MANAGEMENT OF HAZARDOUS MATERIALS TRANSPORTATION: LITERATURE SUMMARY

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Product 0-5929-P2 – Literature Summary

Project 0-5929: Managing the Movements of Hazardous Material Shipments through Texas Population Centers

Published: February 2008

Texas Transportation Institute
The Texas A&M University System
College Station, Texas 77845-3135

URL: http//tti.tamu.edu/documents/0-5929-P2

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1. **Abkowitz, Mark D., Joseph P. DeLorenzo, Ron Duych, Art Greenberg, and Tom McSweeney. "Assessing the Economic Effect of Incidents Involving Truck Transport of Hazardous Materials."** ***Transportation Research Record: Journal of the Transportation Research Board,*** **No. 1763. Transportation Research Board, National Research Council, Washington, D.C., 2001, pp. 125-129.**

In this paper, the authors discuss their method to evaluate the full economic effects of hazardous materials (hazmat) truck transportation incidents and demonstrate its use by sampling a single hazmat class for one year. Key methodological contributions are made in incident occurrence estimation and in impact assessment, particularly for environmental damage and incident delay. Categories of economic effects include injuries and fatalities, cleanup costs, property damage, evacuation, product loss, traffic incident delay, and environmental damage.

2. **Alberta Transportation, Dangerous Goods and Rail Safety Branch.** ***Guidelines for the Establishment of Dangerous Goods Routes in Alberta Municipalities.*** **Edmonton, Alberta, Canada, February 2004.**

The transportation of dangerous goods legislation enacted by the federal, provincial, and territorial governments has prompted municipalities to consider their own bylaws in order to regulate the movement of dangerous goods on highways or roads located within their jurisdictions.

The dangerous goods legislation actually improves enforcement of municipal bylaws by providing a precise definition of a "dangerous good." It also requires a transporter of such goods to display appropriate safety marks and placards when those goods are being transported in sufficient quantity to pose a serious hazard. It provides a consistent way of assessing which loads should be subject to routing restrictions and a visual warning sign of such shipments.

When the transportation of dangerous goods legislation was introduced in 1985, every effort was made to ensure maximum uniformity throughout Canada. Since the legislation is designed to improve public and environmental safety when moving dangerous goods, industry must be provided with a set of requirements that they might reasonably be able to fulfill. Industry members have a very strong desire for a reasonable degree of consistency in the many bylaws they encounter across Alberta and Canada when transporting dangerous goods by road. As a result, the federal, provincial, and territorial governments designed a set of guideline criteria to assist all Canadian municipalities with preparing standardized dangerous goods routing bylaws. These guidelines are intended to help municipalities assess the effect of restrictive routing on those being regulated and on those it might deprive of essential services. All affected parties should be consulted to ensure maximum acceptance and maximum compliance.

A sensible routing bylaw can be a very effective tool for emergency response personnel dealing with a dangerous goods incident, but its effectiveness could be much reduced if affected parties

are not consulted in depth. Provincial and territorial authorities also have a key role to play. In Alberta, the Dangerous Goods and Rail Safety Branch of Alberta Transportation is responsible for the official approval process. The approval process is relatively simple for those municipalities who have made an honest effort to enhance the public's safety in their communities. If a municipality needs to introduce a dangerous goods routing bylaw, it is encouraged to use these guidelines. The guidelines are very practical and tangible. They contain several examples and appendices that assist in planning, preparing and passing the bylaw.

3. Allen, J. and R. Fronczak. "Comparing and Contrasting Highway and Rail Routing." 86th Annual Meeting, Transportation Research Board. Washington, D.C., January 2007.

This presentation discusses current practices and the recently proposed rules in regard to rail routing of selected hazardous materials. The presentation contrasts rail practices to the regulatory perspective for the highway mode. Rail owns, operates, and maintains its right-of-way (ROW) whereas the highway mode uses the public ROW. There are fewer routing alternatives between any given origin-destination pair for rail. A train consists of several interconnected units (cars) whereas every truck is a discrete, independent cargo unit. Avoiding heavily populated urban areas or center cities is more difficult for rail whereas trucks are physically free to travel on beltways or bypasses where available. Larger quantities are transported by a single train and carrier interchange is frequent.

The proposed rules apply to explosives, bulk toxic by inhalation (TIH), and radioactive hazmat. Rail carriers are to be responsible for annually reviewing and selecting the commercially viable route with the least safety and security risk based on commodity data collection and analysis by route and the rail route analysis risk factors included in the legislation. Rail carriers are also responsible to minimize time in transit and increase security in storage of hazmat. Analyses or route decisions are not required to be submitted but must be available for inspection.

Current railroad practices related to hazmat routing as recommended by the Association of American Railroads (AAR) aim to enhance safety and security. They include special requirements for trains and routes transporting large quantities of the most hazardous materials, which are designated as 'key.' They also include operating practices related to rail yards, storage, and shipper emergency notification among others. From a rail safety standpoint, the shortest route is generally the best due to reduced derailment probability. Carrier operational concerns require flexibility in route decisions given there is no single best answer or methodology, especially in working with shippers.

Lastly, it is stated in the paper that "if everyone bans hazmat through jurisdictions sooner or later there will be no hazmat transportation."

4. **Allen, John. *What Does the New Millennium Offer for Hazardous Materials Transportation?* Prepared by ICF Consulting. Transportation Research Board. Washington, D.C.**

This paper discusses some of the key issues and the progress expected in hazmat transportation, including regulatory issues, data needs and availability, and radioactive waste issues. For regulatory issues, it elaborates on the following:

- harmonization and rationalization of hazmat transportation regulations,
- shipper and carrier registration,
- fees for emergency preparedness and response, and
- risk-based regulatory programs for hazmat.

The data needs and availability portion discusses the data issues for risk assessment and use of information and communications technology. Radioactive waste issues include:

- Department of Defense and Department of Energy facility cleanup and closure and
- Commercial Radioactive Waste Management Program.

5. **American Association of State Highway and Transportation Officials (AASHTO). *National Needs Assessment for Ensuring Transportation Infrastructure Security,* Washington, D.C., 2002.**

This study focuses on three program areas in addressing nationwide transportation security issues:

- protection of critical mobility assets,
- enhancement of traffic management capabilities, and
- improvement of state department of transportation (DOT) emergency response.

It provides specific component programs for each of the three security planning areas and estimates the total program cost by a common process:

- establish potential threat dimensions and identify those considered reasonable for deterrence/defense and/or response,
- develop definition of critical assets and key emergency response activities,
- establish generic asset vulnerabilities and appropriate countermeasures, and
- estimate six-year capital and operating costs.

Total costs for the proposed initiatives, including capital investment and operations and maintenance expenses during the TEA-21 (Transportation Equity Act for the 21st Century) six-year reauthorization period are estimated at $10.5 billion.

6. **American Association of State Highway and Transportation Officials (AASHTO). *Protecting America's Roads, Bridges, and Tunnels: The Role of State DOTs in Homeland Security*. Washington, D.C., January 2005.**

This brochure, produced by AASHTO, describes state departments of transportation (DOTs) as the guardians of the nation's transportation infrastructure. As a response to the threat of terror events, state DOTs are expanding their roles to include the protection of the system and the preservation of user safety. In order to accommodate these new roles in supporting emergency management, state DOTs identify the need for resources related to enhanced intelligent transportation system (ITS) capabilities, improved emergency response, and better communications. The needs related to protecting critical transportation assets include bridge retrofits, bridge reconstruction, and tunnel protection costs. As state DOTs are establishing new security-related roles in response to the threat of terrorism, they must continue to adapt and expand their emergency management support roles to meet new homeland security needs and must continue to identify and protect critical highway, bridge, and tunnel assets.

7. **American Transportation Research Institute. *Critical Issues in the Trucking Industry – 2007*. Arlington, VA, October 2007.**

The trucking industry continues to be the primary mover of goods in the United States, with more than three-quarters of all manufactured freight hauled by truck. Despite an essential economic role, the trucking industry continues to struggle with both near-term and long-term issues that threaten its position in a rapidly changing world economy. The document lists 10 top issues and proposes strategies for them. The top issues are as follows:

- hours of service,
- driver shortage,
- fuel issues,
- congestion,
- government regulation,
- tolls/highway funding,
- tort reform/legal issues,
- driver training/driver education,
- environmental issues, and
- on-board truck technology.

8. **Anderson, Robert T., Christopher P. L. Barkan. "Railroad Accident Rates for Use in Transportation Risk Analysis." *Transportation Research Record: Journal of the Transportation Research Board,* No. 1863. Transportation Research Board, National Research Council, Washington, D.C., 2004, pp. 88-98.**

In this paper, the authors indicate that more detailed accident rate statistics than that are currently utilized are required for hazardous materials risk analysis. This paper presents statistics that

"enable more precise determination of the probability that Class I and non-Class I railroad freight trains will be involved in an accident on various classes of main-line track." Components of a risk analysis for the shipment of hazardous materials railcars involve:

- estimating the probability that a train transporting hazardous materials will be involved in an accident,
- the conditional probability that a hazardous materials car will be derailed and exposed to damage, and
- the conditional probability that the derailed car will release its contents.

The findings from the more precise estimates of derailment rate over the period 1992 to 2001 indicate the estimated derailment rates for Class I railroads of 0.53 and 0.32 derailments per million train miles for FRA Class 4 and 5 track, respectively. This compares to the overall average main-line derailment rate of approximately 1.0 per million freight train miles. The authors indicate the bulk of the rail freight is shipped over Federal Railroad Administration (FRA) Class 4 and 5 track. The method presented in this paper demonstrates how the more precise method more accurately depicts the derailment rates over FRA Class 4 and 5 track, which would otherwise be overstated by two or three times the average value.

9. Association of American Railroads (AAR). *Hazmat Transport by Rail*. Washington, D.C., February 2007.

According to the industry, railroads are constantly working to ensure the continued safety of hazardous materials transportation in various ways.

- An industry committee approved the phase-in of new, improved tank cars for chlorine and anhydrous ammonia that will reduce the risk of a release in 2008. These two gases comprise about 80% of rail Toxic by Inhalation (TIH) movements.
- Railroads help communities develop and evaluate emergency response plans. They also train more than 20,000 emergency responders each year directly and through the Transportation Community Awareness and Emergency Response Program (TRANSCAER). They support Operation Respond, a nonprofit institute that develops technologies and training for emergency response personnel.
- Railroads work with chemical manufacturers in the Chemical Transportation Emergency Center (Chemtrec), a 24/7 resource that coordinates and communicates with emergency responders in hazmat incident mitigation.
- Upon request, railroads provide local emergency responders in qualifying communities (those that have an amount of hazmat that puts them in the top 25 communities of hazardous materials transported through their communities) with help in prioritizing emergency response plans.
- Certain trains and routes carrying substantial amounts of highly hazardous materials are subject to special operating procedures.
- Railroads have developed and implemented a Terrorism Risk Analysis and Security Management Plan. They are working with the Department of Homeland Security (DHS) to reduce terrorism opportunities on rail property. Upon request, railroads also provide the Transportation Security Administration (TSA) of DHS with TIH movement data.

- Railroads participate in research and development toward tank car and hazmat safety, e.g. the Tank Car Safety Research and Test Project, which aims to identify causes of tank car releases.
- Railroads offer basic hazmat awareness training to hazmat transportation employees and more in-depth training to emergency response employees.
- Railroads are pursuing various technological advancements to enhance rail and hazmat safety, e.g. advanced train control systems that can prevent accidents by automatically stopping or slowing down at the indication of a hazard.
- Railroads are working with TIH manufacturers, consumers and the government to coordinate routing and reduce mileage and time of TIH transit.

10. Barkan, Christopher, C. Tyler Dick, and Robert Anderson. "Railroad Derailment Factors Affecting Hazardous Materials Transportation Risk." *Transportation Research Record: Journal of the Transportation Research Board*, No. 1825. Transportation Research Board, National Research Council, Washington, D.C., 2003, pp. 64-74.

This paper describes the sophisticated methods utilized to precisely analyze data for hazardous materials risk assessment. It points out that these new sophisticated methods are required since the railroad accident and hazardous materials release rates have declined to such a low level that identifying further safety improvement options is difficult. This paper examines railroad derailment data to identify the conditions most likely to result in a release accident, with the objective to "identify proxy variables that can be used as performance measures." The paper concludes, "the speed of derailment and number of derailed cars are highly correlated with hazardous materials releases."

11. Barkan, Christopher P.L., Satish V. Ukkusuri, and S. Travis Waller. "Optimizing the Design of Railway Tank Cars to Minimize Accident-Caused Releases." *Computers & Operations Research*, No. 34, 2007, pp. 1266-1286.

