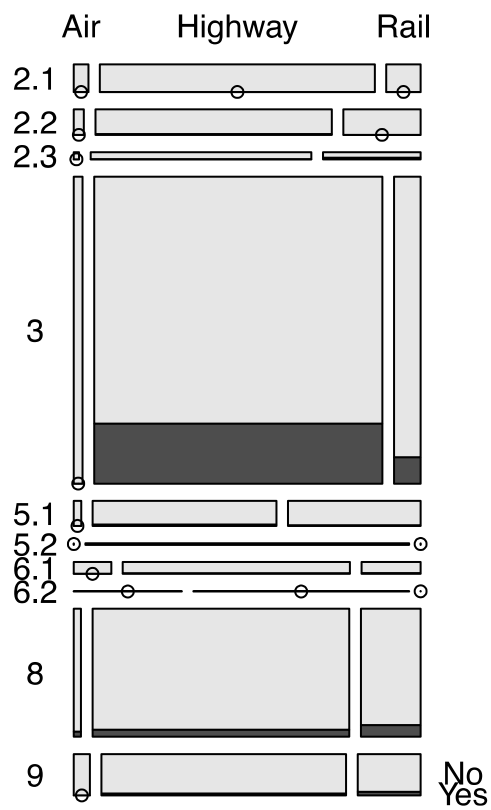
Source: Hazardous Materials Information Reporting System, Codebook. Person-hours of Evacuation are not reported; these are compiled by the authors.

Figure 4 shows the breakdown of the event types by mode and hazardous materials class code for the two binary outcome measures that show the most variation by mode and hazardous materials class.

Evacuation Events



Environmental Damage



Legend

Not serious; Serious

Class 1: Explosives Class 2: Flammable gases Class 3: Flammable liquids Class 4: Dangerous when wet, flammable Class 5: Oxidizers	Class 5: Poisonous materials Class 7: Radioactive materials Class 8: Corrosives Class 9: Miscellaneous ORM-D-Other Regulated Materials, Domestic

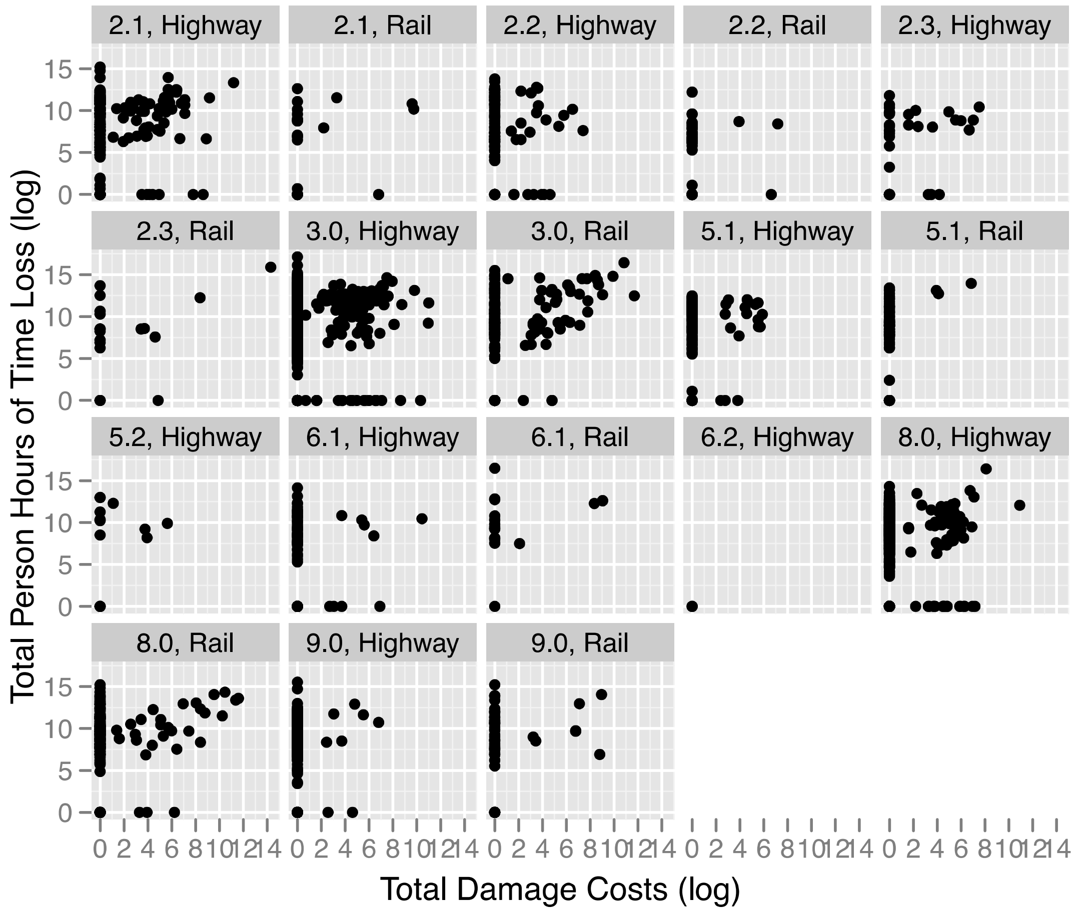
Source: Data from the Hazardous Materials Information, 2000 to 2010, compiled by the authors

Figure 4. Evacuation and Environmental Damage by Mode and Hazardous Materials Class, 2000 to 2010

The plots first show that most serious spills occur for Class 3 hazardous materials, which are flammable liquids—gasoline and other fuels—as we would expected due to the prevalence of the materials.

The serious spills are distributed among hazardous materials classes similar to the prevalence of their shipping, with one exception. Corrosive materials (Class 8) are somewhat more represented in serious spills than in the entire spills record. Because there are so few spills from water transport, those are not illustrated. Infrequent hazardous materials classes are also omitted from the figures.

The binary event variables also have analogues in the HMIRS for continuous measures that reflect the extent or costs of those outcomes. The cost variables measure three significant consequences: the costs to property, the costs associated with time and equipment needed by responders to act on the event, and the remediation and clean-up costs. The data do not include costs associated with productivity loss due to closures or evacuations.


2.1, Highway
2.1, Rail
2.2, Highway
2.2, Rail
2.3, Highway
2.3, Rail
3.0, Highway
3.0, Rail
5.1, Highway
5.1, Rail
5.2, Highway
6.1, Highway
6.1, Rail
6.2, Highway
8.0, Highway
8.0, Rail
9.0, Highway
9.0, Rail
Total Person Hours of Time Loss (log)
0 5 10 15
0 2 4 6 8 10 12 14
Total Damage Costs (log)

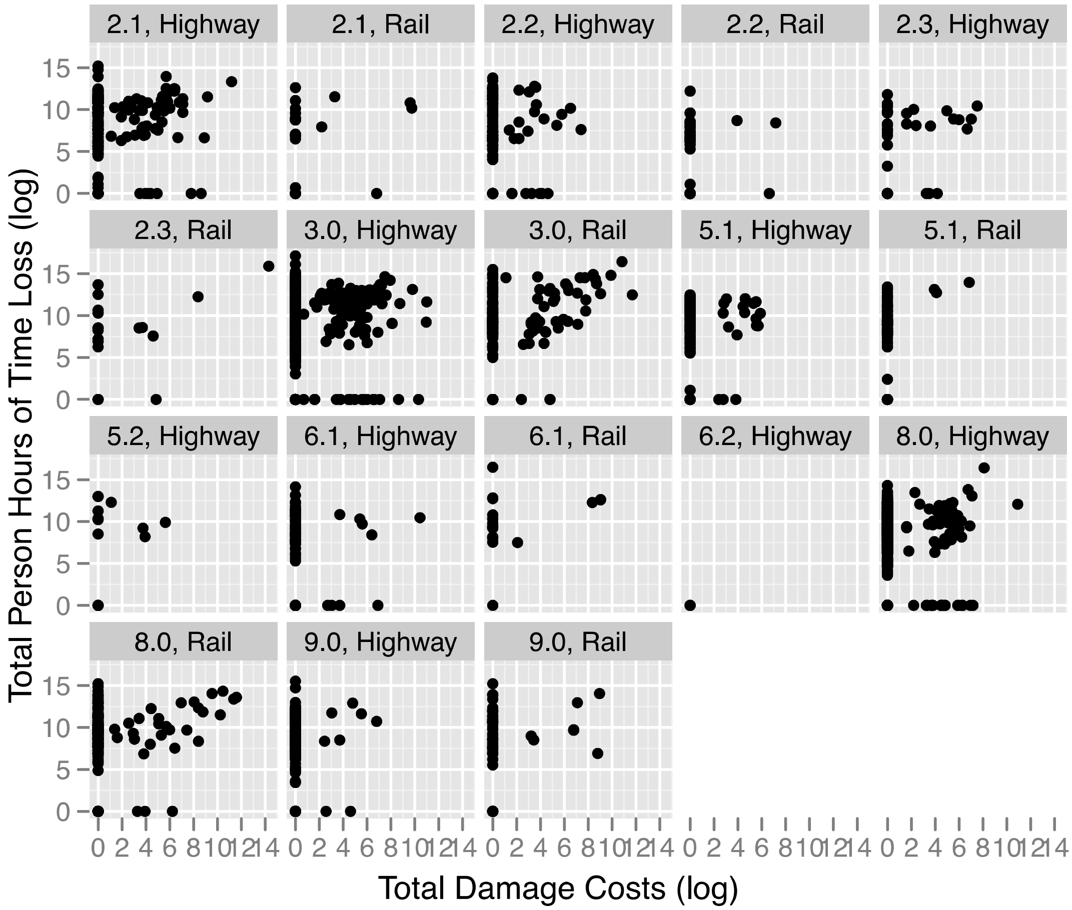


Figure 5 displays response, remediation, and property damage costs plotted against the total costs associated with the spill. The data points are broken out by mode symbolically. Most serious spills cause less than $5 million in damages, and all of the serious water and air hazmat events fall into that cluster of points centered at $5 million and under.

The interesting data points here are the extreme values for highway and railway, both of which had a handful of spills from 2000 to 2010 that imposed higher cost consequences than did other serious spills. Although there are only a few, scattered extreme events, rail modal events are again disproportionately represented among the cost figures. However, the most extreme consequences for response, property, and remediation costs occurred on highways. While serious railway spills were likely to prompt evacuations, highway events have imposed the highest out-of-pocket cost consequences for the companies involved in the spills. Each of these outliers may be good exemplar events for use in analyzing terrorist risks.

Other measures of consequences, such as death, injury, and time loss due to evacuations can also be monetized. Since injuries and fatalities are usually monetized by a standard amount, those measures are perhaps less interesting for illustration than the value of time lost due to evacuations. The value of time lost due to evacuations is a function of the total number of people evacuated, the duration of the evacuation, and the value of time assigned to them.

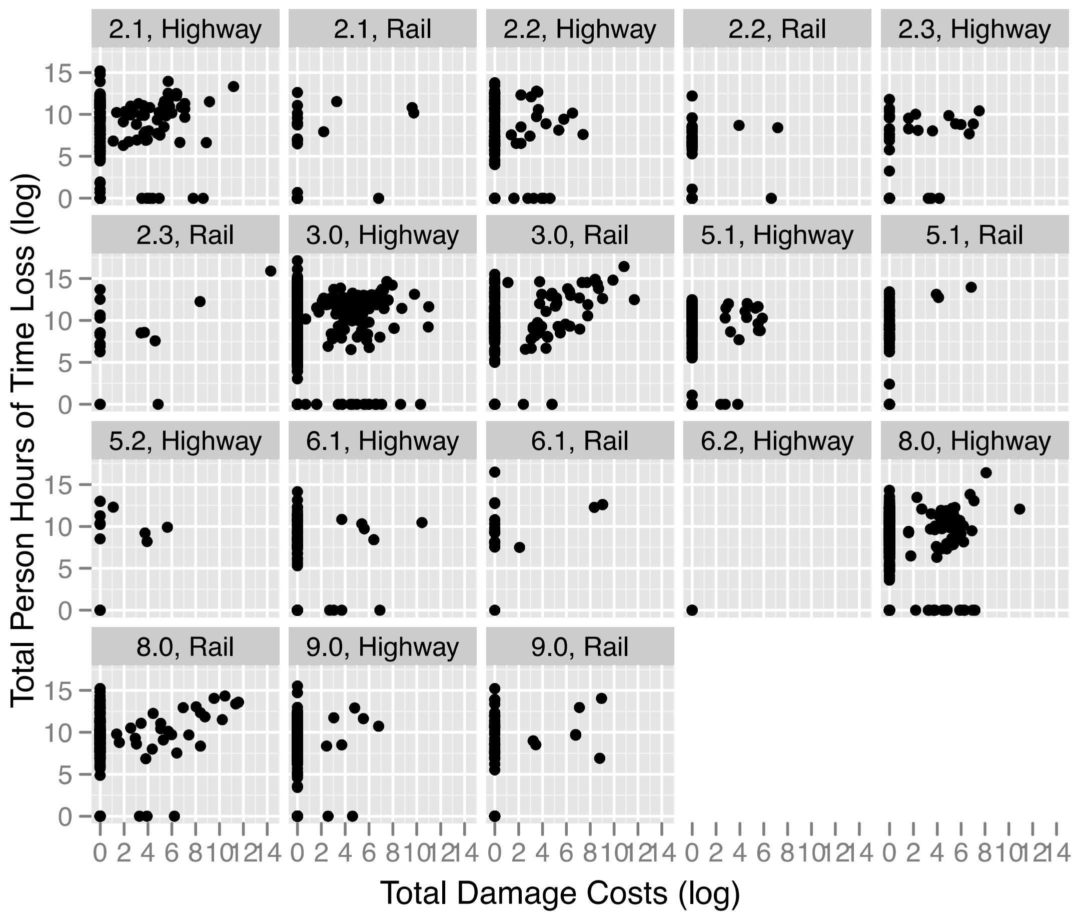


Figure 5. Cost consequences of serious spills by mode, 2000 to 2010

Figure 6 plots the total damage costs (logged) against the person hours of time loss, again using the most prevalent hazards classes and modes. Wages or time values would be a constant, and thus they are not included here; we have allowed for the zero values to be included (modified for the log) so that the figure displays the split in the events between those which cause damage without evacuation, evacuation with low damage costs, and the third group: those events that cause both.

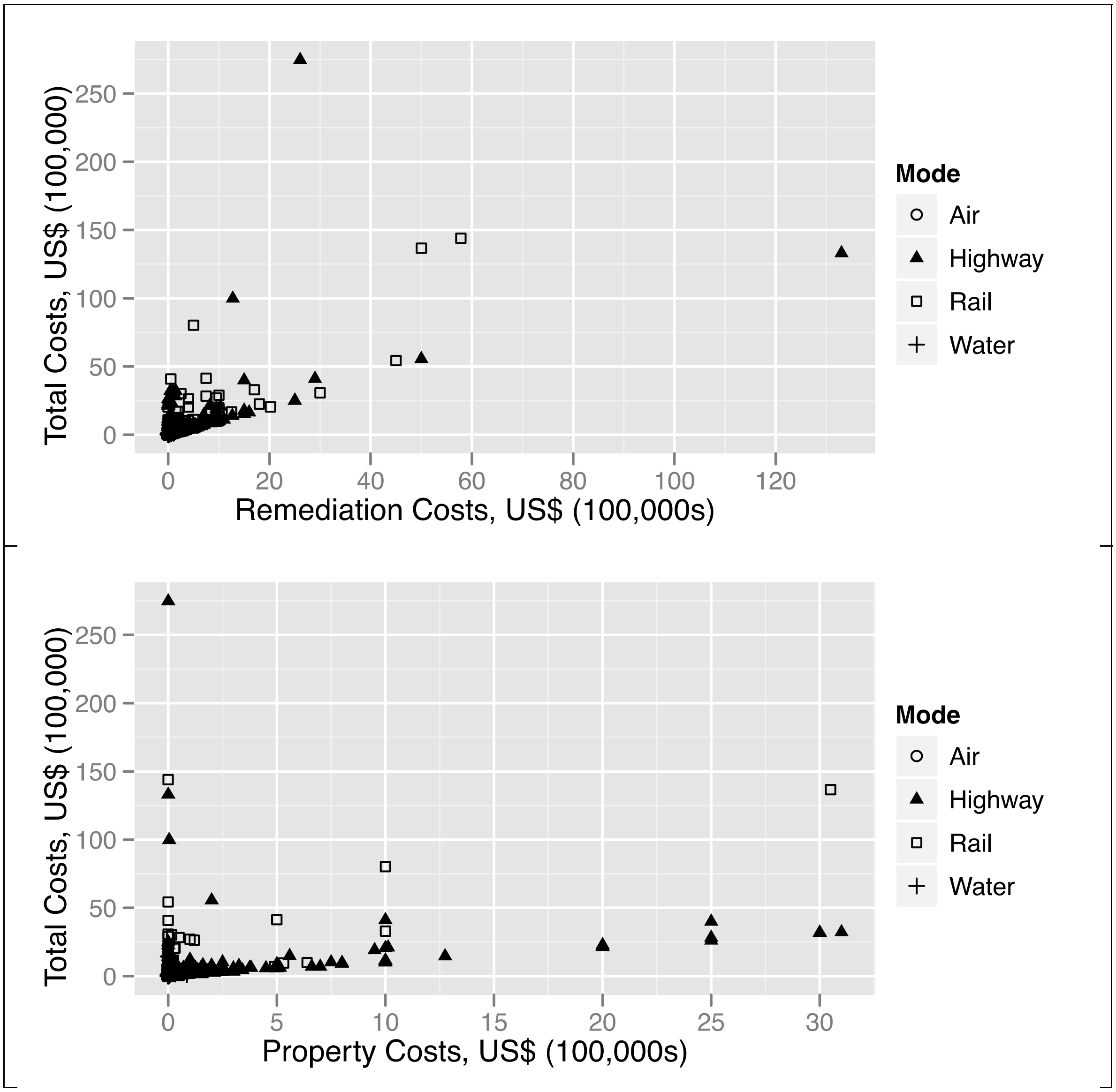


Figure 6. Time Loss and Total Damage by Mode and Hazard Class, 2000 to 2010

That middle group demonstrates a strong and positive association between time loss costs and total damage costs. It is once again possible to see how three classes of materials drive the consequences for serious spills across modes: flammable gases (Class 2.1), flammable liquids (Class 3), and corrosives (Class 8).

