

**Hazardous Material Transport  
via Rail: Bibliography of Recent  
Risk Assessment Literature**

**June 2002**

**Prepared For:  
Joint City/County Impact Alleviation Committee**

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## Bibliography

**TRANSCAER web site, October 2001. <http://www.transcaer.org/public/home/cfm>**

TRANSCAER (Transportation Community Awareness Emergency Response) is a voluntary national outreach effort that focuses on assisting communities prepare for a possible hazardous material transportation incident. TRANSCAER members consist of volunteer representatives from the chemical manufacturing, transportation, distributor, and emergency response industries, as well as government. Two manuals available via this web site are *TRANSCAER Guidance Manual* and the *TRANSCAER Community Awareness Manual*. Neither of these manuals are reviewed for this report, because they focus on risk management, rather than risk assessment. However, they may contain valuable information about planning for hazardous materials transport via rail.

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**Brown, D. F., Dunn, W. E., and Policastro, A. J. *A National Risk Assessment for Selected Hazardous materials Transportation*. Argonne National Laboratory, Decision and Information Division. Operated by the University of Chicago under contract W-31-109-Eng-38. For the United States Department of Energy. December 2000. 239 p.**

This report details a quantitative risk assessment conducted for transportation of selected hazardous materials on a national basis. These materials include the following six toxic-by-inhalation (TIH) chemicals: chlorine, ammonia, sulfur dioxide, hydrogen fluoride, fuming sulfuric acid, and fuming nitric acid. These substances collectively account for more than 90% of the total TIH transportation-related risk. Incidents during an accident (train derailment) and en route incidents (leaky valve) were examined. The report describes hazardous materials and consequence levels evaluated; the risk assessment methodology; the databases used to determine hazardous materials commodity flow and incident rates; and results of the study, including quantitative risk distributions and risk measures for the materials evaluated. The results suggest that compared with other types of transportation risks encountered by the public, overall societal risks due to hazardous materials transportation remain relatively low. However, the potential exists for very serious accidents involving large numbers of injuries and fatalities, especially for TIH materials, although the probability of such events is low.

The study notes that the strong influence of low-probability, high consequence events means that actual data does not provide an adequate basis for defining TIH transportation risks. The fact that the number of deaths and injuries for any given year or for any given decade is small does not necessarily mean that the risk is small. Rather, it may reflect the good fortune that no large toxic releases have occurred near populated areas. As a result, the number of injuries or fatalities in a given time period can differ substantially from an average based on the distribution of possible accidents that account for low-probability/high-consequence events. The true nature of TIH transportation risk cannot

be estimated from the historical record alone because the statistical sample of accidents that drives the risk within the historical record is very low to nonexistent. Therefore, the study conducted a detail analysis of risk associated with TIH chemical transportation in the United States.

The study estimated release probabilities for the substances being analyzed for both highway and rail modes. For rail transportation, calculation of accident rates and release probabilities is more straightforward than that for highway transportation because accurate commodity flow data are available and accident data have been consolidated into a few major databases. Statistics compiled by the Federal Railroad Administration (FRA) show that rail accident rate dropped by a factor of 3 from 14.8 to 4.6 accident/million train-miles between 1978 and 1988. Since 1988, little change has occurred. The current accident rate remains at about 4.5 accidents per million train-miles. When yard accidents are excluded, the rate decreases to 2.4 accidents per million train-miles. Significant variations occur in accident rates along different classes of track. Track is delineated into six classes denoted as Class 1-6, with Class 6 having the most stringent track tolerances and maintenance schedules. Mainline track is generally Class 5 or 6 and the accident rate of 2.4 accident/million train-miles is applicable. Class 1 has an accident rate almost 100 times greater than Classes 4,5, and 6.

The study notes that evacuation and sheltering (remaining indoors) reduce exposure. For transportation, sheltering is the more prevalent avenue for exposure reduction because once a release has occurred, there is rarely time to organize and execute an evacuation. For transportation-related incidents that involve TIH materials, evacuations are most often conducted when a release has not occurred, but there is a strong possibility for a large release. The degree of protection afforded by sheltering depends primarily on the building ventilation rate and secondarily on the passage of time of the vapor cloud.