The authors of this paper indicate that increasing the thickness of tank cars increases safety but by increasing the weight of the tank, additional shipments are required to transport the same amount of product. The increased shipments create additional opportunities for accidents to occur, thus increasing exposure. This paper presents a model that analyzes the tradeoff between increased damage resistance from increased tank car thickness and increased exposure to accidents from the increased number of shipments. Final discussion points indicate that there is an optimal thickness for any particular configuration of tank car that is affected by several factors and that there is no single optimum for all tank cars.

12. **Borchardt, D. W., D. L. Jasek, and A. J. Ballard. *Guidelines for Vehicle Lane Restrictions in Texas,* Research Report 0-4761-S. Texas Transportation Institute, Texas A&M University System, College Station, TX, 2005.**

This research report evaluates truck lane restrictions in Texas and further develops guidelines for future implementations on the freeway system. The truck lane restrictions on the 1-10 East Freeway in Houston have had a long-term (since September 2000) impact in reducing crashes during peak traffic periods. Although vehicle restrictions may not be necessary on all freeways, the restrictions should be implemented:

- if the guidelines are met,
- if it is the opinion of the local traffic engineers that crashes may be reduced,
- if commitment of local law enforcement has been assured, and
- if there are no diverse impacts to truck movement and commerce in terms of goods movement.

13. **Cambridge Systematics, Inc. *Hazardous Cargo Community Risk Assessment and Transportation Route Alternative Analysis for the City of Laredo*. Cambridge, MA, July 2006.**

The study evaluates the potential risks associated with alternative Non-radioactive Hazardous Materials (NRHM) route designations that would include the new World Trade Bridge as an option to cross the U.S.-Mexico border. The methodology follows the hazardous material routing guidelines established in 1996 by the Federal Highway Administration (FHWA). The analysis consisted of seven tasks: definition of objectives and responsibilities, definition of alternative routes, determination of risk, application of through routing criteria, additional analysis, comparison of alternative routes, and public input.

The study's objectives are stated as:

- first to determine if risks to humans or the environment from spills or releases along the designated routes would increase if the World Trade Bridge was opened for hazmat transportation, and
- second to revisit the risks associated with all currently designated hazmat routes given alternative routes, locations of storage warehouses, and population and employment patterns.

Four alternative routes are analyzed according to the criteria set forth by the FHWA routing guide, with Alternative Route 1 being the currently designated route. The primary criteria are population risk exposure and avoidance of undue burden on NRHM transport. Additional factors were congestion delay, environmental risk, and emergency response capabilities. Input from several federal, state, and local agencies was solicited and a public meeting was held. Alternative Route 3 is presented as the most viable option, reducing population risk and not imposing any burden on commerce relative to Alternative Route 1. In addition, it has lower environmental risk, congestion delay, and travel time than Alternative 1. The remaining alternatives do not differ

significantly in population risk from Alternative 1 and also satisfy the remaining criteria, so they remain as viable alternative routes.

14. Corpus Christi, Texas, Metropolitan Planning Organization (MPO). *Final Report: Freight and Hazardous Materials Movement Study*, Olivarri & Associates, Inc., with Public Information Associates and Turner Collie & Braden, 2004.

This report contains information about the number of trucks deployed to move freight, routes used, commodities and volume hauled, hazardous materials moved, and the origin and destination of freight within the Corpus Christi MPO region. It also lists areas where traffic congestion causes delays or "bottlenecks," hazardous materials movements or issues, needed truck services, and policy type issues or issues/projects affecting future movements.

15. Currier, Christina. *Overview of Truck-Only Toll Lanes in the United States*. Government & Business Enterprises Division, Texas Department of Transportation. Policy Research Paper. Austin, Texas, May 2007.

The paper gives an overview of truck-only toll (TOT) lanes, the basic function of which is to separate trucks from other vehicles to aid traffic flow and enhance safety. It talks about several federal programs supporting TOT lanes construction, including value pricing pilot programs, DOT congestion initiatives, and other initiatives. Positive and negative aspects of TOT lanes are discussed as well. Positive aspects include more efficient truck operations, reduced travel time, better quality of traveling experience, improved speed, and potential for a reduction in truck emissions. Negative aspects are mostly due to the prohibitive cost of constructing TOT lanes. The paper also gives some examples of current tolled and non-tolled truck lanes in America, as well as the states examining TOT lanes, including Georgia, Texas, Florida, California, and Virginia.

16. Dilgir, R., Zein, S.R., and Popoff, A. "Dangerous Goods Route Selection Criteria." *2005 Annual Conference of the Transportation Association of Canada*. Hamilton-Finn, Calgary, Alberta. December 2003.

This paper demonstrates the incorporation of safety in the designation of a dangerous goods route network using the City of Calgary's network as an example. A research project was conducted in 2003 by Hamilton-Finn for the Centre of Transportation Engineering and Planning at the University of Alberta, in cooperation with the City of Calgary with the purpose to establish criteria for the selection of dangerous goods routes, review the adequacy of the current network, and identify changes and upgrades using a transparent and repeatable process. The criteria can be equally applicable for other cities in Canada, with minor modifications for local conditions. The review includes the latest research from Europe, Canada and the United States on dangerous goods roads transport, and particularly the research related to route selection criteria and methods.

By reviewing and discussing the existing dangerous goods road network with the City of Calgary, new expectations from an upgraded dangerous goods road network are established. A 'what if' scenario analysis examines alternatives when a designated dangerous goods route is blocked due to an emergency and traffic needs to be diverted. A new set of criteria and a decision support system area are established to allow the city to select a logical dangerous goods route network using objective, transparent, and repeatable measures. Some of the core safety criteria include minimum crash frequency, insurance premium implications, and catastrophe minimization. A combination of these and several non-safety criteria form a practical decision support system for the city.

An example of the application of the decision support system is included in the report. Using the new criteria and decision support system, opportunities for changes or upgrades to the city's existing dangerous goods network are identified, including adding/deleting/confirming routes, and suggestions to physically upgrade existing roads to meet dangerous goods designation criteria, primarily road safety and public exposure to risk.

In summary, the movement of dangerous goods represents a relatively high-risk road transportation operation, and crashes involving trucks carrying dangerous goods could be catastrophic to the road system and to the surrounding environment. Road safety and public exposure to risk are among the main criteria used in establishing a dangerous goods route network.

17. District of Columbia Department of Transportation and National Capital Planning Commission. *Freight Railroad Realignment Feasibility Study*. Washington, D.C., April 2007.

The study objective is to determine the feasibility of relocating the freight rail line as a long-term solution to rail-related security issues in Washington, D.C., with the goal to mitigate security concerns related to transporting hazardous materials through the Monumental Core area and the capital city as a whole. In search of locations for a new alignment, the study reviews extensive information on existing rail lines, highways, and utility rights-of-way, along with data on environmental characteristics, land uses, and locations of population and employment. Railroad facilities and operations, commodity flows, and freight customer locations are reviewed to create an understanding of the possibilities for modifying railroad services. Security factors are also considered. A geographic information system database is used to organize this information and to allow its evaluation.

The study uses a security risk assessment to evaluate the security risks of each freight railroad alignment alternative. The assessment includes consideration of threats, vulnerabilities, and consequences. Because railroads carry TIH materials, their potential impacts on dense population and economic centers are a particular concern. Major considerations for comparing the rail line alternatives include:

- benefit-cost: maximize benefits and minimize capital costs;
- security: minimize proximity to population and employment concentrations within potential plume area:
    - number of year 2030 residential population within 800 feet of alternative rail alignment, and
    - number of year 2030 employees within 800 feet of alternative rail alignment;
- environmental: avoid disproportionate impacts to low-income and minority populations:
    - percent of population below poverty level within 800 feet of alternative rail alignment, and
    - percent of population that is a minority within 800 feet of alternative rail alignment.

According to the study, it "measured the amount of residential population, number of total jobs, and number of federal government jobs within 800 feet of an alternative rail alignment. The U.S. Department of Transportation uses this distance as the initial isolation area, or hot zone, for a major hazmat spill, including a chlorine release from a tanker-car. This criterion responds to not only security, protecting from terrorist attacks, but also the safety concerns from an accidental derailment."

18. Donath, Max, Daniel Murray, and Jeffrey Short. *Homeland Security and the Trucking Industry*. University of Minnesota with the American Transportation Research Institute. Prepared for International Truck & Engine Corporation. Intelligent Transportation Systems Institute, Minneapolis, MN, July 2005.

The modern, post-deregulation trucking industry suffers from severe competition, low operating margins, critical driver shortages, and a growing gap in size, sophistication, and resources between small and large carriers. It is well accepted that the trucking industry possesses some important attributes associated with terrorism including access, sizeable volumes, adequate kinetic energy, and an open operational environment. This report attempts to identify, amalgamate and analyze numerous security initiatives, technologies, and policies that either exist in the industry or are being considered for implementation. The report places considerable attention on the role and impact of technologies in the trucking industry.

19. Farnsworth, Stephen P. *2004 Longview External Survey Technical Summary*. Prepared for Texas Department of Transportation. Texas Transportation Institute, Texas A&M University System, College Station, TX, April 2005.

This report measures and identifies travel patterns into, within, and out of the Longview, Texas, study area, which for purposes of this report is comprised of Gregg, Harrison, Rusk, and Upshur Counties. This report presents a technical summary of the 2004 Longview External Station Survey and documents the data collected and the analysis results for the study area.

20. Farnsworth, Stephen P., and Haobo Ren. *2004 Longview Commercial Vehicle Survey Technical Summary*. Prepared for Texas Department of Transportation. Texas Transportation Institute, Texas A&M University System, College Station, TX, January 2006.

The Longview, Texas, commercial vehicle survey measures commercial vehicle travel patterns in Gregg, Harrison, Rusk, and Upshur Counties. The purpose of the survey is to provide data that allow the Texas Department of Transportation (TxDOT) to forecast commercial vehicle demand and travel patterns within the area.

21. Fitzgerald, A.V., A.F. Dinges, R.W. Holder, and G.S. Sadler. *The Movement of Hazardous Materials on the Gulf Intracoastal Waterway in Texas: An Analysis of Accident Data.* Texas Transportation Institute, Texas A&M University System, College Station, TX, March 1978.

This report documents the importance of the Gulf Intracoastal Waterway (GIWW) in Texas to the movement of hazardous materials. Over 96% of the 50 million total tons transported on Texas waterways in 1970 are hazardous materials. For shipments originating and terminating in Texas the percentage was almost 100% (99.6%). The study objectives strive to improve the safety of waterway operations in the Texas coastal region by identifying the magnitude of the problem of accidents involving hazardous materials, major contributive factors in accidents, and sections of the Texas GIWW that experienced high rates of incidents. The findings of the report specify that 72% of the accidents on the GIWW involved vessels that normally carry hazardous commodities, with only five accidents resulting in a significant spill during the study period.

22. Glickman, Theodore S. "Rerouting Railroad Shipments of Hazardous Materials to Avoid Populated Areas," *Accident Analysis & Prevention*. Vol. 15, No. 3 1983, pp. 329-335.

The paper finds that population exposure can be reduced 25-30% by rerouting at the cost increase of 15-30% for the added distance created by rerouting. It formulates and applies a risk model that shows extensive routing changes can reduce casualties by approximately 50%, but extensive upgrading with or without rerouting can be even more effective. The effects on urban areas of the hypothetical changes are discussed, but financial impacts on the railroads are not addressed in the paper.

23. Han, L.D. "Tool for Railroad Hazmat Routing under Shipment Bans in Major Cities." 85th Annual Meeting, Transportation Research Board. Washington, D.C., January 2006.

A recent hazmat shipment ban in Washington, D.C., led to debates, legal challenges, and considerations by other major cities to pursue similar actions. This paper presents a framework and a Web/Geographic Information System (GIS) tool based on this framework for routing hazmat shipments in railroad networks under situations such as shipment bans. This tool for hazmat routing evaluation and alternative transportation, or THREAT, is capable of searching for the best routes that optimize prescribed objective functions, calculating an array of performance and operational measures for the routes, comparing different routing alternatives, and generating animated routing maps.

A case study for routing hazmat shipments from Jacksonville, FL, to Jersey City, NJ, is conducted using THREAT to identify and assess potential routing alternatives and their associated effects in terms of extra distance to traverse and reduction in risks. The four routing scenarios include a status quo base case, a shortest distance alternative, a least at-risk population alternative, and the most-likely route in the CSX Transportation, Inc. (CSX) network. The results suggest that significant increases in route distance and time in-transit will result, whichever alternative is implemented. While the overall population at risk will not see major decrease as the result of the ban, the average population at risk per track mile will decrease significantly, mainly due to the lengthening of the routes. The paper also identifies ideas for follow-up efforts.