Poisonous gases transported via highway (Class 2.3) have caused more events with both evacuations and total material damage than on railways, and the same is true of oxidizers and organic peroxides (Classes 5.1 and 5.2). Because these are not spill rates, there is no information about what is more prevalent or more likely to spill. Instead, the data simply reflect the consequences of what has occurred by mode and class.

Chapter 4. Isolating the Spill Frequency Trajectory

This section isolates spill frequency by seasons in order to see how much effect we can trace to periods. For all the US highway data, there emerges a clear periodicity in the data.

4.1 Identifying the nonstationarity

The regression coefficients for X, Y, ‹ t=1,2,…,N, are as following:

$$r = \frac{\sum_{t=1}^{N} X_t Y_t - N\bar{X}_t \bar{Y}_t}{\sqrt{\sum_{t=1}^{N} X_t^2 - N\bar{X}_t^2}\sqrt{\sum_{t=1}^{N} Y_t^2 - N\bar{Y}_t^2}}$$

Contrast the cross correlation coefficient as a function of time intervals between two series X_t and Y_t for time t=1,2,..,N are as following:

$$r(k) = r(X_t, Y_{t+k}) = \frac{\sum_{t=1}^{N-k} X_t Y_{t+k} - N\bar{X}_t \bar{Y}_t}{\sqrt{\sum_{t=1}^{N} X_t^2 - N\bar{X}_t^2}\sqrt{\sum_{t=1}^{N} Y_t^2 - N\bar{Y}_t^2}}$$

While r(k) is a number between -1 and 1. For describing the above relationship, if k=3, the amount of r(3) shows the average impact of X_t on $Y_{t+3.}$ This graph appears in Figure 7. The biggest absolute values for r(k) have periodical repetition each 12 periods, and they become smaller when their absolute value for K become larger.

There may be some exogenous changes that contribute to the cross-correlation lags. Both the function for serious spills and all spills are likely to be affected by exogenous changes in total amount of shipping, itself likely to be seasonal.

Figure 7. Cross-correlation functions between spills and serious spills.

```
CCF - correlates spill(t) and Serious(t+k)
-1.0 -0.8 -0.6 -0.4 -0.2  0.0  0.2  0.4  0.6  0.8  1.0
+----+----+----+----+----+----+----+----+----+----+
-23  -0.023                  XX
-22  -0.043                  XX
-21  -0.098                 XXX
-20  -0.180              XXXXXX
-19  -0.255             XXXXXXX
-18  -0.278            XXXXXXXX
-17  -0.293            XXXXXXXX
-16  -0.239             XXXXXXX
-15  -0.148               XXXXX
-14  -0.127                XXXX
-13  -0.054                  XX
-12  -0.001                   X
-11  -0.040                  XX
-10  -0.078                 XXX
-9  -0.142                XXXXX
-8  -0.265             XXXXXXXX
-7  -0.327            XXXXXXXXX
-6  -0.353           XXXXXXXXXX
-5  -0.357           XXXXXXXXXX
-4  -0.287             XXXXXXXX
-3  -0.215               XXXXXX
-2  -0.202               XXXXXX
-1  -0.089                  XXX
0  -0.014                     X
1  -0.102                  XXXX
2  -0.114                  XXXX
3  -0.171                 XXXXX
4  -0.280              XXXXXXXX
5  -0.317             XXXXXXXXX
6  -0.306             XXXXXXXXX
7  -0.339             XXXXXXXXX
8  -0.303             XXXXXXXXX
9  -0.221               XXXXXXX
10  -0.172                XXXXX
11  -0.081                  XXX
12  -0.072                  XXX
13  -0.143                XXXXX
14  -0.190               XXXXXX
15  -0.241              XXXXXXX
16  -0.276             XXXXXXXX
17  -0.319            XXXXXXXXX
18  -0.306            XXXXXXXXX
19  -0.288             XXXXXXXX
20  -0.189               XXXXXX
21  -0.159                XXXXX
22  -0.128                 XXXX
23  -0.073                  XXX
```

That up-and-down variation contributions to an analytical problem for many statistical analyses of the data record: that is, the correlation between the number of serious spills and total spills is likely to be negatively sloped during some periods and positively sloped during other periods, driven by exogenous factors we can not control. This periodic correlation does not matter for spatially referenced analysis as much as it does for aggregate forecasting. According to the tracking, the cycle continues for six months, and after six month there is an opposite directional relationship, and so on—a fairly clear sign that the data exhibits strong, weather-related effects in many parts of the US.

4.2 Selecting the time series

Define S_s as the number of serious spills that occurs over the subsequent six months after given an arbitrary time period t and test it with a linear relationship against the number of all spills N at time t ; $S_s = a + \beta N + e$. The results are shown in Table 4.

Table 4. Test linear regression of spills and new serious spills

Predictor	Coefficient	Standard Error of the Coefficients	t
Constant (a)	27.804	3.352	8.29***
Raw spills	-0.01068	0.002488	-4.30***
Adj R2=0.09			

Source: Data from the Hazardous Materials Information System, 2000 to 2010, compiled by the authors. These are truck spills only.

Drawing the aggregate relationship at a given point in time, (here, December 2007), that of the cycles, the downward trend dominates for the next six months.

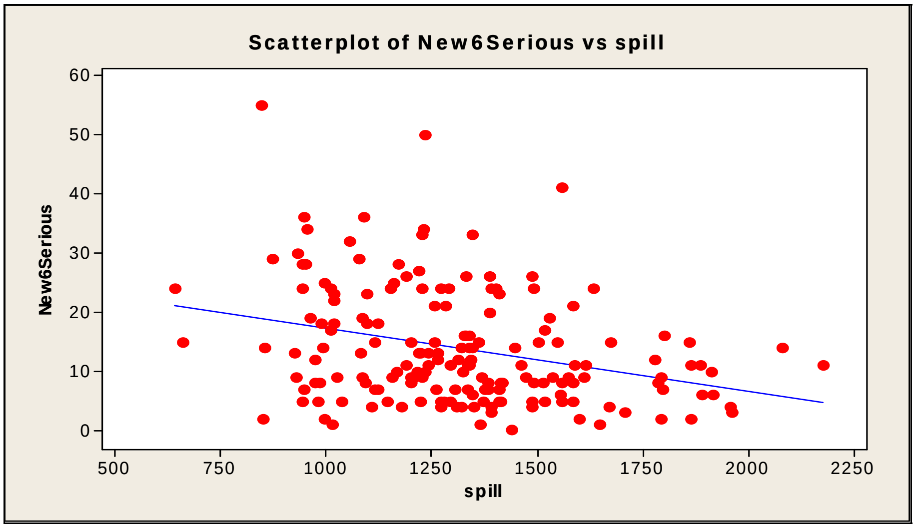


Figure 8. Plot of Total spills to new serious spills over a six month horizon

The directional relationship is counter to expectations, but the relationship is strong enough to be significant in a test model, and the model explains about 9 percent of the variation in the data at these points—much more than you want in a relationship that is likely capturing exogenous changes. Nonetheless, the visual does provide a descriptive contradiction to the basic premise of H3: that locations with more spills are likely to have more serious spills. However, we can not conclude that for certain as the graph changes depending on *t*.

A plot of the residuals and their apparent nonstationary exhibited appears in Figure 9.

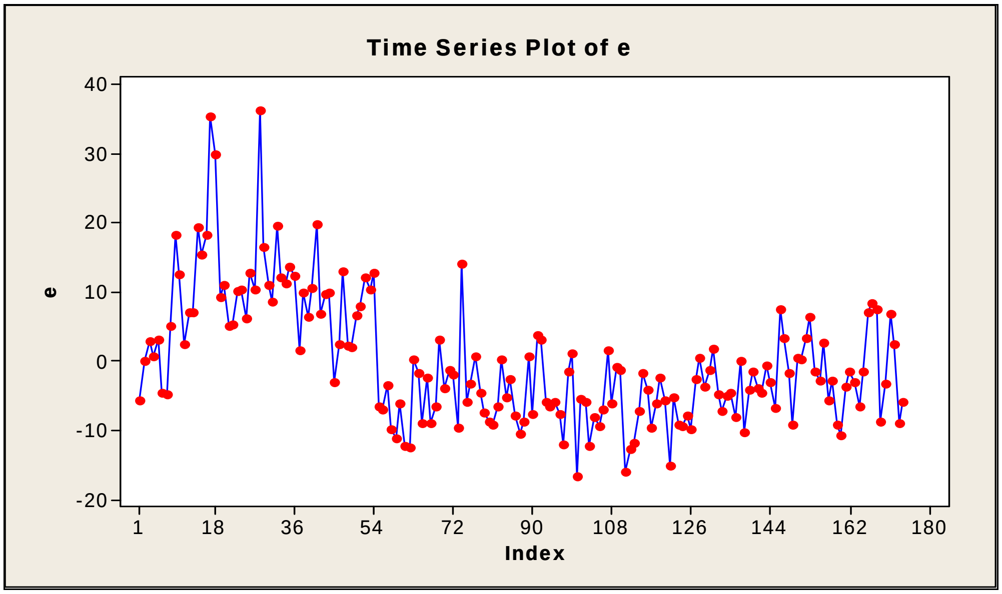


Figure 9. Time series plot of residuals

Differencing the residuals from on period to the next $(de_t = e_t - e_{t-1})$, shown in Figure 10, better approximates white noise. The autocorrelation function for a WSS signal is:

$$\rho_x(\ell) = \frac{\gamma_x(\ell)}{\gamma(0)} = \frac{\gamma_{x(\ell)}}{\sigma_x^2}$$

$$\gamma_x(\ell) = \mathrm{E}\big[[x(n+\ell) - \mu_x]\,[x(n) - \mu_x]*\big] = r_x(\ell) - |\mu_x|^2$$

so that $-1 \leq \rho_x(\ell) \leq 1$ and white noise appears as $x(n) \sim WN(\mu_x, \sigma_x^2)$: $\rho_x(\ell) = \delta(\ell)$. Then if $\hat{\rho}_x(\ell) \approx \delta(\ell)$, the errors differ so little from white noise that the evident nonstationarity is not significant. The ACL function and the resulting envelopes are shown in Figure 10.

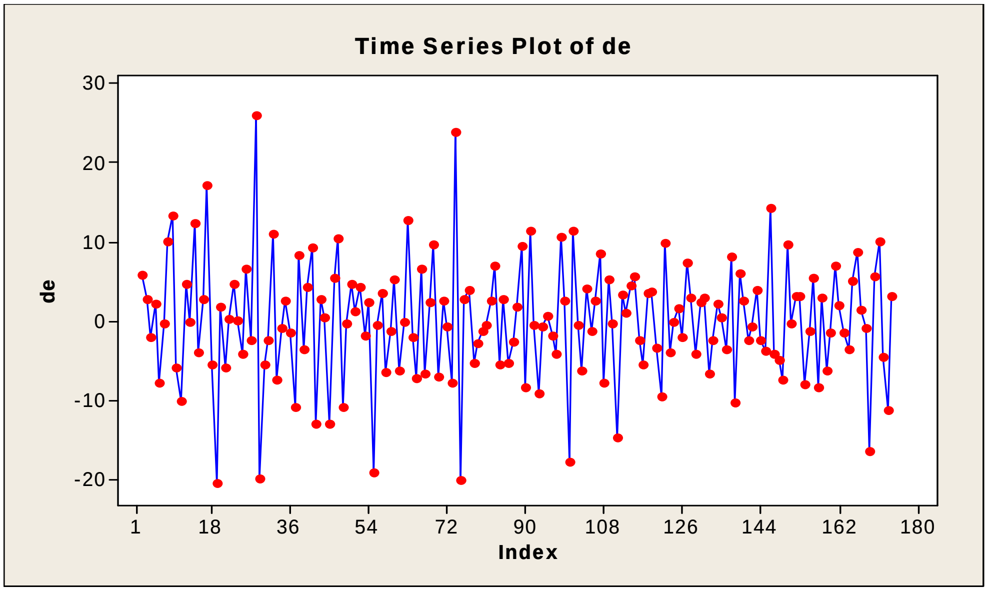


Figure 10. Lagged det

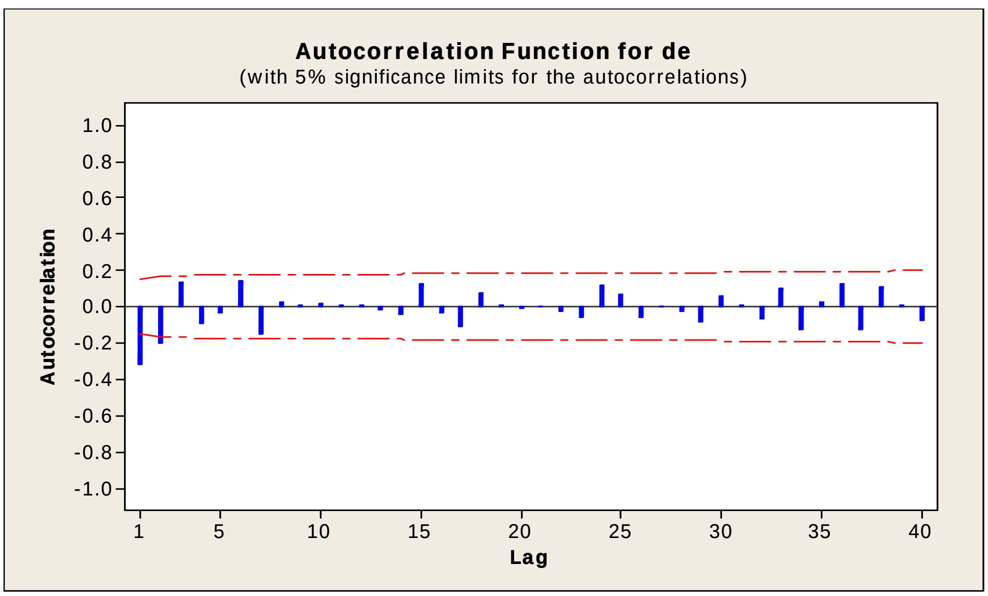


Figure 11. ACL function and envelopes

The partial autocorrelation function is a dual of the ACL. Define:

$$P[x(n)|x(1), \ldots, x(n-1)]$$

as the mean square error linear predictor of x(n), given {x(1), …., x(n-1)}. Then

$$\hat{x}(n) = P[x(n)|x(n-1),\ldots,x(1)] = \sum_{k=1}^{n-1} c_k x(n-k)$$

$$c_k = \underset{c_k}{\text{argmin}}\ \mathrm{E}\left[(x(n) - \hat{x}(n))^2\right]$$

For the minimum mean square error liner predictor of x(0), given the series,

$$\hat{x}(0) = P[x(0)|x(n-1),\ldots,x(1)] = \sum_{k=1}^{n-1} d_k x(n-k)$$

The correlation between the residuals defines a partial correlation function, which, like the ACL, depends on second order properties.

$$\tilde{x}_n(n) \triangleq x(n) - \hat{x}_{1:n-1}(n) = x(n) - p[x(n)|x(n-1),\ldots,x(1)]$$
$$\tilde{x}_n(0) \triangleq x(0) - \hat{x}_{1:n-1}(n) = x(n) - p[x(0)|x(n-1),\ldots,x(1)]$$

$$\alpha(\ell) = \frac{\mathrm{E}[x(\ell) - \hat{x}_n(\ell))(x(0) - \hat{x}_n(0)))]}{\mathrm{E}[(x(0) - \hat{x}_n(0))^2]}$$

and

$$-1 \le \alpha(\ell) \le 1$$

The results of the PACF are shown in Figure 12.

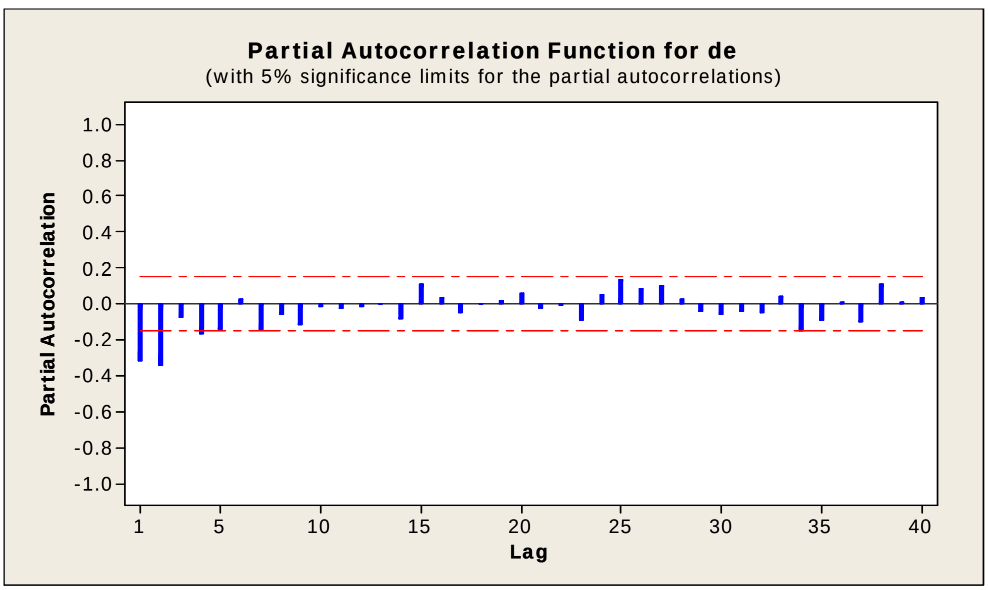


Figure 12. Partial correlation function of de

There are two likely periods outside out of the envelopes the represent the bounds of white noise.

4.3 ARMA models and forecasting spills as a time series

Table 5 shows the reduction of time series factors across two time periods for both autoregressive (AR) and moving average (MA). In the first model with all four parameters, all p-value are greater than 0.005; the data do not support the existence of all four seasonal parameters: AR_1, AR_2, MA_1, MA_2 in model. In such kind of situation, we should omit the parameter that have the biggest p-value, and then run the model again. So we omitted AR_2 with 0.844 for p-value, and then run ARMA(1,2).