The study also calculates the national risk from transporting flammable materials and identifies gasoline and LP gas as the materials that pose the greatest transportation-related risk to the public. Consequence analysis was conducted for each of the substances being evaluated.

Due to the 1971 Hazardous Materials Control Act of 1970, the DOT has a strong record of incidents involving hazardous materials. The DOT must be notified if any of the following conditions exist:

- A person being killed
- A person receiving injuries that require hospitalization
- Property damage in excess of \$50,000
- An evacuation of the general public that lasts one or more hours
- Closing major transportation arteries or facilities for one or more hours
- Interruption of the operational flight pattern or routine of an aircraft

The paper analyzes this database and isolates, fatalities, injuries, and evacuations for both rail and highway accidents and by chemical type and container type. There is also a

detailed analysis of commodity flows based on waybills and a route analysis for rail and highway.

In conclusion, the study notes that although the quantitative results contain substantial uncertainties because of the imprecision in the commodity flow data and consequence modeling, the relative comparisons of risk between materials, packaging, and transportation modes and operations can highlight areas of increased hazardous materials transportation risk. The study supports the premise that the overall societal risk due to hazardous materials transportation is low. However the potential exists for very serious accidents with many injuries and fatalities, although the probability of such events is very low.

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**ICF Consulting. *Risk Management Framework for Hazardous Materials Transportation*. Submitted to the U.S. Department of Transportation Research and Special Programs Administration. Washington, D.C. Delivery Order No. DTRS56-99-D-70123. November 1, 2000.**

The U.S. Department of Transportation (DOT) Research and Special Programs Administration (RSPA) administers a comprehensive safety program in hazardous materials transportation to protect the Nation from risks to life, health, property, and the environment. RSPA has made it a priority to use structured risk management approaches in its own programs and to encourage hazardous materials shippers and carriers, as well as others involved in transporting hazardous materials, to proactively evaluate the risks of their operations and take appropriate steps to further reduce those risks. The purpose of this study is to help involved parties—shippers, carriers, packaging manufacturers, emergency responders, government regulators, and others—to systematically think about and manage, in a cost effective manner, the risks associated with transportation of hazardous materials. The three main elements of the framework outlined here are

- 1) A basic philosophy, which is to proactively assess your risks, then act to reduce them.
- 2) A set of fundamental risk management principles to guide risk management decision and actions; and
- 3) A generic risk management approach that can serve as a model and be adapted to many specific purposes by various players in hazardous materials.

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**ICF Consulting. *Three Case Studies for the Risk Management Framework for Hazardous Materials Transportation*. Submitted to the U.S. Department of Transportation Research and Special Programs Administration. Washington, D.C. Delivery Order No. DTRS56-99-D-70123. November 1, 2000.**

This report is part of a series of reports (see above) regarding DOT's Research and Special Programs Administration (RSPA) that are aimed to develop a new risk management framework that is designed to be used by shippers, carriers, etc. This report

outlines three "case studies" which compare the three following existing risk management protocols with the new framework developed by RSPA:

- 1) The Non-Accidental Release program administered by the Association of American Railroads.
- 2) RSPA's Exemptions Program and the Regulated Medical Waste Exemptions.
- 3) The Risk Management Approaches used by selected members of the trucking industry.

These are comparisons of risk management structures, but not risk assessment protocols.

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**Colon, Peter. C.L. *Rail Transportation of Hazardous Materials in the United States.* Rail International. No. 06. P. 8-17. June 1999.**

This article gives a good overview of the history of rail transport of hazardous materials, safety records, and government and industry efforts to improve safety. The U.S. Department of Transportation (DOT) was formed in 1967 and assumed responsibility for safety regulation. In 1974, Congress promulgated the Hazardous Materials Transportation Act authorizing DOT to regulate materials that pose an unreasonable risk to health and property when transported in commerce. This law was revised in 1990 as the Hazardous Materials Transportation Uniform Safety Act. The article notes that every major railroad in the United States maintains a staff of hazardous materials experts to assure continuous safety improvements. The Transportation Technology Center, Inc. (TTCI), a subsidiary of the Association of American Railroads, has established a Center of Excellence for Hazardous Materials Transportation Safety. This is a new organization that offers a variety of key services for improving transportation safety in the areas of research, development, training, and consulting. TTCI offers advanced emergency response training at its facilities in Pueblo, Colorado and at shipper and carrier facilities. The efforts of the inter-industry task force led to the adoption of additional performance standards including:

- More frequent track inspection for routes with high volumes of hazardous materials traffic.
- Operational standards for trains that carry large numbers of cars containing certain types of hazardous materials.
- Additional training for employees on these routes and trains.
- Thorough inspection of tank cars containing hazardous materials prior to shipment.
- The task force also supported development of a comprehensive risk analysis model for use in determining the effectiveness of risk reduction alternatives.

The article notes that there have been just four fatalities due to hazardous materials releases from train accidents since 1980.

For communities impacted by the transport of hazardous materials, the Chemical Manufacturers Association established its Community Awareness and Emergency Response program several years ago to improve local community preparedness in the

event of a chemical plant accident. This was later expanded to incorporate transportation facilities and is known as TRANSCAER (see above for website). This is a voluntary program in which railroads with transportation facilities in a community work closely with emergency response authorities to help them prepare for a possible accident. Local Emergency Planning Commissions (LEPCs) have been established in every city and county in the United States to formalize plans for dealing with any kind of serious event, including rail accidents involving hazardous materials.

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**Visser, Wieger J. *The Risks in rail Transport of Dangerous Goods: A synthesis of Risk Studies*. Rail International. No. 6. June 1999. P. 18-23.**

This synthesis of the transport of dangerous goods was arranged by the International Union of Railways in association with the Community of European Railways to facilitate the task of making proposals for policy at the European level to improve the safety of rail transport of dangerous goods. Risk studies from Denmark, Germany, France, Italy, Netherlands, Sweden, Switzerland, and the United Kingdom were reviewed. Rail transport of dangerous goods in Europe is subject to the Regulations concerning the International carriage of Dangerous goods by rail (RID).

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**Dennis, Scott M. *Estimating risk costs per unit of exposure for hazardous materials transported by rail*. The Logistics and transportation review. Vol. 32, No. 4. Dec. 1996. P. 351-375.**

The purpose of this study was to determine the risk costs per unit of exposure associated with railroad freight transportation of groups of hazardous materials known to have generated substantial risk costs. A survey of hazardous rail accidents between 1982 and 1992 was conducted to determine the hazardous substance, exposure levels, costs related to the hazardous nature of the cargo. The focus of the study was on costs to the railroad company rather than costs to the individuals exposed or the communities involved. The article notes that between 1982 and 1992 the amount of hazardous materials shipped by rail nearly doubled, while accidents per million train miles were cut nearly in half. Improved tank car design, emergency response procedures, and railroad operating practices for hazardous materials all improved substantially.

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**American Institute of Chemical Engineers, Center for Chemical Process Safety. *Guidelines for Chemical Transportation Risk analysis*. 1995. 382 pages.**

The philosophy behind this volume is to provide an introduction to Transportation Risk Assessment (TRA) methodology in sufficient depth so that an engineer with some practice can undertake basic TRA studies with minimal outside assistance. Detailed quantitative TRA should be used sparingly and only to the depth of study necessary to achieve a study's goals and objectives. If not properly controlled, even in simple quantitative TRA can generate an unmanageable calculation burden. This book discusses

both qualitative and quantitative TRAs, but the emphasis of the examples is on quantitative TRAs. The appropriate application of TRA can allow risk management decisions to be made about:

- alternate modes of transport
- appropriate routes
- travel restrictions (e.g. speed, weather, time of day)
- shipment size (total volume per shipment)
- shipping conditions (pressure and temperatures)
- use of more protective containers
- unit size (e.g., bulk versus drums)

Without the benefit of TRA, judgements about such issues are made subjectively and the status quo is often accepted. The purpose of this book is to give guidance on conducting, overseeing, and/or managing TRA studies, not on specific results or on reduction strategies. A TRA is only useful when its information is incorporated into an action plan. Risk measures that might be utilized for a TRA include: average individual risk, individual risk profiles, societal risk per year, societal risk per trip, societal risk per ton-mile, societal risk per community, and comparative measures.