24. Houston-Galveston Area Council. *Security and Emergency Preparedness in the Transportation Planning Process*. Prepared for Federal Highway Administration. Cambridge Systematics, Inc., Houston, TX, September 2004.

The Houston-Galveston Area Council (H-GAC) is composed of local governments and local elected officials in the 13-county Gulf Coast Planning Region of Texas. Experience in regional planning for weather, hazardous materials, and overall emergency planning and preparedness has put the H-GAC in the forefront of agencies developing materials and forums for future security efforts. Three H-GAC departments specifically address homeland security and emergency preparedness-related issues; their main roles are outlined. The report also documents important lessons learned from the H-GAC experience that may be useful to other metropolitan planning organizations and councils of government.

25. Hwang, Steve T., David F. Brown, James K. O'Steen, Anthony J. Policastro, and William E. Dunn. "Risk Assessment for National Transportation of Selected Hazardous Materials." In *Transportation Research Record: Journal of the Transportation Research Board*, No. 1763. Transportation Research Board, National Research Council, Washington, D.C., 2001, pp. 114-124.

The paper conducts a quantitative risk assessment to estimate the national risk from transporting six TIH chemicals that account for more than 90% of total TIH transportation-related risk, liquefied petroleum gas, gasoline, and explosives. The application is demonstrated for ammonia.

26. Jasek, D. *Hazardous Materials Commodity Flow Study for Brazos County Local Emergency Planning Committee*, Texas Transportation Institute, Texas A&M University System, College Station, TX, 2002.

This report documents the Texas Transportation Institute (TTI)-conducted hazardous materials flow survey for the Brazos County Local Emergency Planning Committee (LEPC). The primary purpose of the study is to identify the types of hazmat that are transported through the county and the routes used for transporting these commodities. The study examines both rail and truck traffic. Two railroads traverse Brazos County, Burlington Northern Santa Fe, and Union Pacific. The data analyzed and collected show that significant amounts of hazardous materials are transported by Union Pacific through the county and the population centers of College Station and Bryan.

The economy of Brazos County is dominated by agriculture and petroleum-related industries. However there are also some manufacturing and technology-based industries based in the county. As expected, the commodities transported on the highways reflect the economic makeup of the county.

State Highway 6 and State Highway 21 are the two major transportation corridors that traverse Brazos County. State Highway 6 travels in a general north/south direction through central and southeastern Brazos County. The highway travels through both Bryan and College Station, which are the two largest populated areas, as well as intersecting most other major highways and arterials. State Highway 21 travels in a general east/west direction through north central Brazos County. The highway travels through Bryan as well as Wixon Valley, Kurten, and Smetana. This study shows that there are significant amounts of hazardous materials being transported through Brazos County. Surveys at selected location show that the percentage of placarded vehicles in truck traffic ranged from 2% to 19.7%.

27. Jasek, D. *Hazardous Materials Commodity Flow Study for Galveston County Local Emergency Planning Committee*, Texas Transportation Institute, Texas A&M University System, College Station, TX, 2003.

This report documents the hazardous materials flow survey performed by TTI for the Galveston County LEPC. The primary purpose of the study is to identify the types of hazmat that are transported through the county and the routes used for transporting these commodities. A hazardous materials commodity flow study conducted in 1997 for Galveston County is used as the baseline for this study. A number of sites are selected for an updated hazmat placard study. This type of update provides planners with a better understanding of hazmat transportation

patterns within the county, provides them with information that shows any changes in hazmat transport patterns, and provides the data necessary to conduct planning and estimate risks.

Interstate 45 is the major corridor roadway that spans Galveston County and one of three north/south transportation corridors. IH 45 originates on Galveston Island in south Galveston County, travels in a generally north/south direction through central Galveston County, and continues through the metropolitan Houston area and east Texas to Dallas and beyond. The truck traffic found on IH 45 in regard to patterns and cycles is representative of truck traffic throughout the county.

The economy of Galveston County is based on the petrochemical industry, petroleum industry, and plant industries found in the county as well as some agricultural and agribusiness industries. Truck traffic patterns show that truck traffic is light during early morning, evening, and nighttime hours. Truck traffic is heaviest and fairly constant throughout the daytime and early evening hours. These patterns are subject to seasonal variations such as harvest and drilling schedules. Trucks traveling to the industries are also generally cyclical with higher numbers of trucks traveling on local highways during mid-morning and mid-afternoon hours. These cycles can be attributed to the just-in-time shipping and supply routines that have been adapted by industries and the distance to port facilities and the industries that either supply or are supplied by the plants.

One aspect that must be considered in hazardous material transportation is the proportion of vehicles carrying hazardous materials in relation to overall truck traffic. There are sizeable amounts of hazardous materials being transported through Galveston County. However, the number of hazardous materials vehicles is only a small percentage of the overall truck traffic; and truck traffic is only a portion of the overall traffic flow in the area. The percentage of hazardous materials in relation to overall traffic ranges between 2% and 15%.

28. Jasek, D. *Hazardous Materials Commodity Flow Study for Leon County Local Emergency Planning Committee,* Texas Transportation Institute, Texas A&M University System, College Station, TX, 2004.

This hazardous materials flow survey, conducted by TTI for the Leon County LEPC, identifies the types of hazmat that are transported through the county and the routes used for transporting these commodities. The study examines both rail and truck traffic. Two railroads traverse Leon County, Burlington Northern Santa Fe and Union Pacific. The data analyzed and collected shows that significant amounts of hazardous materials are transported by both railroads through the county.

Interstate 45 is the major transportation corridor that traverses Leon County. The highway is a restricted-access roadway that has two lanes in each direction that is separated by a grass median. It is part of the national defense highway system and is the main highway route between Houston and Dallas. IH 45 travels in a generally north/south direction and bisects the county. The highway travels through Leona, Centerville, and Buffalo. Leona and Centerville are the two

largest populated areas in the county. IH 45 also intersects US 79 and SH 7 in the Buffalo and Centerville areas, respectively.

One aspect that must be kept in mind is the proportion of vehicles carrying hazardous materials to overall truck traffic. Although this study shows that hazardous materials are being transported through Leon County, the number is not a disproportionate amount. The number of hazardous materials vehicles is only a small percentage of the overall truck traffic; and truck traffic is only a portion of the overall traffic flow in the area. Generally the hazardous materials comprise only 5.5% of the truck traffic countywide, with the vast majority of that traffic on IH 45. On IH 45 the average is slightly higher at approximately 7%. It should be noted that both the hazardous materials traffic and truck traffic overall is cyclical and that both the proportion of hazardous materials traffic and the number of truck may be higher than the numbers noted at certain times of the day or days of the week..

29. Jasek, D. *Hazardous Materials Commodity Flow Study for Matagorda County Local Emergency Planning Committee*, Texas Transportation Institute, Texas A&M University System, College Station, TX, 2000.

The Texas Transportation Institute conducted a hazardous materials flow survey for the Matagorda County LEPC. The primary purpose of the study is to identify the types of hazmat that are transported through the county and the routes used for transporting these commodities. This study examines both truck and rail traffic through the county.

The economy of Matagorda County is dominated by agriculture and petroleum-related industry. As expected, the commodities transported on the highways are dominated by those two industries. State Highway 35 is the major transportation corridor that traverses Matagorda County. Although marked as a north/south highway, SH 35 travels in a general east/west direction through central and southwestern Matagorda County. The highway travels through both Bay City and Palacios, which are the two largest populated areas, as well as intersecting most other major highways and arterials.

The truck traffic found on SH 35 in regard to patterns and cycles is representative of truck traffic throughout the county. Truck traffic patterns show that truck traffic is light during early morning, evening, and nighttime hours. Truck traffic is heaviest and fairly constant throughout the daytime and early evening hours. These patterns are subject to seasonal variations such as harvest. This study shows that there are significant amounts of hazardous materials being transported through Matagorda County. Surveys at selected locations show that the percentage of placarded vehicles in truck traffic ranged from 3% to 21.3%. The study also finds significant “cut-through” truck traffic, including placarded trucks, occurring on some residential streets.

30. Jasek, D., M. Shafer, D. Picha, and T. Urbanik. *Guidelines for Truck Lane Restrictions in Texas,* Research Report 1726-S, Texas Transportation Institute, Texas A&M University System, College Station, TX, 1998.

This report describes a one-year project conducted for TxDOT to assess the current state-of-the-practice in truck lane restrictions and to recommend guidelines for implementing truck lane restrictions in Texas. Researchers conducted several tasks, including an extensive literature review on the application and evaluation of truck lane restrictions, and a survey of state practices to identify states that have implemented truck lane restrictions for operational/safety benefits or for pavement longevity purposes. During this research, the 75th Texas Legislature passed Senate Bill 773 permitting local municipalities to request from TxDOT lane restrictions on certain highways. This bill and the results of the research combine to develop guidelines for TxDOT to implement these lane restrictions when a request is received from a local municipality. The adoption of these guidelines by TxDOT provides consistent implementation across the state for truck lane restrictions.

31. Kara, Bahar Y., and Vedat Verter. "Designing a Road Network for Hazardous Materials Transportation." *Transportation Science*. Vol. 38, No. 2, May 2004, pp. 188-196.

This paper provides a model that focuses on the nature of the relationship between the regulator and carriers to analyze the problem of selecting a road network for dangerous goods shipments from an existing transportation infrastructure. It focuses on a popular measure utilized by regulators to reduce the transport risk in their jurisdictions—that is, a government's authority to close certain road segments to hazmat transportation and, in effect, to decide the road network that can be used for hazmat shipments. Other policy tools available to a government agency for mitigating hazmat transport risk include: requirements pertaining to driver training, driving hours, container specifications, and accident insurance. Establishment of inspection stations to monitor compliance with the regulations, and emergency response systems to minimize consequences of the incidents, are quite common. Carrier companies and governments have different perspectives with regard to dangerous goods movements. Carriers always choose the minimum cost route, while the government identifies the minimum risk route.

The model represents the distinct decisions made by the regulator and the carriers, as well as their interaction in determining the total cost of transportation and the total transport risk. As demonstrated in the application example of Western Ontario, Canada, the proposed framework can be useful not only for identifying the road segments that should be closed to hazmat shipments, but also for evaluating alternative regulatory schemes. The model can also be used for identifying the risk and cost impact of adding new links to an existing road network.

32. Lindquist, E. and J. Slack. *Problems of Hazardous Materials Transport in Texas and the Potential Applicability of ITS Solutions.* Texas Transportation Institute, Texas A&M University System, College Station, TX, January 1999.

This report considers the application of intelligent transportation systems toward solving problems associated with hazardous materials transport. The study found that previous research focused primarily on commercial vehicle applications, post-incident, and route selection applications. This report takes a different approach by focusing on local institutions and processes that are involved in preparing for and responding to hazardous materials incidents. The objective of this approach is to inform decision makers about the utility of ITS in the local environment, rather than limiting their use to the transport vehicle.

Little work was previously done on shipment tracking and monitoring for public safety, the rationale being that pre-incident applications are too costly for the trucking company. The researchers conducted a review of incident response plans in three cities and find that many emergency responders would benefit from ITS-derived information. The report recommends integrating ITS/hazmat applications under the umbrella of larger community and state safety programs—for example, incident response and management. It also recommends tracking hazmat shipments that routinely travel through the same communities, conducting a statewide survey on public perception of risk from hazmat transport, encouraging research that goes beyond the traditional cost-benefit analyses and commercial vehicle applications, and shifting the perspective of the ITS community from an economic to a public safety focus.

33. Mani, Akshay, and Jolanda Prozzi. *State-of-the-Practice in Freight Data: A Review of Available Freight Data in the U.S.*, Report 0-4713-P2, Center for Transportation Research, University of Texas at Austin, February 2004.

This research product summarizes the outcome of the research team's comprehensive review of available U.S. freight data sources – both public and commercial sources. The research team carefully reviewed the objectives, survey methods, assumptions, and limitations of each publicly available database, and the available documentation of commercial databases. In total, details for 31 databases are included in the document covering characteristics such as, sponsoring organization, performing organization, data collected, sampling method, survey method, quality control procedure, geographical coverage, frequency of updates, and the assumptions and limitations inherent to each data source.

34. Middleton, D.R., S.P. Venglar, C.A. Quiroga, D. Lord, and D.L. Jasek. *Strategies for Separating Trucks from Passenger Vehicles: Final Report.* Technical Report 0-4663-2. Texas Transportation Institute, Texas A&M University System, College Station, TX, 2006.