Table 5 ARMA models isolating de and seasonality parameters

Type	Coef	SE Coef	T	P
ARMA (2,2) model				
AR 1	-0.2897	0.4540	-0.64	0.524
AR 2	0.0384	0.1954	0.20	0.844
MA 1	0.2450	0.4454	0.55	0.583
MA 2	0.4611	0.3900	1.18	0.239
ARMA (1,2) model				
AR 1	-0.2613	0.2793	-0.94	0.351
MA 1	0.2768	0.2580	1.07	0.285
MA 2	0.4173	0.1771	2.36	0.020
ARMA (0,2) model				
MA 1	0.5267	0.0738	7.14	0.000
MA 2	0.2478	0.0740	3.35	0.001

The model that removes the seasonal effect is MA(2)—moving averages for two periods

$$de_t = a_t + 0.5467a_{t-1} + 0.k478a_{t-2}$$

Remembering that a is the white noise. In addition, a_t values for different times are independent.

So the above equation shows that each value of de_t is impacted by arbitrary values at the same time (a_t) and also partially impacted by arbitrary values from two periods before (a_{t-2})

$$S^S_{t=6} = 27.8 - 0.0107 S_T + e_t$$
$$de_t = e_t - e_{t-1}$$
$$de_t = a_t + 0.5267 a_{t-1} + 0.2478 a_{t-2}$$

The empirical data are shown plotted against a prediction (a weak one), in Figure 13, which displays the relationship between spills and seasons.

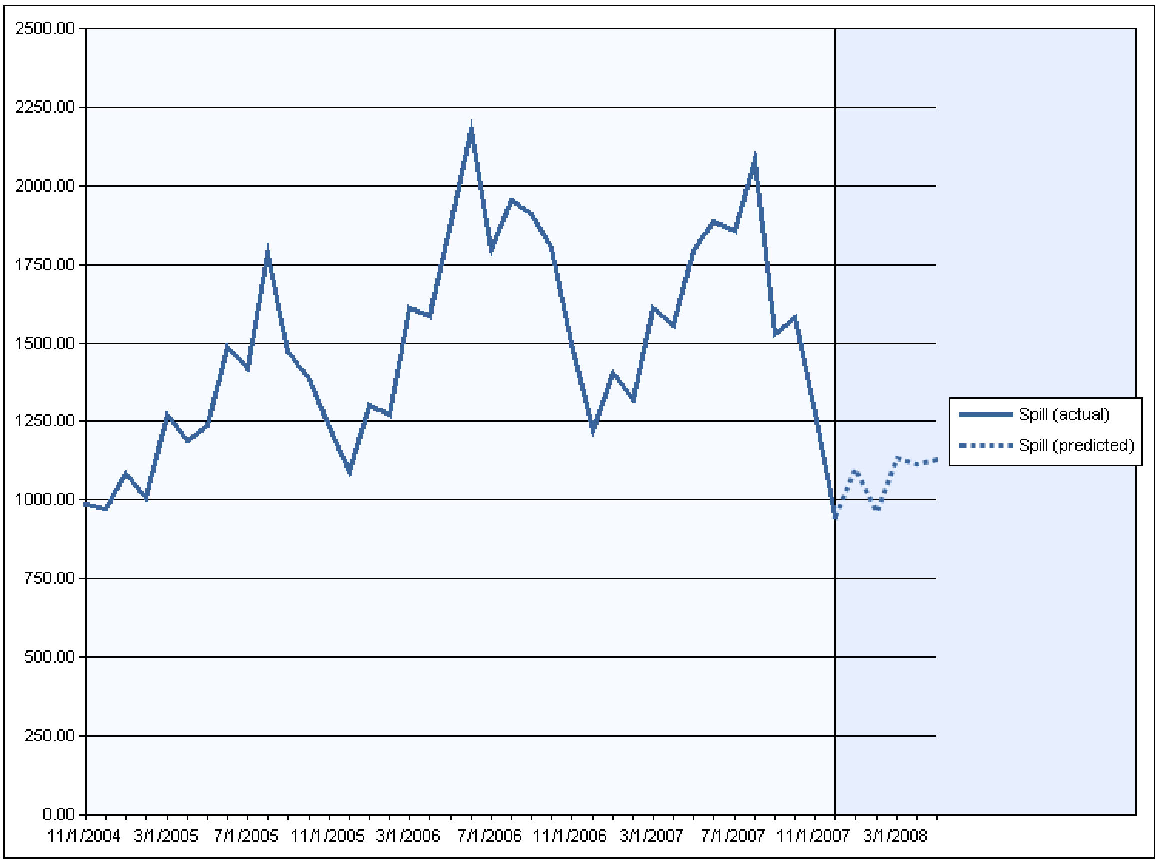


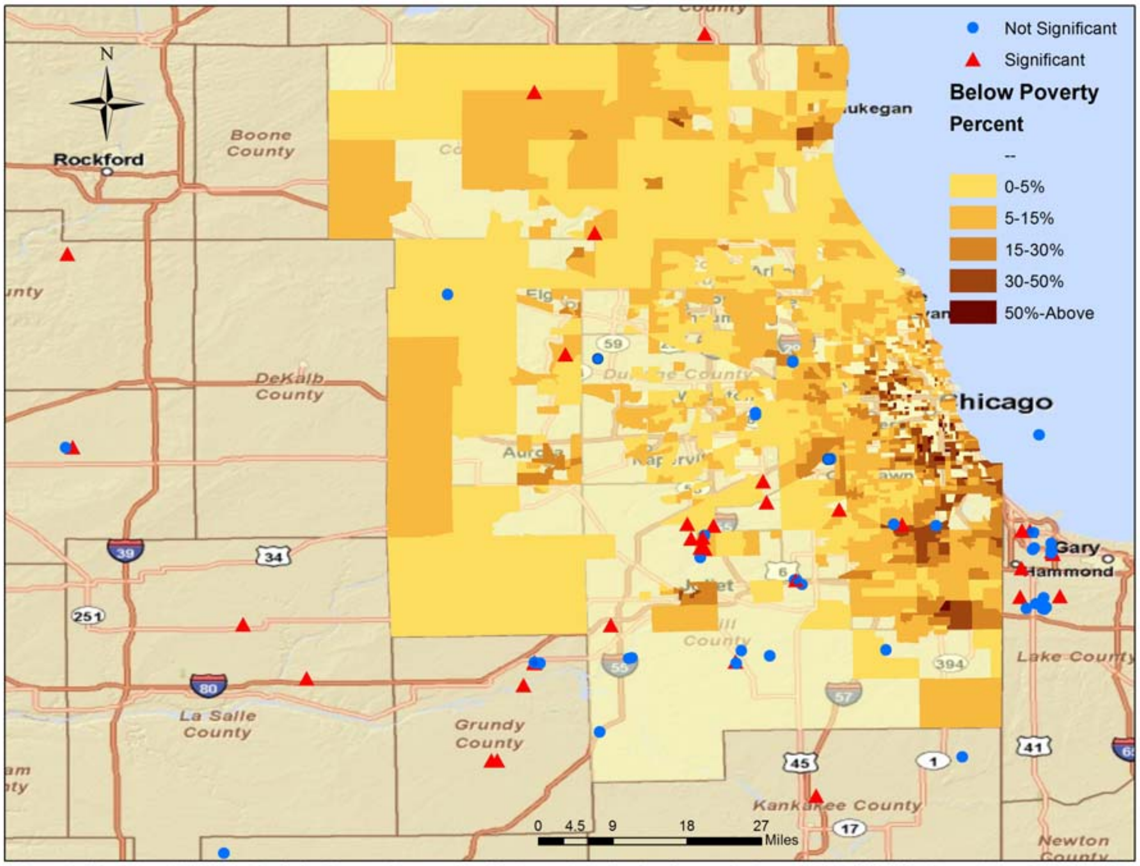
Figure 13. Prediction against the empirical data

4.4 The spatial clustering and exploring forecasts for places

The time aspects of the analysis are apparent enough, and two temporal can capture the seasonality in the variables. For a detail analysis we have chosen California as a case analysis. A subset of 16,062 HAZMATS spills data occurred in CA from 1998 to 2010. A cluster analysis with a tolerance of 100ft was used to identify “unique locations” and the number of spills per unique location was quantified (frequency of spills).

We found 354 unique locations with frequency of spills ranging from 1 to 1288 where approximately two thirds of the locations (239) having a total frequency of 20 or fewer discharges during this time period. Qualitatively, these locations verify the hypothesis that there are really two types of geographic effects with hazmat spills. First, there are spills that happen at various locations throughout the network and the routes, and those types of spills are likely to be explained by roadway characteristics. Second, there is a subset of locations within the US, Calfornia, and within California regions that are foci. These two types of geographic effects should probably be analyzed separately.

Unlike the hazmat spills during road and rail transport, the pipeline spill data are much more spatially dispersed. A sample of those data are illustrated for Chicago in Figure 14, using the lexicon for the PMSA data where “significant” spills are roughly analogous to “serious” spills from the HMIRS.



Source: Incidents data: PHMSA Pipeline Safety Program, Basemap: ArcGIS, Poverty Data: American Community Survey B17001 2005-2009, Census Tracts: Tiger FIles 2010

Figure 14. Maps of the PMSA spills files, 1998 to 2011

With the database created for this Metrans project, however, it is possible to include pipeline events along with the other modes in analysis. Although there is a lot of overplotting in the data, it is possible to see the relative concentration of pipeline spill events in Gary, Indiana. It also has a high concentration of spills from the other modes of transport. The map helps illustrate one of the potential problems with these spatial analyses: The poverty information layer is for the Chicago-area metropolitan statistical area—which does not include Gary. For natives and regional analysts alike, Gary is a well-known industrial suburb of the Chicago region. Leaving it out of a hazards analysis of the region makes no sense. Emergency planning jurisdictional boundaries, thus, can hide hazards right across the artificial border. Splitting the hazards data across multiple agencies can also hide potential cumulative effects. In this case, both issues arise for Gary.

A Gettis-ord-gi* Hotspots analysis (within 0.5 mi circular buffer HSV) was run to find the HAZMAT facilities where the frequency of spills resulted statistically significant and those areas were labeled Hotspots. The Hotspots can be geographically referenced by their XY Coordinates. See

Figure 15 below for hotspots with Z score larger than 1.29 (90 percentile) in California.

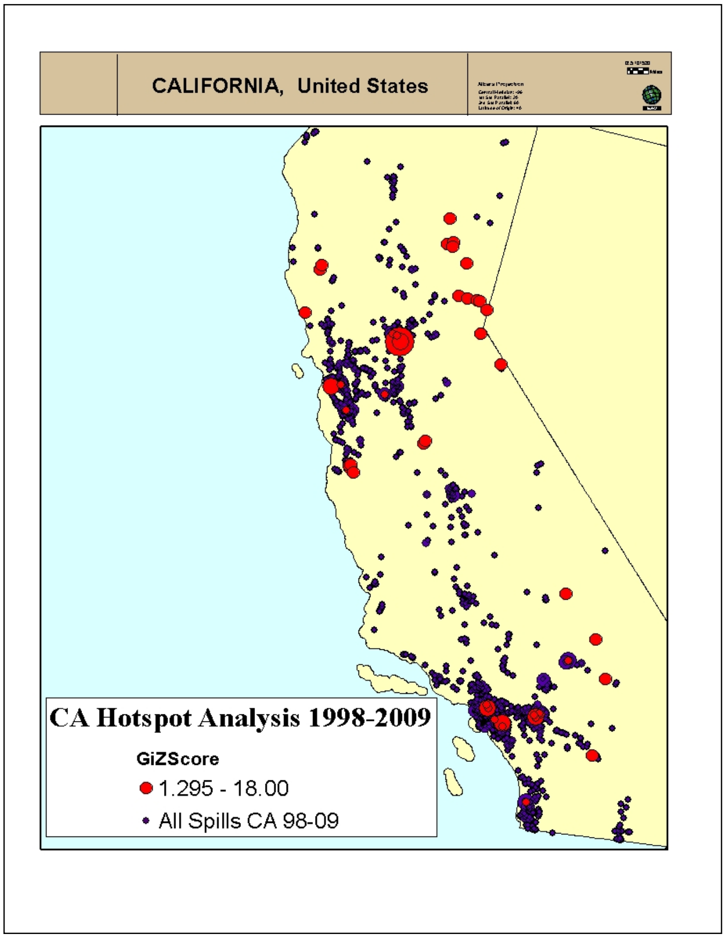


Figure 15. Hotspots analysis of California spills

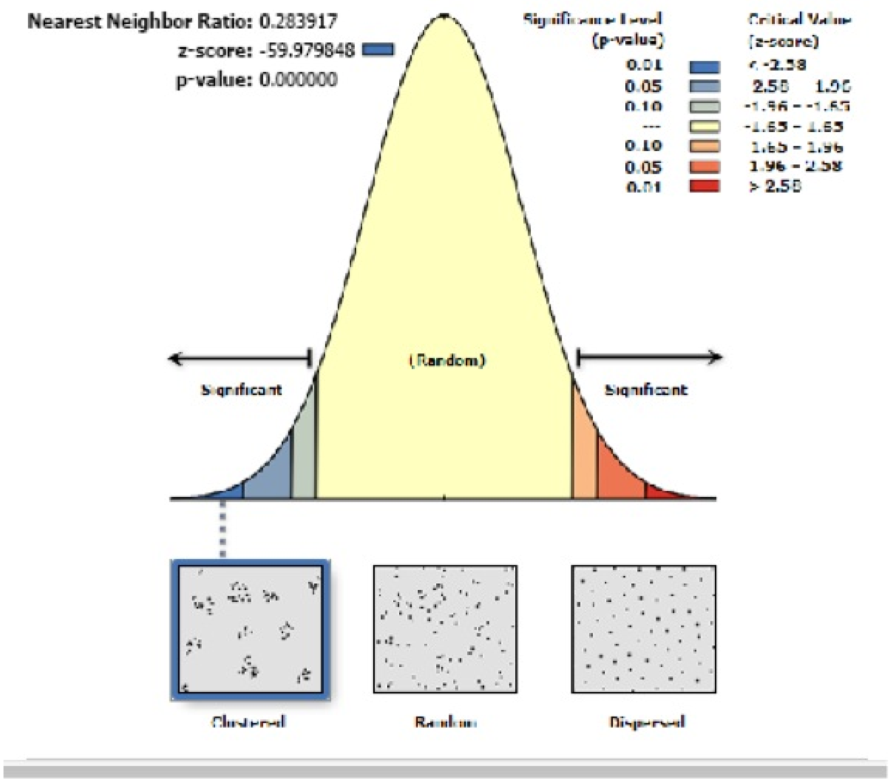
A relatively low frequency point can be labeled as a hotspot when it is relatively high with respect to its neighbors. In rural areas where there are no more discharges within the half of a mile radius even a low frequency point could become of statistical significance with regards to its neighbors. It is important always before making final recommendations to rectify the results of the numeric analysis with other reliable sources of information that may help us to characterize the area to decide if those points labeled "Hotspots' truly fulfill the scope of our study. This characterization can be done by corroboration with local knowledge experts, by local surveys, interviews, focus groups among the local communities or by review of other local reports all ready available.

The hotspot analysis yielded 135 Hotspots with a Z score of 1.29 or more. We overlap those points with a geographic layer and made a spatial join.

While calculating hotspots by the method of nearest neighbor distance analysis it is possible to identify spatial behaviors such as autocorrelation, dispersion or clustering of our sample. Spatial autocorrelation is a measure of interdependence among spatially distributed data; it is the degree of correlation between a hotspot and its neighbors (spatial dependence or spatial association). The nearest neighbor distance analysis measures the distance among every data on the sample and its neighbors and calculates the mean distance value for the sample (observed median distance). We then compare the observe median with the mean distance value that we would expect if the sample was distributed randomly and compare them. If the Nearest Neighbor Ratio is different from 1, we can reject the Null Hypothesis that the spatial distribution of Hotspots is a random distribution. If the Nearest Neighbor Ratio (NNR) is less than 1 the sample is clustered. Clustering is identified with statistical significance by a Nearest Neighbor Ratio < 1, shown in **Figure 16**.

In this case, the nearest neighbor distance analysis was used to obtain the statistic parameters describing the spatial distribution of the Hotspots at state level so we can confirm a significant degree of clustering on the sample. Our NNR yield a 0.283917 value and a Z-score of -59.98, Given the Z score there is less than 1% likelihood that this clustered pattern could be the result of random chance. NNR analysis it has been demonstrated with statistical significance that the Hotspots are clustered.

Hotspots cluster in urban centers with high population densities.



Nearest Neighbor Analysis	
Observed Mean Distance	0.024660
Expected Mean Distance	0.086857
Nearest Neighbor Ratio	0.283917
z-score	-59.979848
p-value	0.0000

Figure 16 Results for CA Hotspots NNR

Any spill that caused evacuation or injuries of 500 or more people, or that have caused casualties has been classified as serious spill into the database. Maps showing the spatial distribution of serious spills are created, and contrasted with the spatial distribution of "Hotspots" for visualization and analysis. See Figure **17**.

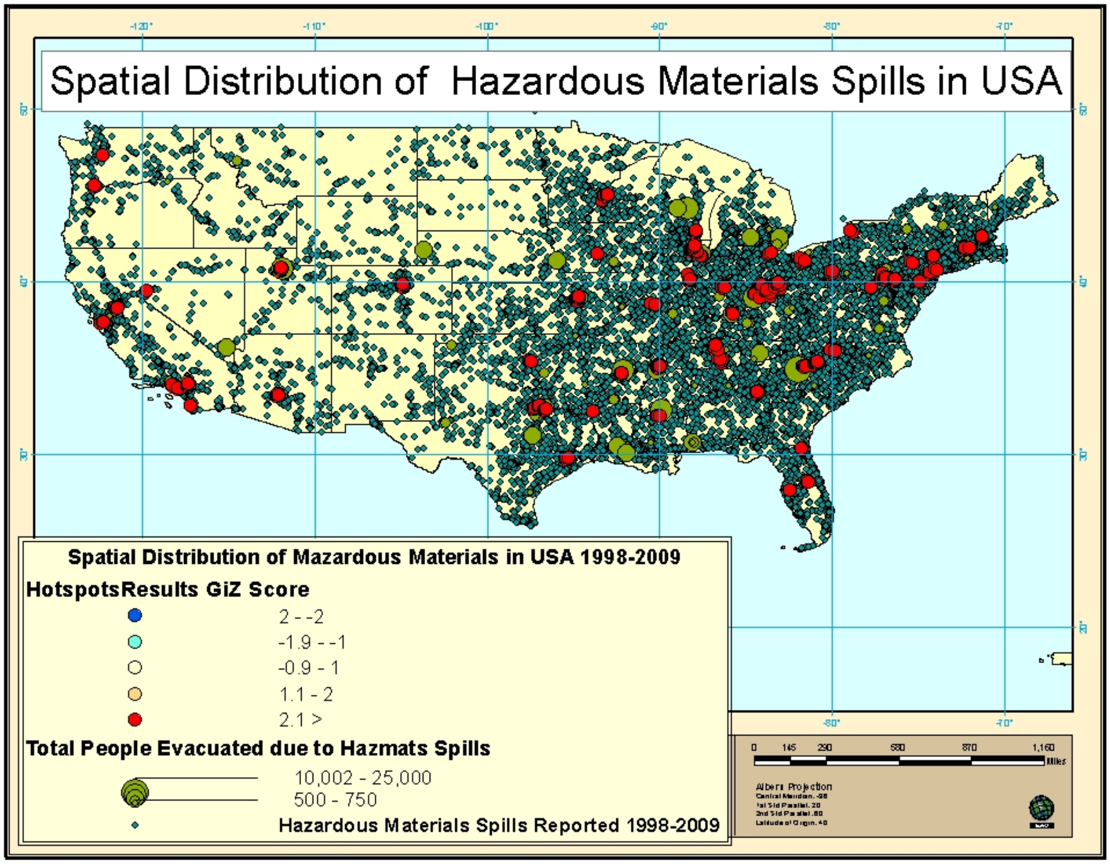


Figure 17. Spatial distribution of Hazmat Spills and Evacuations

Chapter 5. High-impact communities in California

We use California as a case study to find more accurate associations. However, this analysis could be repeated for each state or for each metropolitan region as desired and nation-wide conclusions could be drawn after those regional studies.