Trucks constitute a large and growing segment of the traffic on Texas highways. In order to manage this growth, the Texas Department of Transportation needs to consider special or unique

treatments for trucks such as truck lane restrictions, exclusive truck lanes, and exclusive truck facilities. This research addresses this topic for the state of Texas by developing tools for evaluating needs for special truck facilities, developing a truck route system, and developing recommendations for demonstration of a pilot system.

This report covers the tasks required to accomplish these objectives, beginning with a comprehensive literature review, to include the major corridor studies and an evaluation of special truck facilities implemented outside of Texas. Followed by, establishing criteria for each of the three levels of truck treatments, developing a plan to classify truck facilities, and developing an evaluation framework for these facilities. Based on these tasks, the research then create techniques for evaluating levels of service on truck facilities. The techniques are applied to selected candidate corridors to demonstrate their utility. Finally, an action plan for implementation of the exclusive truck facilities is created.

35. Morgan, C.A., J.E. Warner, C.E. Roco, G.C. Anderson, L.E. Olson, and S.S. Roop. *Rail Relocation Projects in the U.S.: Case Studies and Lessons for Texas Rail Planning*. Report 0-5322-1. Texas Transportation Institute, Texas A&M University System, College Station, TX, March 2007.

This project examines rail relocation projects in the United States to determine best practices, document project costs and expected benefits, and develop recommended policies for TxDOT to use in assessing potential urban rail relocation projects throughout the state. Case studies deliver information on a broad variety of issues to be considered in railroad relocation projects including example project costs, impacts upon urban and outlying communities, potential funding mechanisms, and how potential rail relocation projects may be integrated with planning for other transportation improvements.

Texas Transportation Institute researchers analyzed a range of critical issues related to rail relocations, identified known major rail relocation projects around the country (both past and planned projects), and thoroughly analyzed five of those projects as case studies. The critical information gathered from the literature review and case studies assisted the research team in creating a list of best practices related to implementing this type of project and identified significant factors for TxDOT and local urban rail planners to consider.

The research team developed a table listing information on 30 rail relocation projects around the United States that have been planned, studied, or implemented since 1973 when the Federal Aid to Highways Act implemented a demonstration program addressing rail relocation projects. Several of those projects were later cancelled in the mid-1980s due to the lack of progress, yet other rail relocation projects were advanced using other funding sources. Many of the original projects have only recently been completed—more than 30 years after their inception.

By examining the national relocation projects and the potential Texas rail relocation projects listed in the Texas Rail System Plan, TTI determines that the projects can be classified into three broad classifications:

- Small urban area bypass – Relocation would move the rail line out of a small or mid-sized urban area to minimize traffic and/or safety conflicts.
- Large urban area consolidation/relocation – Consolidation or relocation of routes within a large urbanized area.
- Extra-urban consolidation/bypass – Consolidation or relocation of rail lines to an area outside urbanized boundaries meant to bypass completely the urban area or to minimize traffic conflicts.

Five of the rail relocation projects, selected jointly by TTI and the TxDOT Project Management Committee, are advanced as detailed case studies. The case study projects were chosen based upon similarity to projects being considered in Texas and are located in: Marysville, Kansas; Lafayette, Indiana; Reno, Nevada; Salt Lake City, Utah; and in eastern Colorado (Front Range Project). The in-depth examination of these projects provides critical information related to project motivation, costs and benefits, and lessons learned.

The lessons from the case studies identify several issues important for the state of Texas as it begins to consider rail relocation projects as part of its long-term strategy to address urban highway-rail conflicts. Issue areas include:

- project prioritization/selection characteristics,
- potential funding sources and methods,
- partnering principles for railroad companies and other private sector partners,
- public information/involvement recommendations, and
- corridor relocation and subsequent development recommendations.

36. National Highway Institute (NHI) and Federal Highway Administration (FHWA). *Highway Routing of Hazardous Materials: Guidelines for Applying Criteria*. Arlington, VA, November 1996.

This document provides guidance to states, Indian tribes, and local governments on how to apply and implement the federal standards for establishing, maintaining, and enforcing designated NRHM routes. There are two types of designations: designated routes and restricted routes. Designated routes are those highways on which NRHM must be transported and restricted routes are those highways on which NRHM may not be transported. Restrictions include tunnels, lanes, time of day, prior notice, escort requirements, etc. The federal standards provide for enhancement of safety, public participation, consultation with other parties, through highway routing, reasonable routes to facilities such as terminals, timely agreement between jurisdictions, and timely local compliance. In addition, 13 factors are to be considered in the designation process:

- population density,
- highway type,
- NRHM type and quantity,
- emergency response capabilities,
- consultation with others,

- risk exposure of sensitive areas (e.g. homes, hospitals, schools, water sources, natural areas),
- terrain,
- route continuity,
- consideration of alternative routes,
- effects on commerce,
- delays in transportation of NRHM,
- climatic conditions, and
- congestion and accident history.

The methodology reflects approaches for determination of accident probability and consequences in the primary risk calculations. Different methods requiring varying degrees of input data and calculations provide options to agencies. Additional quantitative and qualitative considerations are included as well as a worked example to illustrate the application of preferred methods identified in the main body.

37. National Research Council, Transportation Research Board. *Cooperative Research for Hazardous Materials Transportation: Defining the Need, Converging on Solutions*. Transportation Research Board Special Report 283. Washington, D.C., 2005.

This study was conducted by a committee of experts in hazardous materials transportation, research management, risk analysis, enforcement, and emergency planning and response. It describes the shared responsibilities and identifies numerous problems that cooperative research can help address. The committee recommends the trial of a national cooperative research program for hazardous materials transportation (at the time of current writing the pilot program is in effect) that would make use of the expertise and perspectives of all those having an interest in overcoming problems and improving capabilities for managing risks, preparing for incidents, and responding to emergencies.

The study provides an overview of the industry, describes safety and other risks associated with hazardous materials transportation, and outlines the many roles and responsibilities of industry and government in managing these risks. It continues with the description of the array of federal research programs related to hazardous materials transportation. It then reviews the kinds of problems that are candidates for cooperative research and offers example projects for illustration purposes. Several existing cooperative research programs are examined, both within and outside the transportation sector, the kinds of research they emphasize, and how they are financed, governed, and managed. Options for structuring a hazardous materials transportation cooperative research program on the basis of insights gained from examining other cooperative research programs are discussed. Finally, the committee's conclusions are presented about the need for cooperative research on hazardous materials transportation, its vision for how a national cooperative research program might be organized to help address this need, and recommended next steps in bringing about such a program.

Some of the data and statistics in this report have been updated by the time of this writing. Qualitative assessments and evaluations, however, remain very much current, such as Table 1, which lists the full array of stakeholders involved in hazardous materials transportation.

Table 1. Listing of Hazardous Materials Transportation Stakeholders

I. **Public Sector** - Government entities that are involved in ensuring the safe and secure transportation of hazardous materials
   1. Federal level: Primary roles are regulation, enforcement and research.
      - Department of Transportation Research and Special Programs Administration
      - Federal Railroad Administration
      - Federal Motor Carrier Safety Administration
      - Federal Aviation Administration
      - Federal Highway Administration
      - Bureau of Transportation Statistics
      - National Highway Traffic Safety Administration
      - Department of Homeland Security
      - United States Coast Guard
      - Transportation Security Administration
      - Bureau of Customs and Border Protection
      - Federal Emergency Management Agency
      - Department of Energy National laboratories
      - Nuclear Regulatory Commission
      - Department of Defense
      - U.S. Army Corps of Engineers
      - Occupational Safety and Health Administration
      - Environmental Protection Agency
      - National Transportation Safety Board
   2. State and local level: Primary roles include infrastructure management, emergency response, and enforcement
      - State emergency planning management offices
      - Local emergency management offices and committees
      - State and local police
      - Local firefighters
      - State, regional, and local hazardous materials response units
      - State highway, railroad, and transportation agencies
      - State and regional airport and marine port authorities
      - State environmental protection agencies
      - State/county/city MPO government in general
      - Adjacent potentially affected states

II. **Private Sector** - Private companies involved in operations, infrastructure, production, or use of hazmat
   1. Carriers: associated with any of the modes truck, railroad, pipeline, barge, maritime
      - They number about 45,000 dedicated carriers and about 500,000 occasional ones
   2. Shippers: They number about 45,000 regulars and about 30,000 occasional ones
   3. Receivers: Located in farms, disposal sites, refineries, factories, retailers, hospitals, swimming pools

III. **Industry Associations** – Responsibility for establishing standards, providing training, and emergency response
   1. Dangerous Goods Advisory Council
   2. Commercial Vehicle Safety Alliance
   3. Association of American Railroads
      - Bureau of Explosives
      - Tank Car Committee
   4. Railway Supply Institute
      - Railway Supply Institute – Association of American Railroads: Tank Car Safety Research and Test Project
   5. American Chemistry Council: CHEMTREC, CHEMNET (with shippers)
   6. American Trucking Association
   7. National Tank Truck Carriers, Inc.

IV. **General Public** – neighborhood associations, citizen groups, community members

38. National Research Council, Transportation Research Board. "Disruption Impact Estimating Tool – Transportation (DIETT): A Tool for Prioritizing High-Value Transportation Choke Points." *NCHRP Report 525, Surface Transportation Security*. Volume 11, Washington, D.C., 2006.

This is the eleventh volume of *NCHRP Report 525, Surface Transportation Security*, and it discusses the disruption impact estimation tool for transportation (DIETT), an electronic analytical tool that "calculates direct transportation and economic impacts (costs) of an event that precludes the use of a transportation choke point, and it prioritizes transportation choke points on the basis of these criteria." High-value transportation choke points include bridges, tunnels, and passes. The report indicates that by using DIETT's prioritized sets of outputs, along with other risk information, decision makers will be able to better focus their capital resource, security, and emergency-preparedness planning.

39. National Research Council, Transportation Research Board. "Guide for Emergency Transportation Operations." *NCHRP Report 525, Surface Transportation Security*. Volume 6, Washington, D.C., 2005.

This is the sixth volume of *NCHRP Report 525, Surface Transportation Security* and provides guidance for the management of the highway system during an emergency incident. These incidents may include traffic incidents, natural disasters, security events, and other emergencies on the highway system. This document indicates that emergencies arising from terrorist threats highlight the need for transportation managers to minimize the vulnerability of travelers, employees, and physical assets through incident prevention, preparedness, mitigation, response, and recovery. By being prepared to respond to terrorism, each transportation agency is simultaneously prepared to respond to natural disasters such as hurricanes, floods, and wildfires, as well as human-caused events such as hazardous materials spills and other incidents.

40. National Research Council, Transportation Research Board. *Project Update: Testing the Effectiveness of Technology-based Safety & Security Systems for Hazardous Materials Transportation*. Washington, D.C., 2004.

The paper provides an update on the project, Hazardous Materials Safety and Security Operational Test. It demonstrates commercial, off-the-shelf technological solutions used in hazmat transportation to enhance safety and security. It tests those technologies by quantifying the benefits and costs of implementing them in the hazardous materials transportation industry.

The test focuses on bulk petroleum transportation, bulk chemical transportation, less-than-truckload transportation, and truckload explosives transportation. The technologies tested include wireless satellite and terrestrial communications with GPS, enhanced digital phones, untethered trailer tracking, routing and geo-fenced mapping software, panic button, biometrics and smart

cards, driver authentication with global login, electronic shipping documentation, intelligent on-board computers with vehicle disabling and cargo locking, and e-seals.

Benefit-cost analysis of the technologies includes two components. The first one is the macroeconomic/societal component, which looks at the benefits to society from increased safety and security of hazmat shipments and compares that to the costs of development. The second component considers the private sector benefit-cost ratio achieved through the use of technology to gain operational efficiency improvements.

41. Nelson, C., A. Cataford, and P. Hwang. "Transportation of Dangerous Goods Policy and Evaluation Framework." 2006 Annual Conference of the Transportation Association of Canada, Charlottetown, Prince Edward Island, September 2006.

This paper describes the City of Calgary study to develop two products: a policy outlining guidelines and principles for the selection of dangerous goods routes, and an evaluation tool to be used in assessing dangerous goods routes. A stakeholder group formed for the study included representation from:

- The City of Calgary,
- The Alberta Motor Transport Association (AMTA),
- Alberta Infrastructure and Transportation (AIT),
- The Centre for Transportation and Engineering Planning (C-TEP) at the University of Alberta, and
- The University of Calgary (Geography and Civil Departments).

A literature review undertaken as part of the study includes the investigation of the practices of other jurisdictions such as Ottawa, Hamilton, Saskatoon, Vancouver, and Edmonton. The salient point from this investigation is that there was no quantitative or explicit/repeatable procedure in place to conduct a review of dangerous goods routes. Nor is there policy in place to guide city administration on how dangerous goods routes are to be reviewed and evaluated. Most jurisdictions approach dangerous goods route selection based on the expertise of city administration and/or industry experts.

Based in part upon the literature review and the practices of the surveyed jurisdictions, the stakeholder group develops a list of evaluation criteria that considers risk management, social implications, environmental impact, and economic considerations in determining whether routes should be designated as dangerous goods routes. After finalizing the evaluation matrix a policy is drafted to identify the process for evaluating dangerous goods routes and includes such items as how the matrix is to be used, who will be involved, how often are reviews to be undertaken and how it is to be included in planning for new routes/communities.

The documentation was finalized and approved by the City of Calgary Council in January 2006. The city is to evaluate all existing and future dangerous goods routes to ensure that all of the appropriate routes have been identified. The bylaw is to be subsequently updated in accordance with the policy and the evaluation criteria to account for any required changes. The policy developed at the City of Calgary creates an administrative framework, ensuring the departments

responsible for decision-making affecting the transportation of dangerous goods network consider impacts. Further, the framework establishes a stakeholder advisory committee to ensure the needs of industry, emergency services, community aesthetics, and the viability of a transportation network are maintained. Finally, the framework has created the technical criteria that provide for a transparent, repeatable, and defendable analysis to ensure the needs of the community at large are provided for.

42. North Central Texas Council of Governments, *Hazmat Routing Study Phase I: Establishing Hazardous Material Truck Routes for Shipments through the Dallas-Fort Worth Area,* Arlington, TX, 1985.

The North Central Texas Council of Governments established in January 1966 is a voluntary association of cities, counties, school districts, and special districts within the sixteen-county North Central Texas region formed to assist local governments in planning for common needs, cooperating for mutual benefit, and coordinating for sound regional development. The report, completed in January 1984, establishes a set of regional hazardous materials truck routes and develops a region-wide routing system for hazardous materials truck shipments traveling through the metropolitan area encompassing the sixteen-county metropolitan region centered around Dallas and Fort Worth.

The approach is based upon the guidelines established by the Federal Highway Administration for systematically analyzing routes with the least amount of risk. The report summarizes the process followed to implement the FHWA risk assessment approach and the results of implementation of the selected routes.

43. Olson, Les, George Rogers, Deborah Jasek, Curtis Morgan, David Bierling, and Jeff Warner. *Alternative Technologies to Railroad Tank Car Placarding*. Texas Transportation Institute, Texas A&M University System, College Station, TX. (Submitted to the Transportation Security Administration, HSTS02-04-MLS006. Final Report 401101-F, 2005.)

As part of Transportation Security Administration's work to develop and establish policy regarding rail shipments of TIH materials, TSA initiated this research to evaluate the potential for alternative, known, and existing technologies to replace the current hazardous material placard system. The stakeholders who rely on the placard for provision of safety information were surveyed as part of this project. They included first responders, the railroad industry, the chemical industry, the emergency management community and public officials. This study concludes that consideration of alternatives to replace the current hazardous materials placard system centers on the balance between potential increases in security provided by the alternative and the potential losses in safety of first responders, emergency personnel, and the public. This issue was raised in every stakeholder meeting in a variety of forms. In brief, the consensus position seems to be that modest gains in security do not warrant the loss of considerable safety. Hence, alternative systems need to be able to fully meet the functional requirements of the

existing system, and should probably exceed them in some areas to warrant the cost (financial, human, and risk) associated with making the change.

44. Orr, M., W Kaye, P. Zeitz, M. Powers, and L. Rosenthal, "Public Health Risks of Railroad Hazardous Substance Emergency Events," *Journal of Occupational and Environmental Medicine*, Vol. 43, No. 2, February 2001, pp. 94-100.

This paper describes the effort to examine the Hazardous Substances Emergency Events Surveillance (HSEES) database for the 1993 to 1998 period regarding public health risks associated with the transport of hazardous materials by rail. The objective of the analysis was to:

- ascertain whether railroad events pose a greater risk to public health, and
- discuss how to lessen this risk.

According to the paper, at least one of the following criteria must be met for an event to be recorded by HSEES:

- a release of at least one hazardous substance in an amount requiring removal, cleanup, or neutralization under federal, state, or local laws; or
- a threatened release (anticipated but not actual release) of at least one hazardous substance in an amount that would have required removal, cleanup, or neutralization under federal, state, or local law and the threat led to an action that could have adversely affected the health of employees, emergency response personnel, or the general public.

Fourteen states participated either partially or fully during the time frame, producing a total of 30,346 recorded events. The results indicate that railroad events made up 1.4% of the total recorded events. The researchers find that railroad events are more likely to occur in residential areas and during times when people were more likely to be at home. The paper also reports that "a greater percentage of members of the public and emergency response personnel were injured during railroad events compared with non-railroad events."

The paper develops suggested recommendations to state and local agencies for community planning; federal agencies, such as FRA, DOT, and Occupational Safety and Health Administration (OSHA); and railroads. In conclusion, the paper indicates that "even small improvements in strategies for primary prevention of releases, and secondary prevention of adverse public health outcomes, could have a large positive impact."

45. Roop, S., Olson, L., Warner, J., Bierling, D. *The Value of Pipelines to the Transportation System of Texas*. Report 0-1858-2. Texas Transportation Institute, Texas A&M University System, College Station, TX, September 2001.

Pipelines represent a major transporter of petrochemical commodities in Texas. The Texas pipeline system represents as much as 17% of the total pipeline mileage in the U.S. and links many segments of the country with energy sources located on the gulf coast. This research was undertaken to provide the Texas Department of Transportation a broad understanding of pipeline

operations and their relationship to other modes of transportation. Physical, business, and policy issues related to pipeline transportation are examined, pipeline interconnections with other modes are inventoried, and pipeline industry operational and regulatory issues and pipeline utilization are reviewed.

46. Saat, M.R. and C.P.L. Barkan. "The Effect of Rerouting and Tank Car Safety Design on the Risk of Rail Transport of Hazardous Materials." ***Proceedings of the 7th World Congress on Railway Research,*** **Montreal, June 2006.**

This paper presents a risk assessment model that can be used to evaluate different rail route alternatives for transporting hazardous materials. The major variables include:

- length of route,
- number of shipments,
- track quality,
- tank car safety design,
- chemical-specific exposure area, and
- population density.

The model uses "up-to-date measurements of accident probability as a function of track quality, tank car accident performance, and chemical-specific hazard analyses." The paper presents risk profiles related to an example case that considers both alternative routing and tank car design.

For the risk analysis model, risk is defined as the multiplication of the annual probability that a tank car is involved in a release accident, probability of a particular release scenario occurring, and the consequence level in terms of number of people affected. For this analysis, population is classified into categories ranging from "remote" (10 people per mile) to "extremely high" (10,000 people per mile). The authors suggest performing a spatial analysis to determine the population densities along the baseline and alternate rail lines. The paper suggests utilizing a 4.6-mile radius away from the track, which represents the worst-case downwind exposure distance for a chlorine release.

The example considered for this paper includes a baseline route and alternative route that would increase the distance traveled with lower-quality track conditions, in combination with existing tank cars and an alternate design, safer tank car. The outcomes of the example analyzed for this project include, as indicated in the paper:

- The combination of a longer route and lower track quality (alternative route) increases the likelihood of having an accident-caused release along the alternative route. Although the reduced exposure to higher-population areas does lower the likelihood of a high-consequence event, the probability of a lower-consequence event is substantially increased.
- The transferal of risk from one population to another presents a difficult public policy decision.
- Strategies considering the alternate design tank car do not transfer risk from one group to another but does reduce the likelihood of an event to all population levels.

47. San Diego Association of Governments. *Security and Emergency Preparedness in the Transportation Planning Process*. Prepared for Federal Highway Administration. Cambridge Systematics, Inc., Cambridge, MA, September 2004.

This report is intended to:

- improve national awareness of how state and local agencies are integrating security and preparedness issues into their planning processes and organizations,
- identify transportation planning agencies who are leaders in the integration of security and preparedness issues into their planning processes and organizations, and
- facilitate technology transfer by documenting leading experiences and lessons learned.

This report documents security planning activities and products developed in response to identified criminal threats to high-value, vulnerable elements of the transportation system. Preparedness planning includes activities and products developed in response to the threat of environmental hazards and natural occurrences. Some of the activities that can be characterized as contributing to the integration of security and emergency preparedness into the transportation planning process include chartering committees and organizations, establishing liaisons or otherwise designating planning staff resources, establishing project categories and program funding, conducting vulnerability and threat assessments, and developing and exercising plans.

48. Shaver, D. K. and M. Kaiser. *Criteria for Highway Routing of Hazardous Materials*. Synthesis of Highway Practice 261, National Cooperative Highway Research Program, Transportation Research Board. Washington, D.C., 1998.

This synthesis is targeted to staff of state departments of transportation responsible for highway routing, traffic engineering, traffic operations and signing, and maintenance. It is also useful to state police, who may be responsible for routing, and other enforcement personnel as well as emergency and fire personnel. The trucking industry will also find the information of value to their operations.

Information is presented on current state practices for the highway routing of vehicles that transport hazardous materials. The Federal Highway Administration in 1994 issued *Guidelines for Applying Criteria to Designate Routes for Transporting Hazardous Materials*, which is used by agencies that elect to designate such routes. This 1998 report of the Transportation Research Board is based on information obtained from a survey of states concerning the routing of hazardous materials vehicles that asked respondents to rate the importance of 24 factors in the categories of roadway, environment, population, or other criteria in establishing routing policy. The survey also identified the principal agencies responsible for routing, as well as other agencies that typically participate in the routing plan. Enforcement and cost issues are discussed, as is risk assessment.

This report presents a discussion of the issues as identified by interviews with trucking trade associations and other organizations involved with hazardous materials transport. In addition, technology applicable to more effective monitoring and enforcement is described. The appendices include commodity flow studies and route designation case studies for selected jurisdictions.

One of the conclusions of the synthesis is that reliable statistics necessary for a route assessment are hard to obtain. It is best if they result from local commodity flow studies that can be difficult and expensive to undertake, especially for smaller jurisdictions. Thus there has been limited activity nationwide for designating hazardous materials transportation routes. In more detail the study found that:

- Sixteen states designate routes for highway transport of hazardous materials.
- The most important of the 24 criteria for routing was cited to be population density, followed by location of special populations, accident history, and highway type.
- In most states, departments of transportation have primary responsibility for routing decisions, followed by state police, state emergency management agencies, and state public safety departments.
- States reported that time requirements to analyze routes range from 20 to over 100 hours.
- About half the responding states indicated that a formal process exists for resolving intrastate routing issues. Fewer states have a formal process for neighboring state issues.
- Most states that designate routes seek public input as well as holding industry and jurisdiction meetings.
- State highway patrols have primary route enforcement responsibility in most states, with several providing training.
- State highway patrols have primary emergency management responsibility, with several providing training.
- Industry responders did not indicate major concerns as to highway routing of hazardous materials and encouraged further designation. Sporadic problems stemmed from inconsistent routes across jurisdictions, time-of-day, lane, and tunnel restrictions.
- A need for funding was expressed, particularly for commodity flow studies for which limited federal funding is available.

The synthesis discusses three case studies related to highway designation of hazardous materials routes:

- Northeastern Ohio-Cleveland Area – The Northeast Ohio Areawide Coordinating Agency (NOACA) conducted a routing study under a grant from the Public Utilities Commission (PUC) to develop recommendations for highway hazmat shipping routes. A task force of representatives of local governments, public interest groups, local industries, and various state agencies was formed to provide input and oversee the study. More than 37 segments of the area expressway system were evaluated according to the federally mandated risk factors and associated weight for each. The analysis resulted in recommended route sequences with the least risk. After a public hearing and comments the recommendations were approved by NOACA and PUC. Comments were received from local governments, environmental industries, trucking companies, and citizens so NOACA was directed to further study the effects of designating a certain interstate as a hazardous materials route.