5.1 Highest frequency locations

For California's spills, there are 10,500 spills in only 354 unique locations with frequency of spills ranging from 1 to 1288 where approximately two thirds of the locations (239) having a total frequency of 20 or less discharges during this time period. The other third are locations with a very large number of spills. Some of these spill locations are docks or transfer sites where handling hazardous materials is a matter of routine, and they have staff and containment materials onsite. These types of locations—for the ten most frequent locations—are shown in Table 6.

Table 6. The 10 most frequent spill locations in California, 1998 to 2010

Incident City	Incident Route	Serious	Spill Count
SACRAMENTO	8200 ELDR CREEK RD	0	588
BLOOMINGTON	330 W. RESOURCE DR.	0	380
SACRAMENTO	8205 BERRY AVENUE	0	320
ANAHEIM	590 E. ORANGETHORPE AVE.	0	211
ONTARIO	3140 EAST JURUPA AVENUE	0	205
SAN DIEGO	9999 OLSON DRIVE STE100	0	190
SAN BERNARDINO	1500 RIALTO	2	175
WEST SACRAMENTO	1380 SHORE	0	166
SAN FRANSISCO	657 FORBES BOULEVARD	0	157
CERRITOS	13233 MOORE ST	0	149

SOURCE: HMIRS data, compiled by the authors.

These locations contradict the hypothesis that locations with frequent spills are likely to have a higher frequency of serious spills. At the every least, the relationship is not monotonically increasing. Quite a few of the serious also spills occur in simply one location—a spill event that occurs somewhere along the route, and becomes serious.

5.2 Model of spill severity by basic shipment parameters

An exploratory modal of spill severity can be formulated using a binomial-logistic formulation, just to see whether we can isolate non-route factors that might influence the severity of a spill; the results appear in Table 7.

According this formulation—remember that it models the likelihood of even severity given that an event has occurred (a separate probability, one that has yet to be estimated). Table 7 reports the odds ratios, which reflect the exponentiated model parameters. These convey the increased likelihood for an event becoming serious according to four major characteristics: Mode; Phase in the mode; Hazard class, and quantity released. The results are pretty straightforward: the more materials released, the more likely the spill event is to become serious. In general, rail spills are 1.36 times more likely to become serious than airline (the baseline) spills.

Table 7. Odds ratios of by mode of a spill turning into a serious spill

		Odds Ratio	Significance
Mode			
	Highway	1.0683158	***
	Rail	1.3658518	***
	Water	0.9676971	
Phase			
	In transit	1.2310136	*
	In transit storage	1.4534563	***
	Loading	1.0511233	
	Unloading	1.0553508	
Materials			
	DWW	0.9027451	
	Explosion-1	0.9875024	
	Explostion-2	0.8698117	
	Combustible liquid	0.9461802	
	Flammable gas	0.9282169	
	Flammable solid	0.9316479	
	Infectious	0.9563995	
	Misc	1.0549958	
	Compressed gas	0.9171575	
	Peroxide	1.0667428	
	ORM	0.9599305	
	Oxidizer	1.0039293	
	Poisonous Gas	1.3578749	
	Poisonous Materials	1.1312069	
	Radioactive Materials	1.1907027	
	Sp. Combustion	0.9252131	
Quantity released		1.00006	***

SOURCE: HMIRS enhanced data, compiled by the authors. N=10,500 spills, range=State of California, 1998-

2010.

The material types are not significant, though the probabilities do align with expectations: poisonous gas spills have a higher odds ratio of becoming serious than other types of spills.

The one surprise in Table 7 concerns the odds ratios by phase.

By far, materials spilled while being held “in transit storage” are 1.5 times more likely to become serious than spills during other phases of transport. In transit storage refers to storage that is incidental to the transport, such as materials sitting at a terminal waiting to be reloaded. That difference does inform our analysis, as it again reinforces the idea that land uses heavily influence the severity of the hazmat event.

In the 12 years of the data, California has only had 15 events that required no-notice evacuations of the public, and the worst event, which occurred in Downey in 2010, caused the evacuation of 100 people. The evacuation lasted for 12 hours, and thus there are 1200 hours of time loss. The worst evacuation, in terms of 6,560 hours lost, occurred on a railroad just outside of Mecca, California, just north of the Salton Sea. The takeaway lesson is that the events are very rare, but that the community disruption can be significant. Keep in mind that not all serious spills cause an evacuation.

Table 8. No-Notice Evacuations in California, 1998-2010

Incident City	Incident Route	Date of Incident	Public Evacuated	Employees Evacuated	Total Evacuation Hours	Person Hours	Mode of Transportation
MECCA	MILEPOST 626.90	3/3/08	80	0	82	6,560	Rail
KEYS		1/27/06	30	0	110	3,300	Highway
DOWNEY	Stewart And Gray Road	5/14/10	100	1	12	1,200	Highway
KEENE		2/20/10	35	0	15	525	Rail
BIEBER	BNSF GATEWAY SUBDIV.MP 90	7/13/06	50	0	7	350	Rail
CHINO		7/6/07	13	9	9	117	Rail
SAN JOSE	SJC AIRPORT	6/14/08	50	5	2	100	Air
CRESCENT CITY	Lauff & Amador	3/25/05	20	0	4	80	Highway
IRVINE		8/12/08	30	30	1	30	Air
SANTA ROSA	440 Hearn Ave	3/17/08	7	3	4	28	Highway
HUGHSON	5824 Geer Road	6/27/05	4	0	2	8	Highway
PLUMAS	MIIEPOST 252.50	6/30/07	2	0	1	2	Rail

5.2 Spill severity and geography

The model in Table 7 uses spills as the units of analysis—there are no controls for location. Controlling the severity by location gives an alternative view of the data. A look at the 10 places in the state of California with the most frequent serious spills appears in Table 9.

Table 9. High-Frequency, High Serious Spill Frequency Locations

Incident City	Incident Route	Serious Spill Count	Spill Count
MORENO VALLEY	17101 HEACOCK	48	60
SACRAMENTO	900 E STREET	45	69
SAN LEANDRO	3050 TEAGARDEN STREET	26	66
FRESNO	3688 EAST CENTRAL AVE	15	15
FONTANA	10661 ETIWANDA AVE	14	96
BARSTOW	200 NORTH AVE H	14	53
BAKERSFIELD	700 MCDIVITT	11	17
RIVERSIDE	779 PALMYRITA AVENUE	10	12
COMMERCE	2747 S VAIL AVE	9	52
MERCED	1535 EAST PECADERO	8	80

Source: HMIRS data compiled by the author.

Define k^l as a binomial distribution, so that a negative binomial model can represent a simplistic relationship between spill counts and serious spill counts ($z = \eta \mathbf{w}$), where $z_i = (y_i - E(y_i))^2 - y_i/\sqrt{2}E(y_i)$ and $w_i = g[E(y_i)]/\sqrt{2}E(y_i)$.

Table 10. Negative Binomial Model of Severe Spills

	Beta	SE
Prior (all spills)	0.02135	0.00160 ***
Phase dummy (In storage)	0.00224	0.00013 ***
Quantity	0.00078	0.00040 ***

SOURCE: Enhanced HMIRS data, California only, 1998 to 2010, n=354.

5.3 Spill frequency, spill location, and spill severity

To answer questions about population affected by particular hotspots, it is necessary to focus in a small geographic scale because population characteristics vary for each community. Therefore we worked with a small sample (only the more significant Hotspots Z Score 1.29 and up) to obtain information about the communities affected by spills. We also conducted an analysis tract-by-tract.

The SF3 population tables had been downloaded for each county and a database incorporating the 63 California counties was compiled to represent the population coverage at state level. We overlap this database with a geographic layer and made a spatial join. The Join with the Bureau of Census TIGER layer "Tracts" for California conferred spatial information attributes so the population data can be geographically referenced at tract level. We now have a layer of percentage of population by race at tract level (PPR). We enabled this layer to report only a proportional part of population information when tract is not intersected in its totality. The hotspots layer is an event layer containing a Z score, and a frequency value associated to a XY coordinate, but each event really represents an area of 0.5 mile radius so another "buffer" layer has been created buffering each event with a 0.5 miles fix radius, allowing for dissolve feature if there are areas where buffers intersect. See Figure 18 below.

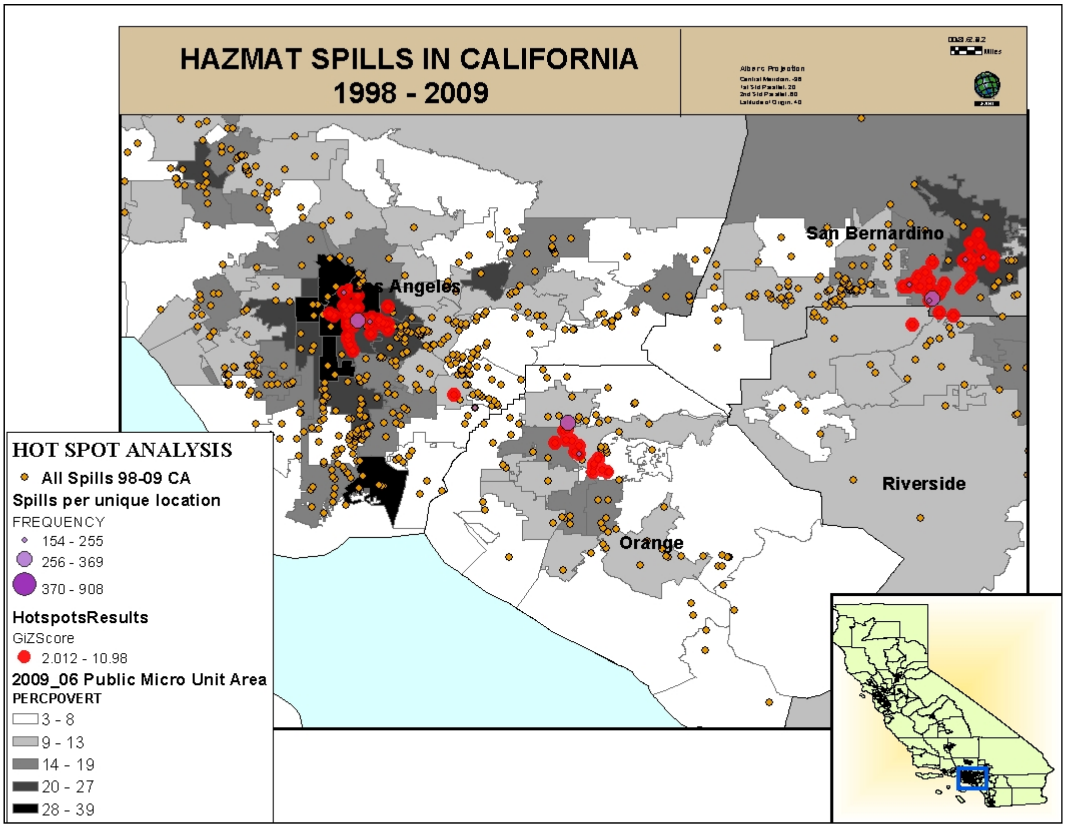


Figure 18. MHA areas aggregated in southern California from hotspot buffers

By clipping the PPR layer with the MHA layer we calculate the percentage of population directly contained within the Hotspots Areas. We can report this information in terms of percentage of population by Census socio-demographic variables.

In general, California has a diverse population. Planning for future events at the high frequency, high consequence locations will likely require multiple approaches in order to help the communities and agencies involved to evaluate the potential issues.

A more general distribution of what has occurred over the past decade requires some baseline understanding of the geography. These areas do change in socio-demographics over time; if the point were to establish a relationship between why a particular population and spill events are geographically proximate. However, our goal here is simply to look for high-consequence spill areas in areas that have high concentrations of socially vulnerable groups—places where the emergency planning should be undertaken with the understanding that the communities there may need special consideration.

Unfortunately, count regressions pose a fairly serious set of modeling challenges, and serious spills are very rare events in the accident records—thereby compounding the issues for statistical analysis. The data are left censored at zero, as it is impossible to have fewer than zero spills. Table 11 though Table 15 present a series of count-based models of serious spill counts by California tract.

Table 11. Poisson regression coefficients, California spills 1998 to 2010

	Estimate	**Std. Error**	**z value**	**Pr(> |z|)**
(Intercept)	-4.1590	0.2838	-14.66	0.0000***
%Black	-0.6088	1.3904	-0.44	0.6615
%Asian	-2.6221	1.2740	-2.06	0.0396*
%American Indian	**4.8198**	**2.3018**	**2.09**	**0.0363***
%NHOPI	10.8767	9.2993	1.17	0.2422
%White, Hispanic	**1.6814**	**0.7772**	**2.16**	**0.0305***
%Asian, Hispanic	28.6213	18.4379	1.55	0.1206
% American Indian, Hispanic	1.9711	13.1751	0.15	0.8811
%NHOPI, Hispanic	39.9657	25.1132	1.59	0.1115
%Renters	**-1.3228**	**0.6748**	**-1.96**	**0.0500***
%Poverty	-0.6005	1.5991	-0.38	0.7073
AIC	850.93			
$\sum \hat{\hat{f}}_i(0)$	7,035			

Table 12. Quasi-Poisson Regression Model, California spills 1998 to 2010

	Estimate	Std. Error	z value	Pr(> |z|)
(Intercept)	-4.1932	0.3595	-11.66	0.0000
%Black	-1.1111	1.7903	-0.62	0.5349
%Asian	-2.1406	1.3933	-1.54	0.1245
%American Indian	**14.9947**	**5.7807**	**2.59**	**0.0095**
%NHOPI	9.7312	13.5878	0.72	0.4739
%White, Hispanic	**1.3270**	**1.0533**	**1.26**	**0.2077***
%Asian, Hispanic	27.5803	30.2830	0.91	0.3624
% American Indian, Hispanic	-11.3230	21.6980	-0.52	0.6018
%NHOPI, Hispanic	97.4704	49.4926	1.97	0.0489
%Renters	-1.2600	0.8207	-1.54	0.1247
%Poverty	-0.4303	1.9774	-0.22	0.8277
AIC	NA			
$\sum \hat{\hat{f}}_i(0)$	7,035			

A fairly consistent story emerges from the exercise. Over the 12 years in the analyses, we have one population group that is disproportionately represented among serious spills locations: American Indians. These models are capturing tracts that have had multiple serious spills and which also have higher than average concentrations of American Indians. The poisson and quasi-poisson model also so some raised incidence among Hispanic white latino populations, although that effect disappears in the three subsequent models that control the overdisperson more directly—the negative binomial, hurdle, and zero-inflated (ZINB) models. With these, the coefficient estimates vary a lot. But the significant effects become more specific: there's a handful of tracts in the state with American Indian residents that are primarily Spanish-speaking where there is a relatively high serious spill counts. Again, , the point is to explore the mass of the data for exactly these kinds of effects that can go unnoticed over periods as a long as a decade.

A similar set of models for all spill events appears in Appendix E.