- Duluth, Minnesota – Minnesota DOT (MnDOT) evaluated the risks posed by hazardous materials transport through three tunnels along IH 35 versus rerouting around them on roadway TH 61. An interagency task force was formed to evaluate the two alternatives. It consisted of representatives from federal, state, county, and city agencies. The task forces calculated the accident rates on each of the two alternatives over a 9-month period. On IH 35 there were 1.91 accidents per million vehicle miles (acc/mvm) and on TH 61 there were 8.30 acc/mvm. The frequency of spills and fires on IH 35 was also calculated. The task force determined that hazardous materials transportation on TH 61 had a higher risk than transport through the tunnels on IH 35. TH 61 passed through business, hospital, and government areas. As a result the restriction on hazardous materials transport through the IH 35 tunnels be lifted. In addition MnDOT, the state patrol, and the Duluth Fire and Police Departments collaborated in developing an emergency contingency plan for the tunnels.
- Pennsylvania Turnpike – Highway hazardous materials transporters were left with only one major north-south route (Route 322) through central Pennsylvania due to several tunnel restrictions on the PA Turnpike. However, Route 322 had several sections of two-lane highway, statistically high hazardous materials incident rates, and fewer emergency response capabilities than the PA Turnpike. The two-lane sections were long and mountainous with sharp curves and steep grades. The installation of runaway truck ramps had been necessary. Route 322 also passed through numerous small towns, Penn State University, and carried commuter and school bus traffic. At the time of writing the synthesis, a study was underway to determine the risk and possible overturn of the hazardous materials restrictions on the turnpike.

49. State University of South Carolina, University Transportation Center. *Risk Management of Hazardous Materials Transportation in South Carolina: An Action Plan*. Orangeburg, SC, June 2003.

This project was undertaken to identify fundamental steps to strengthen South Carolina's ongoing effort to address both the safety and security of transporting hazardous materials within and across the state. In addition to the hazmat risks present in all states, several important factors impact South Carolina. It contains the nation's fourth largest port (Charleston); nuclear research, generation, and storage sites; and a number of major military installations. Many organizations and agencies contributed to the development of this report, collectively defined as the 'stakeholder community' through state, industry, and community representatives who served on the Steering Committee. They expressed a desire to assist in the implementation of the five recommendations culminating from the study that address immediate needs and future challenges:

- Compliance with the laws of South Carolina related to commercial vehicle transportation of hazardous materials would be significantly improved through the consolidation and re-codification of state law.
- A comprehensive and unified incident command plan for South Carolina should be developed and implemented.
- South Carolina should provide additional resources for transportation enforcement, particularly of hazardous materials, and should consider public education efforts.

- A system should be developed and implemented to assure the qualifications of hazmat response personnel.
- A multi-disciplinary work group should be established and function on a continuing basis to analyze information collected and to put forth appropriate proposals on relevant issues.

50. Tatelman, Todd B. "Legal Issues Concerning State and Local Authority to Restrict the Transportation of Hazardous Materials by Rail." ***CRS Report for Congress*****. RS22041. Congressional Research Service, The Library of Congress, February 4, 2005.**

This report for congress investigates the scope of state and local regulatory authority over the transportation of hazardous material by rail. It indicates incidents such as the chlorine gas leak following a train derailment in South Carolina that resulted in deaths, injuries, and evacuations have provoked state and local officials to consider regulatory actions restricting the movement of hazardous materials by rail through communities. Noted within this document is the District of Columbia's temporary ban on the movement of certain highly toxic substances by rail through the District of Columbia.

This report concludes that relevant statutes, including the Hazardous Materials Transportation Act and the Federal Railroad Safety Act, preempt state and local governments from "enacting legislation that would prevent or hinder the transportation of hazardous materials in interstate commerce." Additionally, this report indicates that the Constitution's dormant, or "negative," Commerce Clause may also "prevent a state or locality from imposing such a restriction as it could arguably be seen as imposing an undue burden on interstate commerce."

51. The International Association of Fire Chiefs, Hazardous Materials Committee. ***Report from the Hazardous Materials Roundtable*****. Fairfax, VA, July 29-30, 2003.**

This report summarizes the items determined from the Hazardous Materials Roundtable held to be addressed by federal agencies and the International Association of Fire Chiefs (IAFC). The roundtable event included over 30 of the nation's leading authorities on hazardous materials, according to the paper, with the goal to "review the previous roundtable report, discuss the current and emerging issues in hazardous materials response and establish recommendations for action." Some of the items discussed from the roundtable include:

- For hazardous materials identification method, the IAFC opposes any changes requiring the removal of placards from rail cars until a "better method is created, implemented and proven successful."
- The IAFC indicates that the development of a National Incident Management System provides a great opportunity to conduct interagency training.
- According to the IAFC, terrorism training should not be addressed as a separate issue.
- The committee recommends that regulations be developed to require placards for all intermodal containers, both those loaded in the U.S. and those entering the U.S. through ports.

52. U.S. Department of Agriculture, Agricultural Marketing Service, Transportation and Marketing Programs Transportation Services Branch. *Ethanol Transportation Backgrounder*. Washington, D.C., September 2007.

This document provides an overview of the "transportation issues facing a rapidly expanding U.S. ethanol industry in the context of the U.S. corn market – currently the main source of ethanol production in the U.S." According to the report, as of August 29, 2007, there were 128 ethanol plants with a combined production capacity of 6.78 billion gallons per year. An additional 85 plants were under construction at that same time. Railroads shipped approximately 60% of the ethanol produced in 2005, while trucks moved 30%, and barges moved 10%. Ethanol is primarily produced in the nation's heartland, according to the report, but 80% of the U.S. population lives near its coastlines. This implies that the ability to transport ethanol from the production locations to the locations of demand will continue to remain a critical issue.

53. U.S. Department of Homeland Security (DHS). *Recommended Security Action Items for the Rail Transportation of Toxic Inhalation Hazard Materials*. Washington, D.C., March 2006.

The document contains proposed security action items identified by the U.S. DOT and DHS for the rail transportation of TIH materials. The security action items include three portions:

- system security practices affecting the transportation of TIH materials,
- access control security practices, and
- en-route security practices.

Since there is no one solution that fits all locations and circumstances, a condition recognized by DOT and DHS, these security action items allow for flexibility in implementation based upon the assessed vulnerability of a particular process or operation.

54. U.S. Department of Homeland Security (DHS), Transportation Security Administration (TSA). *Assessment of Highway Mode Security: Corporate Security Review Results*. Washington, D.C., May 2006.

The Corporate Security Review (CSR) program is intended to build a working relationship with stakeholders, provide security program advice and technical expertise, and collect data to quantify the state of security in the industry. The security reviews focus primarily on the state departments of transportation but also include other state agencies with transportation security functions. This report provides information about the selection criteria for the security reviews, the type of information that was collected, and how the data were analyzed to depict the level of security. The report also presents the security review findings with respect to threat assessment, vulnerability assessment, infrastructure protection, credentialing, secure areas, physical security, cyber security, communications, exercises, security planning, and training.

55. U.S. Department of Homeland Security (DHS), Transportation Security Administration (TSA). *National Hazardous Material Commercial Vehicle Tracking System Study*. Washington, D.C., May 2006.

The Transportation Security Administration strives to reduce the risks associated with the transport of hazardous materials by commercial vehicle by providing a system capable of "continuous wireless communications, vehicle positioning, and emergency alert transmissions that can supplement current incident response capabilities." A tiered approach is delivered in this trade study, with each tier presenting a set of options. Minimum criteria are developed that take into consideration the requirements that legislature may issue, TSA's mission, and the vulnerabilities in hazardous materials transport. Two configurations are examined in depth in this study:

- a centralized tracking system, consisting of a central data clearinghouse collecting tracking data from hazardous materials units directly or through existing private and commercial tracking centers; and
- a system that leaves tracking and notification to emergency agencies completely up to the commercial sector.

56. U.S. Department of Homeland Security (DHS), Transportation Security Administration (TSA). "Rail Transportation Security; Proposed Rule." *Federal Register,* Vol. 71, No. 245. Washington, D.C., Thursday, December 21, 2006, pp. 76853-76887.

The Transportation Security Administration proposed this new rule about security requirements for freight railroad carriers; intercity, commuter, and short-haul passenger train service providers; rail transit systems; and rail operations at certain, fixed-site facilities that ship or receive specified hazardous materials by rail.

The newly proposed provisions include codifying the scope of TSA's existing inspection program and require regulated parties to allow TSA and Department of Homeland Security officials to enter, inspect, and test property, facilities, and records relevant to rail security. This rule also proposes coordinator designation by regulated parties who will report significant security concerns to DHS. It further proposes that freight rail carriers and certain facilities handling hazardous materials be equipped to report location and shipping information to TSA upon request and to implement chain of custody requirements to ensure a positive and secure exchange of specified hazardous materials. TSA also proposes to clarify and extend the sensitive security information (SSI) protections to cover certain information associated with rail transportation.

57. U.S. Department of Transportation, Bureau of Transportation Statistics (BTS) and U.S. Census Bureau, Economics and Statistics Administration. *United States: 2002 – Hazardous Materials 2002 Economic Census, Transportation, 2002 Commodity Flow Survey*, 2002.

This report provides information on commodities shipped, their value, weight, and mode of transportation, as well as the origin and destination of shipments of manufacturing, mining, wholesale, and select retail establishments. It presents a great amount of data on hazardous material shipment characteristics by national level.

58. U.S. Department of Transportation. *Department-wide Program Evaluation of the Hazardous Materials Transportation Programs —Executive Summary*. Washington, D.C, March, 2000.

The hazmat program evaluation team (HMPE), which was established by DOT's Strategic Plan for 1997-2002, conducted this department-wide program evaluation of hazmat transportation programs. This document summarizes the assessment of HMPE team for DOT's hazmat programs and provides proposed recommendations for program improvement.

Findings of the HMPE team are:

- DOT's hazardous materials programs lack DOT-wide coordination, direction, and strategic planning;
- DOT's hazardous materials program delivery could be improved; and
- lack of reliable data hampers program delivery decisions.

Besides the recommendations for the specific findings, HMPE team members also determine additional hazmat issues that need to be resolved, as well as DOT's Senior Leadership Team's response to those recommendations.

59. U.S. Department of Transportation. Federal Highway Administration (FHWA), Office of Motor Carrier and Highway Safety. *Hazardous Materials Risk Assessment: Phase I*. Washington, D.C., 1990.

This document is the first part of a two-phase hazardous materials risk assessment project that was designed to assist the U.S. DOT in examining the total impact of commercial vehicle transportation and determining what part of the total is a result of hazmat transportation (by hazmat hazard class). The purpose is to develop a methodology for predicting consequences of hazmat crashes, such as injuries and property damage. It demonstrated a process to evaluate the full impacts of hazmat crashes/incidents by sampling a single hazmat class for one year. The methodology can be applied to determining the impacts of other hazmat classes as well as for non-hazmat shipments.

60. U.S. Department of Transportation, Federal Highway Administration (FHWA). *The Freight Technology Story: Intelligent Freight Technologies and Their Benefits*. FHWA-HOP-05-030. Washington, D.C., June 2005.

The report abstract indicates this report shares information about the state of the art and the adoption of intelligent freight technologies by industries and their customers. It indicates that intelligent freight technologies are used to improve freight system efficiency and productivity, increase global connectivity, and enhance freight system security against common threats and terrorism. The five technology areas currently deployed include:

- Asset Tracking – uses mobile communications, radio frequency identification (RFID), and other tools to monitor the location and status of tractors, trailers, chassis, containers, and, in some cases, cargo.
- On-board Status Monitoring – uses sensors to monitor vehicle operating parameters, cargo condition, and attempts to tamper with the load.
- Gateway Facilitation – uses RFID, smart cards, weigh-in-motion, and non-intrusive inspection technologies to simplify and speed operations at terminal gates, highway inspection stations, and border crossings.
- Freight Status Information – uses web-based technologies and standards to facilitate the exchange of information related to freight flows.
- Network Status Information – uses services to integrate data from cameras and road sensors and uses display technologies to monitor congestion, weather conditions, and incidents.

The report documents the results from intelligent freight technology field operational tests, including a hazardous materials safety and security field operational test. This test performed from 2003 to 2004 examined four hazardous materials operating scenarios: bulk fuel delivery, less than truckload high-hazard shipments, other bulk hazards, and truckloads of explosives. This report emphasizes that this field operational test was focused on rapid implementation of off-the-shelf technologies.

61. U.S. Department of Transportation, Federal Motor Carrier Safety Administration (FMCSA). *A Guide for Building a Model State Hazardous Materials Program.* Washington, D.C., January 2004.

Following the Compliance Effectiveness Study, FMCSA developed a guide to building a model state hazmat program. It not only recognizes core elements required to establish effective hazmat compliance programs, but it also describes preferred practices and enhancements existing in many states' programs. The purpose of this guide is to assist states in the development and implementation of comprehensive hazmat compliance programs impacting transportation safety and security. Additionally, this guide promotes national uniformity and consistency with FMCSA's hazmat compliance program.

62. U.S. Department of Transportation, Federal Motor Carrier Safety Administration (FMCSA). *Comparative Risks of Hazardous Materials and Non-Hazardous Materials Truck Shipment Accidents/Incidents*. Phase II. Battelle Memorial Institute. March 2001.