Table 13. Negative Binomial Regression, California spills 1998 to 2010

	Estimate	Std. Error	z value	Pr(> |z|)
(Intercept)	-4.1932	0.3595	-11.66	0.0000
%Black	-1.1111	1.7903	-0.62	0.5349
%Asian	-2.1406	1.3933	-1.54	0.1245
%American Indian	-14.9947	5.7807	2.59	0.0095**
%NHOPI	9.7312	13.5878	0.72	0.4739
%White, Hispanic	1.3270	1.0533	1.26	0.2077
%Asian, Hispanic	27.5803	30.2830	0.91	0.3624
% American Indian, Hispanic	-11.3230	21.6980	-0.52	0.6018
%NHOPI, Hispanic	97.4704	49.4926	1.97	0.0489*
%Renters	-1.2600	0.8207	-1.54	0.1247
%Poverty	-0.4303	1.9774	-0.22	0.8277

Table 14. Hurdle regression coefficients

truncated poisson with log link				
	Estimate	**Std. Error**	**z value**	**Pr(> |z|)**
(Intercept)	1.391	1.024	1.359	0.174225
%Black	-2.120	3.845	-0.551	0.581330
%Asian	-14.250	7.507	-1.898	0.057679
%American Indian	**-58.774**	**24.474**	**-2.401**	**0.016329 ***
%NHOPI	42.433	36.959	1.148	0.250924
%White, Hispanic	-3.866	3.318	-1.165	0.243842
%Asian, Hispanic	99.650	75.933	1.312	0.189408
% American Indian, Hispanic	**237.464**	**72.121**	**3.293**	**0.000993 *****
%NHOPI, Hispanic	-30.469	187.852	-0.162	0.871152
%Renters	-2.257	2.130	-1.059	0.289502
%Poverty	-5.857	6.092	-0.961	0.336371
Binomial with logit link				
	Estimate	**Std. Error**	**z value**	**Pr(> |z|)**
(Intercept)	-4.4422	0.3216	-13.814	<2e-16 ***
%Black	-1.1636	1.6763	-0.694	0.488
%Asian	-1.6771	1.2757	-1.315	0.189
%American Indian	4.9863	3.1697	1.573	0.116
%NHOPI	9.8432	10.9181	0.902	0.367
%White, Hispanic	1.4327	0.8983	1.595	0.111
%Asian, Hispanic	-2.3826	33.9513	-0.070	0.944
% American Indian, Hispanic	-28.8952	25.4430	-1.136	0.256
%NHOPI, Hispanic	46.6695	28.6313	1.630	0.103
%Renters	-1.1039	0.7429	-1.486	0.137
%Poverty	0.1927	1.7195	0.112	0.911

Table 15. Zero Inflated Negative Binomial

	Estimate	Std. Error	z value	Pr(> |z|)
Poisson with log link				
(Intercept)	-0.04401	0.78201	-0.056	0.9551
%Black	-6.83294	3.72970	-1.832	0.0669 .
%Asian	-4.16442	3.11981	-1.335	0.1819
%American Indian	**-59.71539**	**13.63316**	**-4.380**	**1.19e-05 *****
%NHOPI	48.53676	22.97889	2.112	0.0347 *
%White, Hispanic	0.45147	2.05287	0.220	0.8259
%Asian, Hispanic	56.54752	52.62266	1.075	0.2826
% American Indian, Hispanic	**212.91996**	**38.92046**	**5.471**	**4.48e-08 *****
%NHOPI, Hispanic	68.59487	82.25413	0.834	0.4043
%Renters	-1.13633	1.36893	-0.830	0.4065
%Poverty	-6.06070	3.22712	-1.878	0.0604 .
binomial with logit link				
(Intercept)	4.3462	0.7601	5.718	1.08e-08 ***
%Black	-6.1980	4.9299	-1.257	0.208677
%Asian	-2.0952	2.9963	-0.699	0.484384
%American Indian	**-104.9336**	**23.9181**	**-4.387**	**1.15e-05 *****
%NHOPI	30.3011	22.6186	1.340	0.180359
%White, Hispanic	-0.9911	2.0960	-0.473	0.636321
%Asian, Hispanic	47.4421	58.0391	0.817	0.413691
% American Indian, Hispanic	**216.7348**	**56.3249**	**3.848**	**0.000119 *****
%NHOPI, Hispanic	-22.9950	39.9124	-0.576	0.564524
%Renters	0.1497	1.4624	0.102	0.918473
%Poverty	-6.5601	3.7880	-1.732	0.083312 *

Chapter 6. Conlusions

Looking at the data across the US and in California shows that while most hazardous materials events are minor, there are a large number of events—roughly 10,000 every year. The past spill record for the totals and worst events are compiled in **Table 16**. The US definition of a "serious" spill has a fairly low threshold for damage and off-site consequences. The result is that 1 in every 23 spills in the US is considered to be serious. Of those spills, some become quite serious indeed, both in terms of evacuation costs and total damages, and as we have shown, those two figures tend to move together in a subset of all serious incidents. The relatively low numbers of lives lost and injuries attest to how well most incidents are managed. Nonetheless, the worst events, infrequent though they are, are quite serious for surrounding communities.

Given the geographic analysis in the first chapter , we established that these events are concentrated together with multi-modal facilities. This clustering occurs either as the result of handling at that facility or from multi-modal facility co-location with originating or destination locations through the industrial clustering within US regions. The geographic vulnerability of these locations is therefore apparent, as are the potential consequences for their residential neighbors.

For livability and vulnerability, a complex picture emerges. Multi-modal freight shippers are, even with all their spills, fairly good neighbors—except for those infrequent times when an event spirals. The evidence for the livability argument—that freight and residential populations can co-exist—is mixed. The consequences for human life and injuries of accidental releases have been low, especially compared to the risks and mortality resulting from passenger transport. Nonetheless, the volumes handled at multi-modal facilities and the highways and railways that run through US regions are large, and a few selected events become very serious indeed.

Some exemplary events can help in further understanding the issues raised throughout this analysis. **Table 17** shows a sample of the highest consequence events from around the US. Note that these do not necessarily occur at multi-modal facilities, but they do serve as exemplars for events that have caused pretty serious consequences for those living near hazardous materials shipping. Further study of these events in future research can help analysts envision the consequences of a terrorist strike. For now, they serve to illustrate a final point about security and hazmat shipping.

Table 16. Data Summary Consequences, 2000 to 2010

	California	CA Percent	CA Share of US	US	US Percent
Tons shipped*	**1,997,550,000**	**100%**	**9%**	**22,311,330,000**	**100%**
Total Events	**10,626**		**9%**	**121,405**	**100%**
Serious Events	**297**		**6%**	**5,196**	**4%**
Deaths (total)	**3**		**2%**	**136**	**0%**
Worst	1			9	0%
Mean	—			—	
Injuries	**37**			**1,587**	
Worst †	5	14%	0%	631	12%
Mean	—			—	
Total Evacuation	**6,196**			**154,616**	
Worst †	2,000	32%	1%	25,000	16%
Mean	21			30	
Total Evacuation (hours)	**429**			**7,230**	
Worst †	110	26%	2%	2,016	28%
Mean	1			1	
Total Person-Hours	**135,336**			**2,715,356**	
Worst †	120,000	89%	4%	1,625,000	60%
Mean	455			522	
Total Property	**$1,643,317**			**$68,748,792**	
Worst †	490,000	30%	1%	3,100,000	5%
Mean	5,533			13,230	
Total Response	**$2,373,122**			**$67,681,719**	
Worst †	1,970,065	83%	3%	19,790,000	29%
Mean	79,903			13,030	
Total Remediation	**$31,069,089**			**$230,095,379**	
Worst †	13,300,000	43%	6%	13,300,000	6%
Mean	104,610			44,280	
Total Cost ($)	**$67,738,646**			**$571,114,173**	
Worst †	27,467,818	41%	5%	27,470,000	5%
Mean	228,076			12,300	

Source: Hazardous Materials Information System, data compiled by the authors.
*These data are from the US Commodity Flow Survey, 2007; other years estimated by the authors.
† The worst-case percentages are calculated as a percentage of the US worst cases rather than all spills or all serious spills.

Comparatively common substances have had demonstrably high consequences in isolated events in the past decade. As bad as the nightmare scenario—an intentional strike against radioactive material—would be, everyday materials transport, like gasoline shipments, have prompted two of the four worst events over the past 10 years in terms of property damage and total costs. Gasoline is virtually everywhere in the

US: the shipments are ubiquitous, as are gas stations. The other substance, chlorine, is also common; it has many uses in industry and government, including water treatment.

These are not, in other words, exotic or infrequently handled materials. It is unlikely that the large amounts of gasoline or chlorine—or the other commonly used hazardous materials handled throughout the US every day—will decline any time soon. They provide ready and available material for terrorists to use, and those consequences may be worse than these accidental releases—which are bad enough.

It may be, therefore, a mistake to plan only for strikes against multi-modal facilities only in terms of highly toxic or radioactive materials. As dangerous as those substances are, they may be less readily found than other substances, and they may be isolated more from potential victims. As the US tries to move towards a livable freight agenda, these types of security issues should be analyzed in regions that have human settlements surrounding freight activities.

Turning from terrorism an intentional strikes, the data demonstrate both spatial and time correlation. The original hypothesis regarding spatial clustering was proved true for all incidents and serious incidents. Nonetheless, strict spatial clustering does not explain all serious spills locations. About two thirds do happen along the route, while roughly a third occur within clusters. Given that California is a large state with a full range of extensive shipping activities. The analysis is likely to be generalizable. In places with few freight land uses, multi-modal facilities, or or distribution centers, hazmat spill models that stress routing characteristics are going to capture most of the spills and releases that occur. But in states with multi-modal facilities and other freight-handling land uses, the models should include land use variables or some spatial effect to capture the relationships between land use and hazmat spills we have shown here.

The data also demonstrated a strong seasonality, which we did not originally set out to model. However, the analysis shows distinct seasonal effects. In sum, the prior data demonstrate that routing models should include both land use and seasonlity in their risk assessments.

Table 17. A Sample of Exemplar Events, 2000 to 2010

Location	Exemplar	Measure	Date	Route	Mode	Substance	Event
Detroit, MI	Property Damage Total damage costs	3,100,000.00 27,467,818.00	10/6/03	I-75 Ramp	Highway	Gasoline	Cargo tank release , fire
Burbank, CA	Response Costs	19,790,065.00	6/10/10	Highway 134E	Highway	Gasoline	Cargo tank turned over,
Keys, CA	Remediation Costs	13,300,000.00	1/27/06	Unreported	Highway	Formic Acid	Tank cracked during crash
Graniteville, SC	Duration Person-Hours Fatalities Injuries	 1,625,400 9 631	1/6/05	Milepost 178.3	Rail	Chlorine	Multi-car derailment

Table 18 summarizes the scattered significant findings for the various models constructed to examine the spills counts by location by population type. We have a weak, but suggestive set of results that again highlight potentially vulnerable population groups: Spanish-speaking American Indians. Neither residents living in poverty nor renters are likely to be associated geographically with spill counts. We could make these models more explicitly spatial to try to explain more of the variability, but the results are clear enough: there are a small number of tracts in the state with a comparatively high concentration of Hispanic American Indians residents, and those are also serious spill locations. The consequences for emergency planning in American Indian communities in places like Riverside and San Bernardino mean that strategies need to be tailored for one of the state's most often overlooked ethnic groups.

Table 18. Summary of significant relationships

	%Black	%Asian	%American Indian	%NHOPI	%White, Hispanic	%Asian, Hispanic	%Amierican Indian, Hispanic	%NHOPI, Hispanic	%Renter	%Poverty
Serious Spills										
Poisson			+		+				—	
Quasi			+		+					
NB			—							
Hurdle										
(1)			—				+			
(2)										
ZINB										
(1)			—				+			
(2)			—				+			
All Spills										
Poisson	**+**	—	+	—	+	+	+	+	—	—
Quasi		—	+		+	+	+	+		
NB										
Hurdle										
(1)		—	+		+				—	—
(2)							+	+		
ZINB										
(1)				+	+	+			—	—
(2)			—				+			

Appendix A. Data dictionary for Enhanced HMIRS Database

Data Element	Type	Definition
Report Submission Source	Text	Submission method of incident report (paper form, web or xml transmission).
Report Number	Text	The submission source and 10-digit code that contains the year, month and sequence the incident report was received. The report number uniquely identifies each report.
Number of Lines per Incident [1]	Numeric	Displays the number of lines per Incident due to multiple shippers, commodities, and packages involved in an incident.
Report Type	Text	Type of incident report being filed. Taken from Form DOT F 5800.1, Section I, #1.
Date of Incident	Date	Date the incident occurred. Taken from Form DOT F 5800.1, Section II, #3.
Time of Incident	Text	Time the incident occurred. Taken from Form DOT F 5800.1, Section II, #4.
NRC Number	Text	If this incident was reported to the National Response Center (NRC), this is the report number NRC assigned to the incident. Taken from Form DOT F 5800.1, Section II, #5.
Federal DOT Agency Name	Text	If this incident was reported to another Federal DOT agency, the agency code is entered here. Taken from Form DOT F 5800.1, Section II, #6.
Federal DOT Report Number	Text	If this incident was reported to another Federal DOT agency, the report number is entered here. Taken from Form DOT F 5800.1, Section II, #6.
Incident City	Text	City name in which the incident occurred. Taken from Form DOT F 5800.1, Section II, #7.
Incident County	Text	County in which the incident occurred. Taken from Form DOT F 5800.1, Section II, #7.
Incident State	Text	State in which the incident occurred. Taken from Form DOT F 5800.1, Section II, #7.
Incident Postal Code	Text	Postal code in which the incident occurred. Taken from Form DOT F 5800.1, Section II, #7.
Incident Non-US State	Text	If the incident occurred outside the US the foreign state that the incident occurred.
Incident Country	Text	Country in which the incident occurred.
Incident Route	Text	Street Address, Mile Marker, Yard name, Airport, Body of Water or River on which the incident occurred. Taken from Form DOT F5800.1, Section II, #7.
Mode of Transportation	Text	Describes the mode of transportation in which the incident occurred. Taken from Form DOT F 5800.1, Section II, #8.
Transportation Phase	Text	Transportation phase when the incident occurred. Taken from Form DOT F 5800.1, Section II, #9.
Carrier/Reporter Name	Text	Name of the company responsible for transport of the product. Taken from Form DOT F 5800.1, Section II, #10.

[1] The title is "Multiple Rows per Incident" in the working database

Data Element	Type	Definition
Carrier/Reporter Street Name	Text	Street address of the carrier. Taken from Form DOT F 5800.1, Section II, #10.
Carrier/Reporter City	Text	City name the carrier resides in. Taken from Form DOT F 5800.1, Section II, #10.
Carrier/Reporter State	Text	State the carrier resides in. Taken from Form DOT F 5800.1, Section II, #10.
Carrier/Reporter Postal Code	Text	Postal code the carrier location. Taken from Form DOT F 5800.1, Section II, #10.
Carrier/Reporter Non-US State	Text	If carrier resides outside the US the foreign state that the carrier resides in.
Carrier/Reporter FED DOT ID	Text	Modal carrier identifier number or code. Taken from Form DOT F 5800.1, Section II, #10.
Carrier/Reporter HAZMAT Reg ID	Text	The Hazardous Materials Registration number of the carrier. Taken from Form DOT F 5800.1, Section II, #10.
Carrier/Reporter Country	Text	Country the carrier resides in.
Shipper Name	Text	Name of the company shipping a product. Taken from Form DOT F 5800.1, Section II, #11.
Shipper Street Name	Text	Street address of the shipper. Taken from Form DOT F 5800.1, Section II, #11.
Shipper City	Text	City name that the shipper resides in. Taken from Form DOT F 5800.1, Section II, #11.
Shipper State	Text	State that the shipper resides in. Taken from Form DOT F 5800.1, Section II, #11.
Shipper Postal Code	Text	Postal code that the shipper resides in. Taken from Form DOT F 5800.1, Section II, #11.
Shipper Non-US State	Text	If shipper resides outside the US the foreign state that the shipper resides in.
Shipper Country	Text	Country that the shipper resides in.
Shipper Waybill/Shipping Paper	Text	Identification number of papers used to identify shipment of hazardous materials being transported. Taken from Form DOT F 5800.1, Section II, #11.
Shipper HAZMAT Registration ID	Text	The Hazardous Materials Registration number of the shipper. Taken from Form DOT F 5800.1, Section II, #11.
Origin City	Text	City name where shipment of the hazardous material originated. Taken from Form DOT F 5800.1, Section II, #12.
Origin State	Text	State where shipment of the hazardous material originated. Taken from Form DOT F 5800.1, Section II, #12.
Origin Postal Code	Text	Postal code of state where shipment of the hazardous materials originated. Taken from Form DOT F 5800.1, Section II, #12.
Origin Non-US State	Text	If the shipment originated outside the US, the foreign state that the shipment originated.
Origin Country	Text	Country that the shipment originated.
Destination City	Text	City name where shipment of the hazardous materials is destined. Taken from Form DOT F 5800.1, Section II, #13.
Destination State	Text	State where shipment of the hazardous materials is destined. Taken from Form DOT F 5800.1, Section II, #13.
Destination Postal Code	Text	Zip code of state where shipment of the hazardous materials is destined. Taken from Form DOT F 5800.1, Section II, #13.
Destination Non-US State	Text	If the shipment is destined outside the US, the foreign state that the shipment is destined.

Data Element	Type	Definition
Destination Country	Text	Country that the shipment is destined.
Commodity Short Name	Text	Short name of the product being transported.
Commodity Long Name	Text	Name of the product being transported. Taken from Form DOT F 5800.1, Section II, #14.
Technical/Trade Name	Text	Commonly used name of the product being transported. Taken from Form DOT F 5800.1, Section II, #15.
Identification Number	Text	United Nations identification number of the product being transported. Taken from Form DOT F 5800.1, Section II, #17.
Hazardous Class Code	Text	2-digit code to identify the hazard class of the product being transported. Taken from Form DOT F 5800.1, Section II, #16.
Hazardous Class	Text	The hazard class name of the product being transported. Taken from Form DOT F 5800.1, Section II, #16.
Packing Group	Text	The packing group of the product being transported. Taken from Form DOT F 5800.1, Section II, #18.
Quantity Released	Numeric	Amount of material released converted into standardized units. Taken from Form DOT F 5800.1, Section II, #19.
Unit of Measure	Text	Code that indicates the “Units of Measure” of the standardized units. Taken from Form DOT F 5800.1, Section II, #19.
HAZMAT Waste Indicator	Text	Identifies whether the material being transported is listed as a hazardous waste. The values are 'Yes' or 'No and it defaults to 'No' if no value was entered. Taken from Form DOT F 5800.1, Section II, #20.
HAZMAT Waste EPA Number	Text	EPA Manifest Number of the hazardous waste. Taken from Form DOT F 5800.1, Section II, #20.
HMIS Toxic by Inhalation Ind	Text	Indicates whether the material being transported is listed as a Toxic by Inhalation material.
TIH Hazard Zone	Text	Hazard zone for the Toxic by Inhalation material. Taken from Form DOT F 5800.1, Section II, #21.
Material Shipment Approval Ind	Text	Indicates if the material was shipped under an exemption, an approval, or a Competent Authority Certificate. The values are 'Yes' or ‘No and it defaults to 'No' if no value was entered. Taken from Form DOT F 5800.1, Section II, #22.
Material Shipment Approval Nbr	Text	The exemption, approval, or a Competent Authority Certificate identification number. Taken from Form DOT F 5800.1, Section II, #22.
Undeclared HAZMAT Shipment Ind	Text	Indicates that this is an undeclared hazardous materials shipment. The values are 'Yes' or 'No and it defaults to 'No' if no value was entered. Taken from Form DOT F 5800.1, Section II, #23.
Packaging Type	Text	Indicates the package type. Taken from Form DOT F 5800.1, Section III, #24.
What Failed Code	Text	The numeric code that identifies what part of the packaging failed and was the immediate cause of the release. Taken from Form DOT F 5800.1, Section III, #25.
What Failed Description	Text	The description of the code that identifies what part of the package failed and was the immediate cause of the release. Taken from Form DOT F 5800.1, Section III, #25.
How Failed Code	Text	The numeric code that describes how the corresponding part of the packaging failed. Taken from Form DOT F 5800.1, Section III, #25.
How Failed Description	Text	The description of how the corresponding part of the packaging failed. Taken from Form DOT F 5800.1, Section III, #25.
Failure Cause Code	Text	The numeric code that identifies what caused the corresponding part of the packaging to fail in the way it did. Taken from Form DOTF 5800.1, Section III, #25.