This study assesses and compares the calculated risks associated with the transportation of hazmat and non-hazmat shipments. The results assisted the FMCSA in identifying high-risk motor carriers. Researchers analyze two types of hazmat events—*accidents* and *incidents*. An *accident* occurs when a vehicle transporting hazardous goods is involved in a collision, regardless of whether any material is spilled or released in the atmosphere. An *incident* occurs when a vehicle transporting hazardous goods spills some of the cargo, but is not involved in a collision. An *incident* resulting in the spill or release of hazardous materials during loading or unloading is defined as a *loading/unloading incident.*

Phase I of the three-phase project analyzes the feasibility of conducting a comprehensive risk study of hazmat and non-hazmat transportation. Specifically, one year, 1996, is chosen to look at the costs of transporting flammable/combustible liquids, which represent more than 50% of all hazmat truck transport. The study results are published in the *Hazardous Materials Risk Assessment: Year Portrait of Hazardous Materials Accidents/Incidents and Impacts.* This process is then extended to three years of records, 1995-1997, for flammable gases (Class 2.1 HM) and corrosive materials (Class 8 HM), and provides a preliminary estimate of the cost impact of transporting hazmat shipments.

In Phase II, researchers calculate the risks associated with each of the nine hazmat classes to obtain the overall hazmat risk. This enables the comparison between the risks of transporting any hazmat class to the risks of transporting other hazmat classes and non-hazmat shipments. Researchers use data from a variety of sources including federal and state databases, local authorities, and private companies. For the final analysis, data from 1990 through early 1999 is used to create an annual estimate of hazmat impacts. To derive an estimate of the annual economic impact of hazmat accidents and incidents, several cost impacts are included, such as injuries and deaths, cleanup, property damage, evacuation, product loss, traffic incident delay, and environmental damage. Injuries and fatalities are valued to be the amount the U.S. DOT would be willing to spend to avoid an injury or death, an average of $200,000 and $2,800,000 respectively. The Hazardous Materials Information System (HMIS) is used to derive the cost of product loss, cleanup, and property damage. Traffic delay costs are defined as the total number of people delayed due an incident or accident multiplied by $15 per hour. Environmental damage is identified as the size of an average spill plus the value of environmental contamination calculated from the average of 30 legal settlements. Results are reported in terms of frequency, hazardous materials impacts/costs, non-hazardous materials impacts/costs, comparative risks, and accident rate and cost per mile.

Several findings are reported from the results of the study. The results suggest that:

- Hazmat truck accidents and incidents cost society nearly $1.2 billion annually.
- Injuries and fatalities are the largest components of this cost.
- Flammable and combustible liquids (Class 3 HM) contribute the largest economic cost impact associated with hazmat accidents and incidents.

- Annual economic cost impacts of non-hazmat accidents is considerably higher than for hazmat accidents due to the sheer volume of their occurrences, even though the cost impact of a single accident with an hazmat release is higher than a non-release hazmat accident.
- Accidents with hazmat releases that result in explosions have the highest cost impact followed by hazmat release accidents resulting in fires.

Although public databases contain useful information for conducting risk assessments, they are deficient in a number of areas that can be improved. The research study suggests that better coordination efforts among the multiple agencies that collect transportation data would correct data collection inconsistencies. Also, the collection of data should be done in coordination with other datasets to enhance cross-referencing capabilities, which would enable the FMCSA to improve its safety performance monitoring abilities. The benefit of such improvements allows for the availability of information and a more economical way of maintaining the databases—all of which can be used to help identify high-risk motor carriers and improve the safety of transporting hazardous and non-hazardous materials.

Applying the results of the risk assessment study to the SafeStat algorithm, used to measure the safety fitness of motor carriers, is currently underway. Phase III of the study analyzes the impact of hazmat on the carrier selection methodology and makes recommendations to the FMCSA on the inclusion of hazardous materials risks.

63. U.S. Department of Transportation, Federal Motor Carrier Safety Administration (FMCSA). *Guide to Developing an Effective Security Plan for the Highway Transportation of Hazardous Materials*. Battelle Memorial Institute and TotalSecurityUS, Washington, D.C.

This guide is a tool that motor carriers transporting hazardous materials can use in developing a security plan as required by the U.S. Department of Transportation. It is designed to provide motor carriers with:

- a sufficient background to understand the nature of the threats against hazardous materials transportation,
- the means to identify the vulnerabilities to those threats, and
- an approach to address the vulnerabilities.

64. U.S. Department of Transportation, Federal Motor Carrier Safety Administration (FMCSA). *Hazardous Materials Serious Crash Analysis*. Phase II. Battelle Memorial Institute, Arlington, VA, April 2005.

This study defines a crash as serious if it results in one of the following: a fatality, an injury requiring transport to a facility for immediate medical attention, or at least one vehicle towed from the scene as a result of disabling crash damages. This project had three basic purposes:

- enhance the current methodology for identifying and characterizing serious hazardous material truck crashes in the United States,
- improve the capability to analyze causes and effects of selected serious hazardous materials crashes, and
- support the implementation of hazardous materials truck transportation safety and risk reduction strategies for packages, vehicles, and drivers.

The first phase of this project consists of a pilot test to evaluate the feasibility of enhancing the current approach for serious hazmat truck crash identification, data collection, and analysis. The second phase applies the phase one tools and techniques to roughly half the crashes reported in Motor Carrier Management Information System (MCMIS) for 2002, with the goal of showing how an enhanced hazmat accidents database might be used to improve truck transport safety. Crash analyses utilizing the hazmat accidents database focuses on developing associations between two impact measures and five explanatory variables. Impact measures consist of the number of serious crashes and the number of crashes resulting in spills, fatalities, and injuries. Explanatory variables are crash characteristics that help explain cause and effect—vehicle, driver, packaging, infrastructure, and situational characteristics. A few concise results include:

- Vehicle – The spill percentage increases as trailers are added to the vehicle configuration; e.g., higher spill-to-crash ratio for two or more trailers vs. single trailer. The most common vehicle configuration used in transporting hazardous materials involved in crashes is the tractor/semi-trailer, which is involved in 60% of all crashes.
- Driver – Drivers aged 18-24 years old or with less than 3 years of experience had the highest spill-to-crash ratio. About 75% of serious, single-vehicle crashes were due to hazmat driver error.
- Packaging – Tanks that conformed to the new specifications showed lower spill-to-crash rates than older tanks. Of all spills, 78% involved cargo tanks. Likelihood to rollover increased with cargo weight since the center of gravity is higher for full tanks. There was a strong correlation between rollovers and spills. Entry and exit ramps had an 87% of rollovers result in a spill.
- Infrastructure – 18% of crashes on all road types resulted in a spill but 14% of crashes on interstates resulted in a spill, due to safer design elements.
- Situational – 60% of all crashes are multi-vehicle crashes that occur while the hazmat vehicle is within the traffic lane.

65. U.S. Department of Transportation, Federal Motor Carrier Safety Administration (FMCSA). *State Hazardous Materials Compliance Effectiveness Study.* Battelle Memorial Institute, Arlington, VA, February 2003.

This study reviews state hazardous materials transportation compliance programs to identify exemplary initiatives and programs that could serve as models for other states to consider. A comprehensive survey and analysis of all state hazardous materials programs was conducted and then eight states were selected for a more in-depth study to identify unique or exemplary initiatives that may be of interest to other states. It is not intended that these states necessarily have the “best” compliance programs, but they do have a comprehensive and effective overall

program based on the results of the survey analysis. Each of the individual programs highlighted in this report have been successfully implemented in their respective states and have produced substantial benefits.

Information collected in the survey questionnaire and during the in-depth follow up visits is broken down in the Model State Program into the following seven components:

- Facility Compliance Reviews,
- Roadside Inspections,
- Regulatory Training & Outreach,
- Permitting, Registration & Routing,
- Regulatory Authority & Enforcement,
- Other Program Initiatives, and
- Program Resources.

The report identifies California and Colorado as having the most noteworthy routing programs.

California Highway Patrol's (CHP's) Routing Program applies to placarded quantities of three types of hazmat: (1) explosives, (2) poison-by-inhalation materials, and (3) radioactive materials. Routing is required for these materials by state statute and incorporated into Title 13 of the California Code. Carriers are notified of the routing requirements through the hazmat licensing application process. Separate routing guides are issued to carriers for each type of hazardous material subject to routing. A critical component of the routing guides is the listing of Safe Stopping Places and Safe Parking Places applicable to each route. Safe Stopping Places are locations where a driver can stop the vehicle to rest; however, they must remain with the vehicle. Safe Parking Places are locations that a driver can park and leave the vehicle unattended temporarily for meals or sleeping accommodations. These locations include truck stops, designated parking places along the road, and other commercial businesses. CHP personnel within each district who are familiar with the roads designate the locations, which are continuously reviewed and updated.

Carriers can petition CHP to establish a new route. CHP utilizes a computer program to determine the preferred route based on predetermined criteria. These criteria are risk-based and include such factors as distance, accident rates, travel time, and allowances for pickup and delivery off the main route. A CHP representative physically drives each route before it is designated as a hazmat route to identify any issues that cannot be represented or addressed through the computer analysis. CHP also goes through a public hearing process before designating a route.

California will be both an origin state and a through state for shipments of transuranic wastes to the Waste Isolation Pilot Plant (WIPP) and spent nuclear fuel to Yucca Mountain. The California Energy Commission is the state representative to the Western Governors Association, which works with the Department of Energy in coordinating shipments to WIPP and Yucca Mountain. CHP coordinates with the Energy Commission on designation of routes and enforcement of transportation requirements for these shipments.

The Colorado State Patrol (CSP) is authorized by Colorado Revised Statutes to adopt rules and regulations for the routing of hazardous materials by motor vehicle within the state of Colorado. CSP also has authority to enforce the use of designated routes. The process of designating a hazardous materials route originates with local governments that apply to CSP either for a new hazardous materials route designation or for a change in an existing route. The petitioners must submit a package to CSP that includes a route analysis of the proposed and alternative routes. Applicants may include any other information that they consider necessary to support their requests. CSP evaluates the petition according to provisions in the state statute. After a route has been approved, CSP will periodically review the route in order to confirm that the designation still meets the provisions of Colorado state regulations. If CSP determines that the risk level on the route has increased, a revised petition may be requested from the local government. This could lead to a change in the hazmat status of the route.

In Colorado, there are currently 30 north-to-south routes and 38 east-to-west routes that are designated to be used for hazmat shipments. One route that currently is being petitioned for designation as a hazardous materials route would eliminate 160 miles from the route that must currently be used.

CSP has promulgated rules for the shipment of radioactive materials. With the exception of portions of several state routes designated to give access to the Rocky Flats facility northwest of Denver, all of the routes follow interstate highways. However, no radioactive materials are allowed on IH 70 west of Denver.

66. U.S. Department of Transportation, Federal Motor Carrier Safety Administration (FMCSA). "Transportation of Hazardous Materials: Designated, Preferred, and Restricted Routes," *Federal Register*, Vol. 65, No. 233. Washington, D.C., Monday, December 4, 2000, pp. 75771-75816.

This article in the *Federal Register* provides a listing of all restricted, designated, and preferred road and highway routes for transporting radioactive materials and non-radioactive hazardous materials. This listing includes all routes submitted by states and Indian tribal routing agencies as of November 14, 2000.

67. U.S. Department of Transportation, Federal Railroad Administration (FRA). *National Rail Safety Action Plan Progress Report 2005-2007*. Washington, D.C., May 2007.

The *National Rail Safety Action Plan* launched in 2005 includes initiatives in several areas, including:

- reducing human factors accidents,
- addressing fatigue among railroad operating employees,
- improving track safety,
- hazardous materials safety and emergency preparedness,
- strengthening the FRA compliance program, and

- improving highway-rail grade crossing safety.

This report details the progress in implementing the elements of the *Action Plan* between 2005 and 2007.

The three action items designed to improve hazardous material safety and emergency preparedness include:

- identify technology to improve safety in dark (non-signaled) track territory,
- ensure emergency responders have access to key information about hazardous materials transported by rail, and
- accelerate research into hazardous materials rail tank car structural integrity.

The report indicates that all three action items have made progress since 2005. It is noted that beginning in March 2005, the railroads were scheduled to provide to local emergency responders, upon written request, a ranked listing of the top 25 hazardous materials transported by rail through their communities.