Data Element	Type	Definition
Failure Cause Description	Text	The description of what caused the corresponding part of the packaging to fail in the way it did. Taken from Form DOT F 5800.1, Section III, #25.
Identification Markings	Text	Identifies package markings or other information. Taken from Form DOT F 5800.1, Section III, #26a.
Cont1 Packaging Type	Text	Package type for the non-bulk, IBC, or non-specification package. Taken from Form DOT F 5800.1, Section III, #26b.
Cont1 Material of Construction	Text	Material of construction for the non-bulk, IBC, or non-specification package. Taken from Form DOT F 5800.1, Section III, #26b.
Cont1 Head Type	Text	Head type for the non-bulk, IBC, or non-specification package. Taken from Form DOT F 5800.1, Section III, #26b.
Cont1 Package Capacity	Numeric	The package capacity, converted into standardized units. Taken from Form DOT F 5800.1, Section III, #27.
Cont1 Package Capacity UOM	Text	Code that indicates the "Units of Measure" of the standardized package capacity. Taken from Form DOT F 5800.1, Section III, #27.
Cont1 Package Amount	Numeric	The amount of material, converted into standardized units, in the package. Taken from Form DOT F 5800.1, Section III, #27.
Cont1 Package Amount UOM	Text	Code that indicates the "Units of Measure" of the standardized amount of material in the package. Taken from Form DOT F 5800.1, Section III, #27.
Cont1 Pkg Number in Shipmen	Numeric	Number of packages being transported. Taken from Form DOT F 5800.1, Section III, #27.
Cont1 Pkg Shipment Nbr Failed	Numeric	Number of packages releasing material in the incident. Taken from Form DOT F 5800.1, Section III, #27.
Cont1 Package Manufacturer	Text	Name of the company that manufactures the packaging. Taken from Form DOT F 5800.1, Section III, #28.
Cont1 Pkg Manufacturer Date	Date	Date that the package was manufactured. Taken from Form DOT F 5800.1, Section III, #28.
Cont1 Package Serial Number	Text	The package serial number. Taken from Form DOT F 5800.1, Section III, #28.
Cont1 Package Last Test Date	Date	Date that the bulk package was last tested or inspected. Taken from Form DOT F 5800.1, Section III, #28.
Cont1 Test Material Of Const	Text	Material that the bulk package is constructed. Taken from Form DOT F 5800.1, Section III, #28.
Cont1 Pkg Dsign Pressure Rpted	Numeric	The design pressure for the package. Taken from Form DOT F 5800.1, Section III, #28.
Cont1 Dsign Pressure UOM Rpted	Text	Code that indicates the "Units of Measure" for the design pressure. Taken from Form DOT F 5800.1, Section III, #28.
Cont1 Pkg Shell Thickness Rptd	Numeric	The shell thickness for the package. Taken from Form DOT F 5800.1, Section III, #28.

Data Element	Type	Definition
Cont1 Shell Thickness UOM Rptd	Text	Code that indicates the "Units of Measure" for the shell thickness. Taken from Form DOT F 5800.1, Section III, #28.
Cont1 Head Thickness Reported	Numeric	The head thickness for the package. Taken from Form DOT F 5800.1, Section III, #28.
Cont1 Head Thickness UOM Rpted	Text	Code that indicates the "Units of Measure" for the head thickness. Taken from Form DOT F 5800.1, Section III, #28.
Cont1 Pkg Srvc Pressure Rpted	Numeric	The service pressure for the package. Taken from Form DOT F 5800.1, Section III, #28.
Cont1 Srvc Pressure UOM Rpted	Text	Code that indicates the "Units of Measure" for the service pressure. Taken from Form DOT F 5800.1, Section III, #28.
Cont1 Valve or Device Fail Ind	Text	Indicate that a valve or device failed. Taken from Form DOT F 5800.1, Section III, #28.
Cont1 Valve or Device Type	Text	Valve or device type. Taken from Form DOT F 5800.1, Section III, #28.
Cont1 Val Device Manufacturer	Text	The valve manufacturer. Taken from Form DOT F 5800.1, Section III, #28.
Cont1 Valve or Device Mode	Text	The valve model. Taken from Form DOT F 5800.1, Section III, #28.
Cont2 Package Type	Text	Inner package type for the non-bulk, IBC, or non-specification package. Taken from Form DOT F 5800.1, Section III, #26b.
Cont2 Material of Construction	Text	Inner package material of construction for the non-bulk, IBC, or non-specification package. Taken from Form DOT F 5800.1, Section III, #26b.
Cont2 Package Capacity	Numeric	The inner package capacity as reported by the preparer. Taken from Form DOT F 5800.1, Section III, #27.
Cont2 Capacity UOM Reported	Text	The "Units of Measure" for the inner package capacity as reported by the preparer. Taken from Form DOT F 5800.1, Section III, #27.
Cont2 Package Amount	Numeric	The inner package capacity as reported by the preparer. Taken from Form DOT F 5800.1, Section III, #27.
Cont2 Package Amount UOM	Text	The "Units of Measure" for the inner package capacity as reported by the preparer. Taken from Form DOT F 5800.1, Section III, #27.
Cont2 Pkg Number in Shipment	Numeric	Number of inner packages being transported. Taken from Form DOT F 5800.1, Section III, #27.
Cont2 Pkg Shipment Nbr Failed	Numeric	Number of inner packages releasing material in the incident. Taken from Form DOT F 5800.1, Section III, #27.
RAM Package Category	Text	Indicates the Radioactive Packaging category (A = Type A, B = Type B, C = Type C, E = Excepted, and I = Industrial). Taken from Form DOT F 5800.1, Section III, #29.
RAM Package Certification	Text	Indicates the certification of the radioactive package (S = Self Certified and U = U. S. Certification). Taken from Form DOT F 5800.1, Section III, #29.
RAM Package Certification Nbr	Text	Indicates the Radioactive Certificate Number that the package is shipped under. Taken from Form DOT F 5800.1, Section III, #29.

Data Element	Type	Definition
RAM Nuclide(s) Present	Text	Indicates the Radioactive Nuclide(s) present in the package. Taken from Form DOT F 5800.1, Section III, #29.
RAM Transport Index	Numeric	Indicates the transport index of the Radioactive materials present in the package. Taken from Form DOT F 5800.1, Section III, #29.
RAM UOM	Text	Units of measure for the transport index, for the Radioactive materials present in the package. Taken from Form DOT F 5800.1, Section III, #29.
RAM Activity Rpted	Numeric	Indicates the activity of the Radioactive materials present in the package. Taken from Form DOT F 5800.1, Section III, #29.
RAM UOM Rpted	Text	Units of measure for the activity, for the Radioactive materials present in the package. Taken from Form DOT F 5800.1, Section III, #29.
RAM Activity	Numeric	The activity of the Radioactive materials present in the package, converted into standardized units. Taken from Form DOT F 5800.1, Section III, #29.
RAM Activity UOM	Text	Code that indicates the “Units of Measure” of the standardized units for the activity of the Radioactive materials present in the package. Taken from Form DOT F 5800.1, Section III, #29.
RAM Material Safety Index	Text	Indicates the Critical Safety Index of the Radioactive materials present in the package. Taken from Form DOT F 5800.1, Section III, #29.
Spillage (Result) Ind	Text	Identifies whether the commodity released as a consequence of the incident. The values are 'Yes' or 'No and it defaults to 'No' if no value was entered. Taken from Form DOT F 5800.1, Section IV, #30.
Fire (Result) Ind	Text	Identifies whether a fire occurred as a consequence of the incident. The values are 'Yes' or 'No' and it defaults to 'No' if no value was entered. Taken from Form DOT F 5800.1, Section IV, #30.
Explosion (Result) Ind	Text	Identifies whether an explosion occurred as a consequence of the incident. The values are 'Yes' or 'No' and it defaults to 'No' if no value was entered. Taken from Form DOT F 5800.1, Section IV, #30.
Water Sewer (Result) Ind	Text	Identifies whether the commodity entering a waterway or sewer system was a consequence of the incident. The values are 'Yes' or 'No' and it defaults to 'No' if no value was entered. Taken from Form DOT F 5800.1, Section IV, #30.
Gas Dispersion (Result) Ind	Text	Identifies whether gas dispersion was a consequence of the incident. The values are 'Yes' or 'No' and it defaults to 'No' if no value was entered. Taken from Form DOT F 5800.1, Section IV, #30.
Environmental Damage (Result)	Text	Identifies whether environmental damage occurred as a consequence of the incident. The values are 'Yes' or 'No' and it defaults to 'No' if no value was entered. Taken from Form DOT F 5800.1, Section IV, #30.
No Release (Result) Ind	Text	Identifies if there was no release of material for this incident. The values are 'Yes' or 'No' and it defaults to 'No' if no value was entered. Taken from Form DOT F 5800.1, Section IV, #30.
Fire/EMS Report Ind	Text	If a fire crew or EMS unit responded to the incident. The values are 'Yes' or 'No' and it defaults to 'No' if no value was entered. Taken from Form DOT F 5800.1, Section IV, #31.
Fire EMS/EMS Report Nbr	Text	If a fire crew or EMS unit responded to the incident, include the report number. Taken from Form DOT F 5800.1, Section IV, #31.
Police Report Ind	Text	If a police unit responded to the incident. The values are 'Yes' or 'No' and it defaults to 'No' if no value was entered. Taken from Form DOT F 5800.1, Section IV, #31.
Police Report Nbr	Text	If a police unit responded to the incident, include the report number. Taken from Form DOT F 5800.1, Section IV, #31.

Data Element	Type	Definition
In-House Cleanup Ind	Text	In-house cleanup occurred for this incident. The values are 'Yes' or 'No' and it defaults to 'No' if no value was entered. Taken Form DOT F 5800.1, Section IV, #31.
Other Cleanup Ind	Text	Other cleanup occurred for this incident. Taken from Form DOT F 5800.1, Section IV, #31.
Damage More Than 500	Text	Estimated damages exceed $500. The values are 'Yes' or 'No' and it defaults to 'No' if no value was entered. Taken from Form DOT F5800.1, Section IV, #32.
Material Loss	Numeric	Dollar value of the material lost. Taken from Form DOT F 5800.1, Section IV, #32.
Carrier Damage	Numeric	Dollar value of the damage sustained by the carrier. Taken from Form DOT F 5800.1, Section IV, #32.
Property Damage	Numeric	Dollar value of the damage sustained to public or private property. Taken from Form DOT F 5800.1, Section IV, #32.
Response Cost	Numeric	Dollar value of the response cost. Taken from Form DOT F 5800.1, Section IV, #32.
Remediation Cleanup Cost	Numeric	Dollar value of the remediation cost. Taken from Form DOT F 5800.1, Section IV, #32.
Damage Other (Old Form)	Numeric	Dollar value of other damage. Taken from the old Form DOT F.5800.1, Section V, and #23E.
Total Amount of Damages	Numeric	Total Amount of Damages. This figure includes the cost of the material lost, carrier damage, property damage, response costs, and remediation clean-up costs.
HAZMAT Fatality Indicator	Text	A person was fatally injured by contact with the hazardous material or its vapors or by a fire or explosion that resulted from the hazardous material. The values are 'Yes' or 'No' and it defaults to 'No' if no value was entered. Taken from Form DOT F 5800.1, Section IV, #33a.
HAZMAT Fatalities Employees	Numeric	Number of employees fatally injured due to the hazardous material. Taken from Form DOT F 5800.1, Section IV, #33a.
HAZMAT Fatalities Responders	Numeric	Number of emergency responders fatally injured due to the hazardous material. Taken from Form DOT F 5800.1, Section IV, #33a.
HAZMAT Fatality General Public	Numeric	Number of the general public fatally injured due to the hazardous material. Taken from Form DOT F 5800.1, Section IV, #33a.
Hazmat Fatalities (Old Form)	Numeric	Number of fatalities due to the hazardous material (the value has been taken from incident data prior to 2005).
Total Hazmat Fatalities	Numeric	Total fatalities due to the hazardous material.
Non_HAZMAT Fatality Indicator	Text	A person was fatally injured but it was not caused by contact with the hazardous material or its vapors or by a fire or explosion that resulted from the hazardous material. The values are 'Yes' or 'No' and it defaults to 'No' if no value was entered. Taken from Form DOT F 5800.1, Section IV, #33b.
Non-HAZMAT Fatalities	Numeric	Number of people fatally injured due to causes other than the hazardous material. Taken from Form DOT F 5800.1, Section IV, #33b.
HAZMAT Injury Indicator	Text	A person was injured by contact with the hazardous material or its vapors or by a fire or explosion that resulted from the hazardous material. The values are 'Yes' or 'No' and it defaults to 'No' if no value was entered. Taken from Form DOT F 5800.1, Section IV, #34.

Data Element	Type	Definition
HAZMAT Hospitalized Employees	Numeric	Number of employees hospitalized, admitted to a medical facility, due to the hazardous material. Taken from Form DOT F 5800.1, Section IV, #34.
HAZMAT Hospitalized Responders	Numeric	Number of emergency responders hospitalized, admitted to a medical facility, due to the hazardous material. Taken from Form DOT F5800.1, Section IV, #34.
HAZMAT Hospitalized Gen Public	Numeric	Number of the general public hospitalized, admitted to a medical facility, due to the hazardous material. Taken from Form DOT F5800.1, Section IV, #34.
HAZMAT Hospitalized (Old Form)	Numeric	Number of hospitalized injuries due to the hazardous material (the value has been taken from incident data prior to 2005).
Total Hazmat Hosp Injuries	Numeric	Total hospitalized injuries due to the hazardous material.
HAZMAT NonHosp Employees	Numeric	Number of employees injured, but not hospitalized, due to the hazardous material. Taken from Form DOT F 5800.1, Section IV, #34.
HAZMAT NonHosp Responders	Numeric	Number of emergency responders injured, but not hospitalized, due to the hazardous material. Taken from Form DOT F 5800.1, Section IV, #34.
HAZMAT NonHosp General Public	Numeric	Number of the general public injured, but not hospitalized, due to the hazardous material. Taken from Form DOT F 5800.1, Section IV, #34.
HAZMAT NonHosp (Old Form)	Numeric	Number of non-hospitalized injuries due to the hazardous material (the value has been taken from incident data prior to 2005).
Total Hazmat NonHosp Injuries	Numeric	Total non- hospitalized injuries due to the hazardous material.
Total Hazmat Injuries	Numeric	Total hospitalized and non-hospitalized injuries due to the hazardous material.
Evacuation Indicator	Text	The incident required the evacuation or removal of persons from a specific area because of possible or actual contact with the hazardous materials involved in the incident. The values are 'Yes' or 'No' and it defaults to 'No' if no value was entered. Taken from Form DOT F 5800.1, Section IV, #35.
Public Evacuated	Numeric	Number of the general public that were evacuated. Taken from Form DOT F 5800.1, Section IV, #35.
Employees Evacuated	Numeric	Number of employees that were evacuated. Taken from Form DOT F 5800.1, Section IV, #35.
Total Evacuated	Numeric	Total number of people that were evacuated. Taken from Form DOT F 5800.1, Section IV, #35.
Total Evacuation Hours	Numeric	The duration, to the nearest hour, of the evacuation. Taken from Form DOT F 5800.1, Section IV, #35.
Major Artery Closed	Text	A road or transportation facility was closed due to the incident. The values are 'Yes' or 'No' and it defaults to 'No' if no value was entered. Taken from Form DOT F 5800.1, Section IV, #36.
Major Artery Hours Closed	Numeric	The duration, to the nearest hour, the road or transportation facility was closed. Taken from Form DOT F 5800.1, Section IV, #36.
Material Involved in Accident	Text	The hazardous material was involved in a crash or derailment. The values are 'Yes' or 'No' and it defaults to 'No' if no value was entered. Taken from Form DOT F 5800.1, Section IV, #37.
Estimated Speed	Numeric	The estimated speed at the time of the crash. Taken from Form DOT F 5800.1, Section IV, #37.

Data Element	Type	Definition
Weather Conditions	Text	The weather conditions at the time of the crash. Taken from Form DOT F 5800.1, Section IV, #37.
Vehicle Overturn	Text	Identifies whether a vehicle overturned. The values are 'Yes' or 'No' and it defaults to 'No' if no value was entered. Taken from Form DOT F 5800.1, Section IV, #37.
Vehicle Left Roadway/Track	Text	Identifies whether a left the roadway or track. The values are 'Yes' or 'No' and it defaults to 'No' if no value was entered. Taken from Form DOT F 5800.1, Section IV, #37.
Passenger Aircraft Indicator	Text	Indicates whether the shipment in question was on a commercial passenger aircraft. The values are 'Yes' or 'No' and it defaults to 'No' if no value was entered. Taken from Form DOT F 5800.1, Section V, #38.
Cargo Passenger Baggage Ind	Text	Indicates if the material was tendered (accepted for shipment) as cargo, or was located in a passenger's baggage, either in the cabin or baggage compartment on a commercial passenger aircraft. Taken from Form DOT F 5800.1, Section V, #38.
Incident Occurrence	Text	Indicates where in the course of transportation the incident occurred or was discovered. Taken from Form DOT F 5800.1, Section V, #39.
Shipphase Non-Transported Ind	Text	Shipment had not been transported. The values are 'Yes' or 'No' and it defaults to 'No' if no value was entered. Taken from Form DOT F 5800.1, Section V, #40.
Shipphase Air First Flight Ind	Text	Shipment had been transported by air (first flight). The values are 'Yes' or 'No' and it defaults to 'No' if no value was entered. Taken from Form DOT F 5800.1, Section V, #40.
Shipphase Air SubFlight Ind	Text	Shipment had been transported by air (subsequent flights). The values are 'Yes' or 'No' and it defaults to 'No' if no value was entered. Taken from Form DOT F 5800.1, Section V, #40.
Shipphase Init Transport Ind	Text	Shipment had been transported by highway to the cargo facility. The values are 'Yes' or 'No' and it defaults to 'No' if no value was entered. Taken from Form DOT F 5800.1, Section V, #40.
Shipphase Transfer Indicator	Text	Shipment had been transferred at a sort center/cargo facility. The values are 'Yes' or 'No' and it defaults to 'No' if no value was entered. Taken from Form DOT F 5800.1, Section V, #40.
Contact Name	Text	Name of the incident report preparer. Taken from Form DOT F 5800.1, Section VIII.
Contact Title	Text	Title of the incident report preparer. Taken from Form DOT F 5800.1, Section VIII.
Contact Business Name	Text	Business Name of where incident report preparer works. Taken from Form DOT F 5800.1, Section VIII.
Contact Street	Text	The street address of the business, which the incident report preparer works. Taken from Form DOT F 5800.1, Section VIII.
Contact City	Text	The city name of the business, which the incident report preparer works. Taken from Form DOT F 5800.1, Section VIII.
Contact State	Text	The state of the business, which the incident report preparer works. Taken from Form DOT F 5800.1, Section VIII.
Contact Postal Code	Text	The postal code of the business, which the incident report preparer works. Taken from Form DOT F 5800.1, Section VIII.
Contact Non-US State	Text	If the business is outside the US, the foreign state of the business, that the incident report preparer, resides.
Contact Country	Text	The country of the business, which the incident report preparer works.
Preparer of Incident Report	Text	Function of preparers business; carrier, shipper, facility owner/operator of the incident report preparer. Taken from Form DOT F 5800.1, Section VIII.