68. U.S. Department of Transportation, Pipeline and Hazardous Materials Safety Administration (PHMSA). "Hazardous Materials: Enhancing Rail Transportation Safety and Security for Hazardous Materials Shipments; Proposed Rule." ***Federal Register*****, Vol. 71, No. 245. Washington, D.C., December 21, 2006, pp. 76834-76850.**

The Pipeline and Hazardous Materials Safety Administration (PHMSA) proposed this new rule (NPRM: Notice of Proposed Rulemaking) to require rail carriers to:

- compile annual data on specified shipments of hazardous materials,
- use the data to analyze safety and security risks along rail transportation routes where those materials are transported,
- assess alternative routing options, and
- make routing decisions based on those assessments.

The proposed rule also includes clarifications of the current security plan requirements to address en route storage, delays in transit, delivery notification, and additional security inspection requirements for hazardous materials shipments. Two rules are included: 49 CFR Part 172, in which §172.820 is added, and 49 CFR Part 174, in which §174.9 is revised.

Applicable parts from current hazmat transportation safety and security requirements include requirement of security plans development for persons who offer certain hazardous materials for transportation or transport certain hazardous materials in commerce. Security awareness training is also required of all hazardous materials employees. Certain railroad operating practices are required by the Association of American Railroads protocol such as designating 'key trains' and 'key routes,' operating speed and equipment restrictions for key trains, setting standards for track inspection, and wayside defect detectors. Newly proposed provisions are included in §172.820, and additional planning requirements for transportation by rail are included in §174.9, such as safety and security inspection and acceptance.

69. U.S. Department of Transportation, Research and Special Programs Administration (RSPA). *2004 Emergency Response Guidebook*. Washington, D.C., *2004*.

The *2004 Emergency Response Guidebook* (ERG) states it was developed jointly by Transport Canada, the U.S. Department of Transportation, the Secretariat of Transport and Communications of Mexico, and with the collaboration of Centro de Información Qumica para Emergencias (CIQUIME) of Argentina "for the use by fire fighters, police, and other emergency services personnel who may be the first to arrive at the scene of a transportation incident involving dangerous goods." It is primarily a guide to aid first responders in (1) quickly identifying the specific or generic classification of the material(s) involved in the incident, and (2) protecting themselves and the general public during the initial response phase of the incident.

70. U.S. Department of Transportation, Research and Special Programs Administration (RSPA). *Enhancing Security of Hazardous Materials Shipments against Acts of Terrorism or Sabotage Using RSPA's Risk Management Self-Evaluation Framework (RMSEF)*. Revision 1, Washington, D.C., January 2002.

This template or overlay for the Risk Management Self-Evaluation Framework applies the methodology to the issue of security. It is a tool and not a regulatory requirement. Its use, like that of the basic framework, is voluntary. U.S. Department of Transportation's Research and Special Programs Administration, Office of Hazardous Materials Technology, DHM-20, 400 7th Street, S.W., Washington, D.C. 20590, or by accessing the website at http://hazmat.dot.gov/risk.htm.

71. U.S. Department of Transportation, Research and Special Programs Administration (RSPA). *Hazardous Materials Transportation Enhanced Security Requirements*. Washington, D.C.

RSPA has established new security requirements that make use of two strategies for hazardous materials transported in commerce: developing and implementing security plans, and employee training.

The security plans require that whoever offers transportation or transports certain quantities of hazmat must develop and implement a security plan. RSPA provides guidance to assist hazmat carriers in developing security plans appropriate to their specific industry and operations. RSPA also requires persons or firms who offer certain hazardous materials for transportation or transport certain hazardous materials to provide training to their employees who are responsible for implementing the security plan.

72. U.S. Department of Transportation, Research and Special Programs Administration, Office of Hazardous Materials Safety, along with John A. Volpe National Transportation Systems Center. *The Role of Hazardous Material Placards in Transportation Safety and Security,* Washington, D.C., January 15, 2003.

This paper summarizes the findings from two workshops focused on the use of placards from the perspective of both safety and security. The paper presents the following publicly viewable results from the review:

- placards are critical sources of hazard information;
- placards provide information about hazards, but not necessarily about commodities;
- effective emergency response is a critical component of security;
- enhancing security through alternative means is more appropriate than replacing placarding; and
- the department of transportation is currently working to enhance hazmat security.

This study concludes that "the existing placarding system should be retained; and as DOT continues to develop a comprehensive security program from hazardous materials transportation, it should continue to review the use of operational procedures and technological development as security enhancements and as alternatives to placards in specific high risk situations as well as for broad application."

73. U.S. Department of Transportation, Research and Special Programs Administration, Office of Hazardous Materials Safety. *Guidance for Conducting Hazardous Materials Flow Surveys*. Washington, D.C., January 1995.

This report provides step-by-step guidance to states, LEPCs, and other planners on how to conduct a commodity flow study for hazardous materials moving by highway. It discusses the need and objectives for this type of study and details how to review baseline information and design the study. It includes examples and instructions for collecting the data via field studies, analyzing the results, and applying these results back to the purpose of the study. Descriptions of selected recent state and local hazardous material flow studies are provided. A case study example is included that illustrates how to conduct and complete a hazmat flow survey from beginning to end.

Upon completion of a commodity flow study based on this guidance, planners will have a better understanding of hazardous materials transportation patterns and can use these data to conduct planning and estimate risks facing the jurisdiction. Depending on the specific type of study that is designed and the resources and time available, a commodity flow study can be used to assess total truck traffic, daily and seasonal variations in traffic, awareness and training of drivers and emergency response personnel in the area, and frequently used transportation routes.

Prior to this guide, federal hazardous materials law established a grants program for states that wish to address transportation-related risks in emergency response planning and provide training funds for emergency responders. Commodity flow surveys are one of the activities eligible for

funding under the legislation. Federal laws also authorizes states to designate hazardous materials highway routes. Prior to designating routes, planners need to analyze the risks associated with hazardous materials transportation within their jurisdiction. Conducting an analysis of commodity flows is an important step in assessing transportation-related hazardous materials risks.

The guide discusses the international hazard classification system of the nine classes of hazardous materials. It further states the most recent statistics on hazardous materials transportation at the time it was written. Although the absolute numbers may be different today, the trends are roughly similar. From 1982 to 1993, the highway transport of hazardous materials represented about 62% (927 million tons) of the total volume (1.5 billion tons) of hazardous materials transported in the U.S. It contributed to only a very small fraction of the average annual injuries (249) and deaths (11) attributable to hazardous materials transportation incidents (6175). The majority of the 1.5 billion tons represent a small subset of hazardous materials and hazard classes. Almost 50% of the shipments were gasoline and petroleum products, and approximately 13% were chemicals. By decreasing total volume (tons), the major hazard classes/divisions shipped were Class 3 (flammable and combustible liquids), Division 6.1 (poison B), Division 2.3 (poison A), Division 2.1 (flammable compressed gases), and Division 4.1 (flammable solids). By decreasing volume shipped per ton-mile, the hazard classes/divisions were Class 3 (flammable and combustible liquids), Division 6.1 (poison B), Division 4.1 (flammable solids), and Class 8 (corrosives).

An RSPA study developed a model to allocate commodity flows between producers and consumers. The study was intended to determine whether secondary data sources used in a model could provide estimates of truck movements in the absence of specific data. Using the model, truck movements were estimated for three chemicals, dodecene-1, phosphorus pentasulfide, and 1-butanol. These chemicals were selected from a list of 147 large-volume chemicals that were identified as accounting for at least 80% of truck shipments of hazardous chemicals in the U.S. Appendix A of the guide provides a brief description of the model, a list of the 147 large-volume chemicals, brief overviews of the three chemicals assessed, and graphic displays of the model output for these three chemicals. The model may be useful for predicting national trends, but state movements of hazardous chemicals can be determined more accurately using a commodity flow study.

74. U.S. Environmental Protection Agency (EPA), Chemical Emergency Preparedness and Prevention Office. *National Institute for Chemical Studies, Local Emergency Planning Committees and Risk Management Plans: Encouraging Hazard Reduction*. CX824095, Washington, D.C., June 2001.

This study examines how LEPCs could use risk management plans to improve community safety and promote hazard reductions. The study finds that although encouraging hazard reductions was recognized as a logical role of many LEPCs, there were a number of challenges and concerns that hindered them from implementing that role. LEPC concerns include: lack of mandate under the Emergency Planning & Community Right to Know Act (EPCRA), lack of resources, lack of technical expertise, unclear responsibilities, public apathy, and lack of support. The study team

recommends a number of ways that the EPA could address LEPC concerns and strengthen their role in hazard reduction.

75. U.S. General Accounting Office (GAO). *Biofuels – DOE Lacks a Strategic Approach to Coordinate Increasing Production with Infrastructure Development and Vehicle Needs*. Report to Congressional Requesters. Report GAO-07-713. Washington, D.C., June 2007.

This GAO study examines the "status of and impediments to expanding biofuel production, distribution infrastructure, and compatible vehicles as well as federal policy options to overcome the impediments." From 2004 to 2006, ethanol and biodiesel production increased from 3.4 billion gallons to 4.9 billion gallons. Railroads are the main mover of biofuels, and the report described uncertainty in the ability of the rail system to meet the growing demands. Concerns are also echoed for the entire biofuel distribution infrastructure network's ability to handle the demand because of limited capacity on the infrastructure.

76. U.S. General Accounting Office (GAO). *Rail Safety and Security Some Actions Already Taken to Enhance Rail Security, but Risk-based Plan Needed*. Report GAO-03-435. Washington, D.C., April 2003.

With the concern about the safety of rail shipments of hazardous materials by rail amplified in the wake of the terrorist attacks of September 11, 2001, the GAO "examined recent steps taken by industry and government to improve the safety and security of these shipments and steps taken by local jurisdictions to prepare to respond to hazardous material rail incidents." The findings indicate both industry and government took steps to improve the safety and security of rail movements of hazardous materials. The railroads and chemical industries both developed security plans, while the Department of Homeland Security initiated the development of an overall intermodal transportation security plan. Pertaining to this subject matter, several issues appear to remain unresolved, including:

- the need for measures to better safeguard hazardous material temporarily stored in rail cars while awaiting deliver to their ultimate destination and
- the advisability of requiring companies to notify local communities on the type and quantities of such materials stored or passing through their communities.

The report also finds that nine of the ten cities visited by GAO for the study felt they were generally prepared to respond to hazardous materials incidents.

77. U.S. General Accounting Office (GAO). *Undeclared Hazardous Materials – New DOT Efforts May Provide Additional Information on Undeclared Shipments*. Report to Congressional Committees. Report GAO-06-471. Washington, D.C., March 2006.

This report addresses the concern for undeclared hazardous materials, defined as materials subject to hazard communication requirements and offered for transportation in commerce without any visible indication that a hazardous material is present. Undeclared hazardous materials pose a threat to transportation workers, emergency responders, and the public during an incident due to the unknown presence and nature of the material. Security is also a major concern due to the threat of terrorist attacks. The two most frequent explanations for undeclared shipments are:

- shipper's lack of knowledge – an unawareness or misunderstanding of the requirements for properly declaring and transporting hazardous materials and
- economic – an attempt to avoid additional costs that may be associated with shipping regulated hazardous materials, including special placarding, packaging, additional training, and insurance.

This report finds that the federal government has no specific program aimed at discovering the amount of undeclared hazmat entering the U.S. According to the report, discovering undeclared hazardous material shipments "typically occurs in one of the following ways: as a result of an accident or incident, during a routine cargo inspection, or when a tip is provided to officials."

78. Verma, Manish, and Vedat Verter. "Railroad Transportation of Dangerous Goods: Population Exposure to Airborne Toxins." *Computers & Operational Research*. Vol. 34, 2007, pp. 1287-1303.

This journal article presents an analytical framework in the assessment of transport risk that incorporates the differentiating features of trains, notably volume and nature of cargo. It focuses on hazardous materials that are airborne upon an accidental release into the environment. The risk assessment of trains requires representation of multiple release sources in the model since each railcar is a potential source of release. The article proposes a risk approximation approach for the assessment of population exposure associated with the "Ultra-train" that passes through the city of Montreal everyday.

79. Zhang, Jianjun, John Hodgson, and Erhan Erkut. "Using GIS to Assess the Risks of Hazardous Materials Transport in Networks." *European Journal of Operational Research*. Vol. 121, 2000, pp. 316-329.

This journal article uses a Gaussian Plume model to model the dispersion of airborne contaminants such as ammonia and chlorine, which impose risks on human population in the process of hazmat transportation. Then an expected consequence approach is applied, whereby risk is treated as the product of this probability and the population affected. Map algebra

techniques of GIS are used to combine concentration mathematically with the population distribution to estimate risk, for a release at any point on a network, for all parts of the study area. These risk estimates are applied by map algebra to every link in the network as well.