Data Element	Type	Definition
Description of Events	Text	The text entered in the “Description of Events and Packaging Failure,” Part VI of Form DOT F 5800.1
Recommendations/Actions Taken	Text	The text entered in the “Recommendations/Actions Taken to Prevent Recurrence,” Part VII of Form DOT F 5800.1
HMIS Serious Incident Ind	Text	The values are 'Yes' or 'No' and are based on the new definition of a serious incident. See http://hazmat.dot.gov/pubs/inc/serious_incident_new_def.pdf for definition.
HMIS Serious Fatality	Text	The values are 'Yes' or 'No' and are based on the new definition of a serious incident. See http://hazmat.dot.gov/pubs/inc/serious_incident_new_def.pdf for definition.
HMIS Serious Injury	Text	The values are 'Yes' or 'No' and are based on the new definition of a serious incident. See http://hazmat.dot.gov/pubs/inc/serious_incident_new_def.pdf for definition.
HMIS Serious Flight Plan	Text	The values are 'Yes' or 'No' and are based on the new definition of a serious incident. See http://hazmat.dot.gov/pubs/inc/serious_incident_new_def.pdf for definition.
HMIS Serious Evacuations	Text	The values are 'Yes' or 'No' and are based on the new definition of a serious incident. See http://hazmat.dot.gov/pubs/inc/serious_incident_new_def.pdf for definition.
HMIS Serious Major Artery	Text	The values are 'Yes' or 'No' and are based on the new definition of a serious incident. See http://hazmat.dot.gov/pubs/inc/serious_incident_new_def.pdf for definition.
HMIS Serious Bulk Release	Text	The values are 'Yes' or 'No' and are based on the new definition of a serious incident. See http://hazmat.dot.gov/pubs/inc/serious_incident_new_def.pdf for definition.
HMIS Serious Marine Pollutant	Text	The values are 'Yes' or 'No' and are based on the new definition of a serious incident. See http://hazmat.dot.gov/pubs/inc/serious_incident_new_def.pdf for definition.
HMIS Serious Radioactive	Text	The values are 'Yes' or 'No' and are based on the new definition of a serious incident. See http://hazmat.dot.gov/pubs/inc/serious_incident_new_def.pdf for definition.
HMIS Container Short Descr[2]	Text	The container short description assigned by PHMSA based on Packaging Description, Identification Markings (Form DOT F 5800.1, Section III, #24, #26a and #26b) or the Description of Events (Form DOT 5800.1, Section VI)
HMIS Container Code	Text	The container code assigned by PHMSA based on Packaging Description, Identification Markings (Form DOT F 5800.1, Section III, #24, #26a and #26b) or the Description of Events (Form DOT 5800.1, Section VI)
HMIS Container Description	Text	The container description assigned by PHMSA based on Packaging Description, Identification Markings (Form DOT F 5800.1, Section III, #24, #26a and #26b) or the Description of Events (Form DOT 5800.1, Section VI)

[2] The title is “HMIS General Package Type” in the database available with this report—it was changed for analytical ease.

Data Element	Type	Definition
HMIS Bulk Incident Indicator	Text	Identifies if the incident involved a bulk or non bulk package. Assigns a value of 'Yes' or 'No' based on the container size. Form DOT F 5800.1, Section III, #24 and #27.
Undeclared Shipment	Text	Identifies if the incident had an undeclared shipment. Assigns a value of 'Yes' or 'No' based on the information provided in Form DOT F 5800.1, Section I, #1 and Section II, #23.

Notes:
1. An electronic version of the Hazardous Materials Incident Report Form DOT F 5800.1 is published at http://hazmat.dot.gov/pubs/inc/spill/IncidentForm010105.pdf
2. The data dictionary references the new Form DOT 5800.1 and not the form used prior to 2005. The new from might or might not contain all the fields in the old form.

Citation:
Office of Hazardous Materials Safety. “Data Dictionary”. Incident Reports Database Search, <https://hazmatonline.phmsa.dot.gov/IncidentReportsSearch/Search.aspx>

Master Database Field Descriptions

yColumnN me	DataTy pe	Leng th	CREATE TABLE SQL ...	ALIAS	ORIGINAL FIELD NAME
			CREATE TABLE IncidentMaster (	INSERT INTO IncidentMaster (	SELECT
Id	identity		intId int identity (1,1),		
tNumber	char	20	rptNumber char (20),	rptNumber,	LEN(RTRIM([Report Number])) AS [Report Number],
Number	char	10	idNumber char (10),	idNumber,	LEN(RTRIM([Identification Number])) AS [Identification Number],
	float		x float ,	x,	LEN(RTRIM([X])) AS [X],
	float		y float ,	y,	LEN(RTRIM([Y])) AS [Y],
tSource	varchar	255	rprtSource varchar (255),	rprtSource,	LEN(RTRIM([Report Submission Source])) AS [Report Submission Source],
ltiple	varchar	255	multiple varchar (255),	multiple,	LEN(RTRIM([Multiple Rows per Incident])) AS [Multiple Rows per Incident],
rrier	varchar	255	carrier varchar (255),	carrier,	LEN(RTRIM([Carrier/Reporter Name])) AS [Carrier/Reporter Name],
ta	varchar	255	ruta varchar (255),	ruta,	LEN(RTRIM([Incident Route])) AS [Incident Route],
y	varchar	255	city varchar (255),	city,	LEN(RTRIM([Incident City])) AS [Incident City],
tado	varchar	255	estado varchar (255),	estado,	LEN(RTRIM([Incident State])) AS [Incident State],
cha	varchar	255	fetcha varchar (255),	fetcha,	LEN(RTRIM([Date of Incident])) AS [Date of Incident],
ra	varchar	255	hora varchar (255),	hora,	LEN(RTRIM([Time of Incident])) AS [Time of Incident],
antity	varchar	255	quantity varchar (255),	quantity,	LEN(RTRIM([Quantity Released])) AS [Quantity Released],
its	varchar	255	units varchar (255),	units,	LEN(RTRIM([Unit of Measure])) AS [Unit of Measure],
me	varchar	255	name varchar (255),	name,	LEN(RTRIM([Commodity Long Name])) AS [Commodity Long Name],
asif	varchar	255	clasif varchar (255),	clasif,	LEN(RTRIM([Hazardous Class])) AS [Hazardous Class],
alities	varchar	255	fatalities varchar (255),	fatalities,	LEN(RTRIM([Total Hazmat Fatalities])) AS [Total Hazmat Fatalities],
uries	varchar	255	injuries varchar (255),	injuries,	LEN(RTRIM([Total Hazmat Hosp Injuries])) AS [Total Hazmat Hosp Injuries],
nHospInjuri	varchar	255	nonHospInjuries varchar (255),	nonHospInjuries,	LEN(RTRIM([Total Hazmat NonHosp Injuries])) AS [Total Hazmat NonHosp Injuries],
mages	varchar	255	damages varchar (255),	damages,	LEN(RTRIM([Total Amount of Damages])) AS [Total Amount of Damages],
ipper	varchar	255	shipper varchar (255),	shipper,	LEN(RTRIM([Shipper Name])) AS [Shipper Name],
yOrigin	varchar	255	cityOrigin varchar (255),	cityOrigin,	LEN(RTRIM([Origin City])) AS [Origin City],

Origin State	stateOrigin	varchar	255	stateOrigin varchar (255),	stateOrigin,	LEN(RTRIM([Origin State])) AS [Origin State],
Mode of Transportation	TMode	varchar	255	TMode varchar (255),	TMode,	LEN(RTRIM([Mode of Transportation])) AS [Mode of Transportation],
Identification Markings	markings	varchar	255	markings varchar (255),	markings,	LEN(RTRIM([Identification Markings])) AS [Identification Markings],
Cont1 Material of Construction	pakMaterial	varchar	255	pakMaterial varchar (255),	pakMaterial,	LEN(RTRIM([Cont1 Material of Construction])) AS [Cont1 Material of Construction],
Cont1 Packaging Type	pakType	varchar	255	pakType varchar (255),	pakType,	LEN(RTRIM([Cont1 Packaging Type])) AS [Cont1 Packaging Type],
Cont1 Package Capacity	pakCapacity	varchar	255	pakCapacity varchar (255),	pakCapacity,	LEN(RTRIM([Cont1 Package Capacity])) AS [Cont1 Package Capacity],
Cont1 Package Capacity UOM	pakCapacityUOM	varchar	255	pakCapacityUOM varchar (255),	pakCapacityUOM,	LEN(RTRIM([Cont1 Package Capacity UOM])) AS [Cont1 Package Capacity UOM],
Cont1 Pkg Number in Shipment	pakNumber	varchar	255	pakNumber varchar (255),	pakNumber,	LEN(RTRIM([Cont1 Pkg Number in Shipment])) AS [Cont1 Pkg Number in Shipment],
Cont1 Pkg Shipment Nbr Failed	pakShipment	varchar	255	pakShipment varchar (255),	pakShipment,	LEN(RTRIM([Cont1 Pkg Shipment Nbr Failed])) AS [Cont1 Pkg Shipment Nbr Failed],
Cont2 Material of Construction	pak2Material	varchar	255	pak2Material varchar (255),	pak2Material,	LEN(RTRIM([Cont2 Material of Construction])) AS [Cont2 Material of Construction],
Cont2 Package Type	pak2Type	varchar	255	pak2Type varchar (255),	pak2Type,	LEN(RTRIM([Cont2 Package Type])) AS [Cont2 Package Type],
Cont2 Package Capacity	pak2Capacity	varchar	255	pak2Capacity varchar (255),	pak2Capacity,	LEN(RTRIM([Cont2 Package Capacity])) AS [Cont2 Package Capacity],
Cont2 Capacity UOM Reported	pak2CapacityUOM	varchar	255	pak2CapacityUOM varchar (255),	pak2CapacityUOM,	LEN(RTRIM([Cont2 Capacity UOM Reported])) AS [Cont2 Capacity UOM Reported],
Cont2 Pkg Number in Shipment	pak2Number	varchar	255	pak2Number varchar (255),	pak2Number,	LEN(RTRIM([Cont2 Pkg Number in Shipment])) AS [Cont2 Pkg Number in Shipment],
Cont2 Pkg Shipment Nbr Failed	pak2Shipment	varchar	255	pak2Shipment varchar (255),	pak2Shipment,	LEN(RTRIM([Cont2 Pkg Shipment Nbr Failed])) AS [Cont2 Pkg Shipment Nbr Failed],
What Failed Description	whatDesc	text		whatDesc text ,	whatDesc,	LEN(RTRIM([What Failed Description])) AS [What Failed Description],
How Failed Description	howDesc	text		howDesc text ,	howDesc,	LEN(RTRIM([How Failed Description])) AS [How Failed Description],
Failure Cause Description	causeDesc	text		causeDesc text ,	causeDesc,	LEN(RTRIM([Failure Cause Description])) AS [Failure Cause Description],
Description of Events	genDesc	text		genDesc text ,	genDesc,	LEN(RTRIM([Description of Events])) AS [Description of Events],
HMIS Serious Incident Ind	srsIncID	varchar	255	srsIncID varchar (255),	srsIncID,	LEN(RTRIM([HMIS Serious Incident Ind])) AS [HMIS Serious Incident Ind],
HMIS Serious Bulk Release	srsBulkRelease	varchar	255	srsBulkRelease varchar (255),	srsBulkRelease,	LEN(RTRIM([HMIS Serious Bulk Release])) AS [HMIS Serious Bulk Release],
HMIS Serious Evacuations	srsEvacuartion	varchar	255	srsEvacuartion varchar (255),	srsEvacuartion ,	LEN(RTRIM([HMIS Serious Evacuations])) AS [HMIS Serious Evacuations],
HMIS Serious Fatality	srsFatalities	varchar	255	srsFatalities varchar (255),	srsFatalities,	LEN(RTRIM([HMIS Serious Fatality])) AS [HMIS Serious Fatality],

HMIS Serious Flight Plan	srsFlightPlan	varchar	255	srsFlightPlan varchar (255),	srsFlightPlan,	LEN(RTRIM([HMIS Serious Flight Plan])) AS [HMIS Serious Flight Plan],
HMIS Serious Injury	srsInjuries	varchar	255	srsInjuries varchar (255),	srsInjuries,	LEN(RTRIM([HMIS Serious Injury])) AS [HMIS Serious Injury],
HMIS Serious Major Artery	srsMajorArtery	varchar	255	srsMajorArtery varchar (255),	srsMajorArtery,	LEN(RTRIM([HMIS Serious Major Artery])) AS [HMIS Serious Major Artery],
HMIS Serious Marine Pollutant	srsMarine	varchar	255	srsMarine varchar (255),	srsMarine,	LEN(RTRIM([HMIS Serious Marine Pollutant])) AS [HMIS Serious Marine Pollutant],
HMIS Serious Radioactive	srsRadioactive	varchar	255	srsRadioactive varchar (255)	srsRadioactive)	LEN(RTRIM([HMIS Serious Radioactive])) AS [HMIS Serious Radioactive],
				)		

Appendix C: Scripts for Database Management

```
--
-- Create indexes on important columns
--

CREATE INDEX idxPKIncClnXDes ON IncidentCleanXDesc (intId, rptNumber,
idNumber);
CREATE INDEX idxPtIncClnXDes ON IncidentCleanXDesc (x, y);

CREATE INDEX idxPKIncDes ON IncidentDescription (intId, rptNumber,
idNumber);

CREATE INDEX idxPKIncMast ON IncidentMaster (intId, rptNumber,
idNumber);

--
-- Insert statement to populate IncidentDescription table
-- NOTE: intId is just carried over from IncidentMaster
--       - this id is no longer auto-generated but carried over to all
tables
--       - to allow linking the records as required.
-- If you want to do a clean insert into this table - you can delete
all the
-- rows and run this same insert statement again.  It will load a
description
-- for every incident ID in the IncidentCleanXDesc table.
--

INSERT INTO IncidentDescription (
intId, rptNumber, idNumber,
whatDesc, howDesc, causeDesc, genDesc
)
SELECT
      intId, rptNumber, idNumber,
      whatDesc, howDesc, causeDesc, genDesc
FROM IncidentMaster
WHERE
      intId IN (SELECT intId FROM IncidentCleanXDesc)

--
-- Create table for description columns
--

CREATE TABLE IncidentDescription (
      intId int,
      rptNumber char (20),
      idNumber char (10),
      whatDesc text ,
      howDesc text ,
      causeDesc text ,
      genDesc text
)
```

```
--
-- Insert statement to populate IncidentClean table
-- No description columns, no repeats, and no null X or Y
-- NOTE: intId is just carried over from IncidentMaster
--       - this id is no longer auto-generated but carried over to all
tables
--       - to allow linking the records as required.
--

INSERT INTO IncidentCleanXDesc (
      intId, rptNumber, idNumber, x, y, rprtSource, multiple,
      carrier, ruta, city, estado, fetcha,
      hora, quantity, units, name, clasif, fatalities,
      injuries, nonHospInjuries, damages, shipper,
      cityOrigin, stateOrigin, TMode, markings,
      pakMaterial, pakType, pakCapacity, pakCapacityUOM, pakNumber,
pakShipment,
      pak2Material, pak2Type, pak2Capacity, pak2CapacityUOM,
pak2Number, pak2Shipment,
      srsIncID, srsBulkRelease, srsEvacuartion , srsFatalities,
srsFlightPlan,
      srsInjuries, srsMajorArtery, srsMarine, srsRadioactive
)
SELECT
      intId, rptNumber, idNumber, x, y, rprtSource, multiple,
      carrier, ruta, city, estado, fetcha,
      hora, quantity, units, name, clasif, fatalities,
      injuries, nonHospInjuries, damages, shipper,
      cityOrigin, stateOrigin, TMode, markings,
      pakMaterial, pakType, pakCapacity, pakCapacityUOM, pakNumber,
pakShipment,
      pak2Material, pak2Type, pak2Capacity, pak2CapacityUOM,
pak2Number, pak2Shipment,
      srsIncID, srsBulkRelease, srsEvacuartion , srsFatalities,
srsFlightPlan,
      srsInjuries, srsMajorArtery, srsMarine, srsRadioactive
FROM IncidentMaster
WHERE
      (x is not null OR y is not null)
  AND       multiple = 'No'


--
-- Create table for all incidents - without description columns
-- incidents and multiple rows per incident
--

CREATE TABLE IncidentCleanXDesc (
      intId int,
      rptNumber char (20),
      idNumber char (10),
      x float ,
      y float ,
      rprtSource varchar (255),
      multiple varchar (255),
```

```
        carrier varchar (255),
        ruta varchar (255),
        city varchar (255),
        estado varchar (255),
        fetcha varchar (255),
        hora varchar (255),
        quantity varchar (255),
        units varchar (255),
        name varchar (255),
        clasif varchar (255),
        fatalities varchar (255),
        injuries varchar (255),
        nonHospInjuries varchar (255),
        damages varchar (255),
        shipper varchar (255),
        cityOrigin varchar (255),
        stateOrigin varchar (255),
        TMode varchar (255),
        markings varchar (255),
        pakMaterial varchar (255),
        pakType varchar (255),
        pakCapacity varchar (255),
        pakCapacityUOM varchar (255),
        pakNumber varchar (255),
        pakShipment varchar (255),
        pak2Material varchar (255),
        pak2Type varchar (255),
        pak2Capacity varchar (255),
        pak2CapacityUOM varchar (255),
        pak2Number varchar (255),
        pak2Shipment varchar (255),
        srsIncID varchar (255),
        srsBulkRelease varchar (255),
        srsEvacuartion  varchar (255),
        srsFatalities varchar (255),
        srsFlightPlan varchar (255),
        srsInjuries varchar (255),
        srsMajorArtery varchar (255),
        srsMarine varchar (255),
        srsRadioactive varchar (255)
)


-- Insert statement to populate IncidentMaster table
-- Change table name as required to move data from 1998 - 2007 incident
tables.
-- Also replace bg_lat and bg_long for X, Y for the 2006, 2007 tables
--

INSERT INTO IncidentMaster (
rptNumber, idNumber, x, y, rprtSource, multiple,
carrier, ruta, city, estado, fetcha,
hora, quantity, units, name, clasif, fatalities,
injuries, nonHospInjuries, damages, shipper,
cityOrigin, stateOrigin, TMode, markings,
pakMaterial, pakType, pakCapacity, pakCapacityUOM, pakNumber,
pakShipment,
```

```
pak2Material, pak2Type, pak2Capacity, pak2CapacityUOM, pak2Number,
pak2Shipment,
whatDesc, howDesc, causeDesc, genDesc,
srsIncID, srsBulkRelease, srsEvacuartion , srsFatalities,
srsFlightPlan,
srsInjuries, srsMajorArtery, srsMarine, srsRadioactive
)
SELECT
[Report Number],[Identification Number],[X],[Y],[Report Submission
Source],[Multiple Rows per Incident],
[Carrier/Reporter Name],[Incident Route],[Incident City],[Incident
State],[Date of Incident],
[Time of Incident],[Quantity Released],[Unit of Measure],[Commodity
Long Name],[Hazardous Class],[Total Hazmat Fatalities],
[Total Hazmat Hosp Injuries],[Total Hazmat NonHosp Injuries],[Total
Amount of Damages],[Shipper Name],
[Origin City],[Origin State],[Mode of Transportation],[Identification
Markings],
[Cont1 Material of Construction],[Cont1 Packaging Type],[Cont1 Package
Capacity],[Cont1 Package Capacity UOM],[Cont1 Pkg Number in
Shipment],[Cont1 Pkg Shipment Nbr Failed],
[Cont2 Material of Construction],[Cont2 Package Type],[Cont2 Package
Capacity],[Cont2 Capacity UOM Reported],[Cont2 Pkg Number in
Shipment],[Cont2 Pkg Shipment Nbr Failed],
[What Failed Description],[How Failed Description],[Failure Cause
Description],[Description of Events],
[HMIS Serious Incident Ind],[HMIS Serious Bulk Release],[HMIS Serious
Evacuations],[HMIS Serious Fatality],[HMIS Serious Flight Plan],[HMIS
Serious Injury],[HMIS Serious Major Artery],[HMIS Serious Marine
Pollutant],[HMIS Serious Radioactive]
FROM <INCIDENTIMPORTTABLE>


--
--  Create single master table for all incidents.
--

CREATE TABLE IncidentMaster (
      intId int identity (1,1),
      rptNumber char (20),
      idNumber char (10),
      x float ,
      y float ,
      rprtSource varchar (255),
      multiple varchar (255),
      carrier varchar (255),
      ruta varchar (255),
      city varchar (255),
      estado varchar (255),
      fetcha varchar (255),
      hora varchar (255),
      quantity varchar (255),
      units varchar (255),
      name varchar (255),
      clasif varchar (255),
      fatalities varchar (255),
      injuries varchar (255),
```

```
        nonHospInjuries varchar (255),
        damages varchar (255),
        shipper varchar (255),
        cityOrigin varchar (255),
        stateOrigin varchar (255),
        TMode varchar (255),
        markings varchar (255),
        pakMaterial varchar (255),
        pakType varchar (255),
        pakCapacity varchar (255),
        pakCapacityUOM varchar (255),
        pakNumber varchar (255),
        pakShipment varchar (255),
        pak2Material varchar (255),
        pak2Type varchar (255),
        pak2Capacity varchar (255),
        pak2CapacityUOM varchar (255),
        pak2Number varchar (255),
        pak2Shipment varchar (255),
        whatDesc text ,
        howDesc text ,
        causeDesc text ,
        genDesc text ,
        srsIncID varchar (255),
        srsBulkRelease varchar (255),
        srsEvacuartion  varchar (255),
        srsFatalities varchar (255),
        srsFlightPlan varchar (255),
        srsInjuries varchar (255),
        srsMajorArtery varchar (255),
        srsMarine varchar (255),
        srsRadioactive varchar (255)
)
```

Script for Major Evacuation Query:

```
--
-- withn this query I selected srsevacuation=yes and liked to the
desvcription by internal ID field.
--

SELECT * FROM IncidentMaster WHERE srsEvacuartion = 'Yes'

SELECT *
FROM IncidentCleanXDesc icx, IncidentDescription ides
WHERE icx.srsEvacuartion = 'Yes'
  AND icx.intId = ides.intId




--
-- Find all incidents which have multiple rows per incident
-- Use the IncidentMaster table, WHERE multiple = 'Yes'
-- Sort this data by rptNumber, idNumber, intId
```

```
-- FIGURE OUT A BETTER WAY TO DO THIS
--

SELECT * FROM IncidentMaster
WHERE rptNumber + '|' + idNumber
   IN (
            SELECT dups.rptNumber + '|' + dups.idNumber FROM
                  (SELECT rptNumber, idNumber, COUNT(*) AS theCount
                     FROM IncidentMaster
                    GROUP BY rptNumber, idNumber
                   ) dups
             WHERE dups.theCount > 1
      )
ORDER BY rptNumber, idNumber, intId
```

Matlab Script for Data Interoperability Excel- ArcMap10

```
file_extensions={'*.csv';'*.txt';'*.xls'};
file_separators={',',' ',' '};
file_types={'archivo con separador de comas';...
            'archivo de texto';...
            'archivo excel'};

oldpath=cd;
  [xls_files,files_path]=uigetfile(pwd, 'Indique los archivos de
Entrada',...
                        '*.xls','MultiSelect','on');
cd(files_path);
fileNames=sort(xls_files)

default_selection=1;
screen=get(0,'MonitorPositions'
[selection,ok] = listdlg('PromptString','Tipo de archivo de
salida:',...
                'SelectionMode','single',...
                'ListSize', [screen(3)/4,screen(4)/10],...
                'ListString',file_types,...
                'InitialValue', default_selection, ...
                'Name',[mfilename ' input']);
if (ok==1)
    outfile_ext=file_extensions{selection};
    outfile_sep=file_separators{selection};
else
    outfile_ext=file_extensions{default_selection};
    outfile_sep=file_separators{default_selection};
end

[out_filename,outfile_path]=uiputfile(outfile_ext,...
                          'Seleccione nombre para el archivo
concatenado');

%inicializacion del ciclo
num_files=length(fileNames);
info_todos=[];
```

```
remove_hdr=false;               %flag que indica no remover el
encabezado (del primer archivo)
h_wait=waitbar(1/(2*num_files),[mfilename,' procesando: ']);

for idx_file=1:num_files;
    [numeros,texto, info]=xlsread(fileNames{idx_file});
    header_lines=length(texto)-length(numeros);
    clear numeros  texto;
    if remove_hdr && header_lines>0
        info=info(1+header_lines:end,:);
        remove_hdr=true;
    end
    info_todos=[info_todos;info];
    waitbar(idx_file/(num_files+2),h_wait);
end

num_fields=size(info_todos,2);
info_todos=info_todos';
fid=fopen(out_filename,'w');
eol=[13 10];
if isequal(outfile_ext,'*.xls');
    try
        xlswrite(out_filename,info_todos,',');
    catch
        warndlg(['Demasiados datos: ',num2str(length(info_todos)), eol,
...
                ' El maximo es ', num2str(2^16)],[mfilename '
warning']);
    end
else
    sep=outfile_sep;
    %escribe el encabezado
    header=info_todos(:,1);
    header=strrep(header,' ','');
    header=strrep(header,'_','');
    texto_raiz=['%s',outfile_sep];
    u=texto_raiz(ones(num_fields,1),:);
    ut=u';
    format_str=ut(:)';
    format_str=[format_str(1:end-1),eol];
    fprintf(fid,format_str,header{1:num_fields});

=findstr(format_str,'%');
    muestra=info_todos(:,end);

    for id_field=1:num_fields;
       if ischar(muestra{id_field})
           num_type='%s';
       elseif isreal(muestra{id_field})
           num_type='%f';
       else
           num_type='%d';
       end
       idx=percent_id(id_field);
       format_str(idx:idx+1)=num_type;
    end
```

```
   fprintf(fid,format_str,info_todos{:,2:end});
end

%final settings
fclose(fid);
waitbar(1,h_wait,['Proceso terminado. ',
num2str(length(info_todos)),...
                ' registros concatenados']);
pause(0.5);
close(h_wait);
cd(oldpath)
```

Appendix D: Scores for top clusters in California

FID_1	Frequency	GIZScore	GIPValue	Place/County Subdivision
47	906	17.929	0.00000	Sacramento
56	369	3.784	0.00015	Southeast
48	365	13.344	0.00000	Sacramento
3	313	3.053	0.00219	South San Francisco
101	306	3.229	0.00124	Anaheim-Santa Ana-Garden Grove
117	273	5.117	0.00000	San Bernardino
130	257	2.950	0.00307	San Bernardino
90	250	2.557	0.01056	San Diego
59	242	1.691	0.05664	Southeast
97	230	2.521	0.01171	Anaheim-Santa Ana-Garden Grove
33	213	1.768	0.07702	East Yolo
69	212	1.413	0.15759	Downey-Norwalk
125	206	2.058	0.03961	San Bernardino
60	201	2.453	0.01376	Los Angeles
114	198	4.658	0.00000	San Bernardino
13	164	1.707	0.08773	San Jose
137	161	1.927	0.05404	Barstow-Victorville
9	178	1.875	0.05061	Oakland
111	156	2.522	0.01168	San Bernadino
41	156	2.133	0.03290	Sacramento
37	121	2.309	0.02094	East Yolo
104	105	1.653	0.09625	Anaheim-Santa Ana-Garden Grove
76	95	1.336	0.18166	San Fernando Valley
31	69	1.901	0.05729	East Yolo
81	76	3.076	0.00209	Los Angeles
112	71	1.951	0.05111	San Bernardino
42	43	2.014	0.04400	Sacramento
39	34	2.084	0.03718	East Yolo
120	33	2.854	0.00419	San Bernardino
56	30	4.656	0.00000	Southeast
127	29	2.025	0.04266	San Bernardino
67	29	1.876	0.06066	Whittier
77	24	1.938	0.05267	Los Angeles
36	17	1.519	0.12863	East Yolo
19	13	1.472	0.14115	Oakland
131	11	2.950	0.00307	San Bernardino
1	11	0.853	0.00012	South San Francisco
116	10	4.669	0.00000	San Bernardino
29	10	1.686	0.09171	Sacramento

Appendix E: Scores for top clusters in California

Table 19. Poisson regression model of all spill counts by tract

	Estimate	Std. Error	z value	Pr(> |z|)
(Intercept)	-3.4508	0.1783	-19.36	0.0000
%Black	**1.4531**	**0.5997**	**2.42**	**0.0154***
%Asian	**-2.6257**	**0.7872**	**-3.34**	**0.0009***
%American Indian	**5.4073**	**1.3282**	**4.07**	**0.0000***
%NHOPI	**13.9368**	**4.7911**	**2.91**	**0.0036**
%White, Hispanic	**2.6311**	**0.4488**	**5.86**	**0.0000***
%Asian, Hispanic	**41.6960**	**8.2044**	**5.08**	**0.0000***
% American Indian, Hispanic	**17.2901**	**4.7993**	**3.60**	**0.0003***
%NHOPI, Hispanic	**52.5149**	**10.8373**	**4.85**	**0.0000***
%Renters	**-1.1324**	**0.4030**	**-2.81**	**0.0050***
%Poverty	**-2.1944**	**0.9988**	**-2.20**	**0.0280***
AIC=2107.2				
$\sum \hat{\hat{f}}_i(0)$=7035				

Table 20. Quai-Poisson model of all spill counts

	Estimate	Std. Error	t value	Pr(> |t|)
(Intercept)	-3.4508	0.3482	-9.91	0.0000
%Black	1.4531	1.1715	1.24	0.2149
%Asian	**-2.6257**	**1.5377**	**-1.71**	**0.0878Ψ**
%American Indian	**5.4073**	**2.5945**	**2.08**	**0.0372****
%NHOPI	13.9368	9.3587	1.49	0.1365
%White, Hispanic	**2.6311**	**0.8767**	**3.00**	**0.0027****
%Asian, Hispanic	**41.6960**	**16.0262**	**2.60**	**0.0093****
% American Indian, Hispanic	**17.2901**	**9.3748**	**1.84**	**0.0652 Ψ**
%NHOPI, Hispanic	**52.5149**	**21.1693**	**2.48**	**0.0131***
%Renters	-1.1324	0.7872	-1.44	0.1504
%Poverty	-2.1944	1.9510	-1.12	0.2607
AIC=NA				
$\sum \hat{\hat{f}}_i(0)$=7035				

Table 21. Negative Binomial Model of All Spills, 1998 to 2010

	Estimate	Std. Error	z value	Pr(> |z|)
(Intercept)	-3.5287	0.2901	-12.16	0.0000
%Black	0.7145	1.1570	0.62	0.5369
%Asian	-1.8319	1.0196	-1.80	0.0724 Ψ
%American Indian	24.4263	5.6038	4.36	0.0000***
%NHOPI	16.1503	10.5912	1.52	0.1273*
%White, Hispanic	1.6828	0.8434	2.00	0.0460*
%Asian, Hispanic	39.5396	24.8456	1.59	0.1115
% American Indian, Hispanic	9.4482	13.5225	0.70	0.4847
%NHOPI, Hispanic	73.9221	48.6049	1.52	0.1283
%Renters	-1.2780	0.6281	-2.03	0.0419*
%Poverty	-0.6384	1.5076	-0.42	0.6719
AIC=1,413				

Table 22. Hurdle models of all spills, 1998-2010

Count model coefficients (truncated poisson with log link):				
	Estimate	**Std. Error**	**z value**	**Pr(>|z|)**
(Intercept)	0.3932	0.3050	1.289	0.19737
%Black	0.1882	1.1373	0.166	0.86854
%Asian	**-2.2307**	**1.3561**	**-1.645**	**0.09998 Ψ**
%American Indian	**2.5228**	**4.8268**	**0.523**	**0.60121**
%NHOPI	**18.0567**	**7.2870**	**2.478**	**0.01321 ***
%White, Hispanic	**1.9959**	**0.6759**	**2.953**	**0.00315 ****
%Asian, Hispanic	**121.0263**	**16.3048**	**7.423**	**1.15e-13 *****
% American Indian, Hispanic	4.3390	5.7957	0.749	0.45406
%NHOPI, Hispanic	13.5676	16.1163	0.842	0.39987
%Renters	**-1.5465**	**0.6417**	**-2.410**	**0.01596 ***
%Poverty	**-2.6662**	**1.2050**	**-2.213**	**0.02692 ***
Zero hurdle model coefficients (binomial with logit link):				
Estimate	**Std. Error**	**z value**	**Pr(>|z|)**	
(Intercept)	-4.0065	0.2350	-17.053	<2e-16 ***
%Black	0.3071	0.9213	0.333	0.7389
%Asian	-1.4031	0.8893	-1.578	0.1146
%American Indian	3.9608	2.4324	1.628	0.1035
%NHOPI	8.6496	7.9450	1.089	0.2763
%White, Hispanic	0.8487	0.6553	1.295	0.1953
%Asian, Hispanic	-16.4907	27.0928	-0.609	0.5427
% American Indian, Hispanic	**13.3988**	**7.8235**	**1.713**	**0.0868 .**
%NHOPI, Hispanic	**49.6711**	**20.6168**	**2.409**	**0.0160 ***
%Renters	-0.6407	0.5080	-1.261	0.2072
%Poverty	0.1607	1.1611	0.138	0.8899

Table 23. Zero-inflated Negative Binomial Model

Poisson with log link				
	Estimate	**Std. Error**	**z value**	**Pr(>|z|)**
(Intercept)	0.3990	0.3126	1.276	0.201821
%Black	-0.1398	1.2298	-0.114	0.909467
%Asian	-1.6661	1.3056	-1.276	0.201899
%American Indian	-5.2839	3.8789	-1.362	0.173133
%NHOPI	**18.9761**	**6.9937**	**2.713**	**0.006662 ** **
%White, Hispanic	**2.4825**	**0.6756**	**3.674**	**0.000238 *** **
%Asian, Hispanic	**113.7333**	**15.8801**	**7.162**	**7.95e-13 *** **
% American Indian, Hispanic	5.4758	4.9130	1.115	0.265046
%NHOPI, Hispanic	1.6704	18.8395	0.089	0.929346
%Renters	**-1.5826**	**0.6426**	**-2.463**	**0.013781 * **
%Poverty	**-3.0513**	**1.1408 -**	**2.675**	**0.007479 ** **
binomial with logit link				
	Estimate	**Std. Error**	**z value**	**Pr(>|z|)**
(Intercept)	3.94335	0.31565	12.493	< 2e-16 ***
%Black	-0.54534	1.30274	-0.419	0.67550
%Asian	0.09682	1.29924	0.075	0.94059
%American Indian	**-23.65583**	**8.63731**	**-2.739**	**0.00617 ** **
%NHOPI	0.85197	9.03254	0.094	0.92485
%White, Hispanic	0.51213	0.80936	0.633	0.52689
%Asian, Hispanic	**60.97039**	**30.95996**	**1.969**	**0.04892 * **
% American Indian, Hispanic	-9.37490	8.83207	-1.061	0.28848
%NHOPI, Hispanic	-61.18217	41.27945	-1.482	0.13830
%Renters	-0.35072	0.70560	-0.497	0.61916
%Poverty	-2.24018	1.51492	-1.479	0.13921

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