Chapter 2 focuses on TRA Frequency Analysis, with section 2.2 discussing accident rates, failure modes, release probabilities, for railroads. Chapter 7 includes an example of a rail risk assessment in which two suppliers are being considered for chlorine. Although this example outlines rail risk assessment parameters, it does not appear relevant to the conditions or situation in Lincoln County.

The book notes that in general studies in the United States are initiated by chemical companies and address their own products. In most other countries, studies seem to be initiated by government requests or the U.S. portion of an international company.

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**Lindberg, Erik. *A method for risk analysis of the transportation of hazardous materials by road and rail* : project summary /, Erik Lindberg and Bertil Morén. [Linköping] : Statens väg- och transportforskningsinstitut, 1994. III, 55 p. ; 24 cm. Series title: VTI rapport ; 386:1A 0347-6030.**

This report describes a project aimed at developing a method for risk analysis of the transportation (excluding loading, unloading and temporary storage) of hazardous materials by road and railroad in Sweden. The goals of the project are to produce a method which make it possible to; 1) estimate the accident probability involved in the transportation of hazardous materials by road and rail; 2) estimate the accident's consequences in the transportation of various types of materials, and; 3) estimate the expected socioeconomic accident costs in the transportation of various types of materials using alternative transport methods. The results of the rail portion of the study indicate that it may be difficult to identify technical measures for risk reduction which are

motivated on a socio-economic basis with due regard to the already low cost of railroad accidents involving hazardous material. However, measures relating to traffic planning and training may be indicated.

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**Levin, John. *The transportation of hazardous materials by rail : a recommendation for reform* . John Levin. In: *Transportation law journal*. Vol. 22, no. 1 (1994) p. 41-60.**

This article notes that the U.S. DOT estimates that over four billion tons of regulated hazardous materials are transported in the United States each year. In 1989, over 1.5 million carloads of hazardous materials originated for transportation by rail. Between 1985 and 1989, the Federal Railroad Administration recorded 2,121 accidents involving railcars carrying hazardous products. Of these 254 resulted in a release of product. The purpose of this article was to review the current regulatory and legal structure, propose reforms to promote the safer transportation of hazardous materials, promote rational compensation for those injured by releases of hazardous products, and encourage safer behavior by the transportation industry. This article reviews all current legislation pertaining to rail movements of hazardous materials, including the 1990 Hazardous Materials Transportation Uniform Safety Act, the Locomotive Inspection Act, the Accidents Reports Act, and the Comprehensive Environmental Response Compensation and Liability Act of 1980. The article also discusses negligence, liability, failure to warn, and punitive damages. The author finds that the current law applicable to the transportation of hazardous materials by rail has generally failed. Neither formal regulation nor tort law provide a fair and efficient system to both minimize accidents and equitably compensate injured parties.

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**Purdy, Grant. *Measurement of risk from transporting dangerous goods by road and rail* Grant Purdy. In: *World Conference on Transport Research (6th : 1992 : Lyon, France)*. Selected proceedings of the Sixth World Conference on Transport Research. Vol. 3. France : Shirat, 1993. p. 1861-1872 : ill. ; 24 cm.**

This study was based in the United Kingdom and was precipitated due to a general discussion throughout Europe regarding the relative safety of transporting hazardous materials via rail versus road. Other countries have enacted legislation requiring a shift of hazardous material from road to rail for safety purposes. This study was based on the hypothetical transport of chlorine between two towns in the United Kingdom via rail and road. This study is unique in that it included motorists and rail passengers as populations at risk, rather than only considering the surrounding populations. The results of this study indicate that:

- The risk by rail is approximately five times that by road.
- Risks to rail users is double that to motorists.

- Risks to off-rail populations are approximately eight times higher than those to off-road populations.

The dominance of rail risk is due to the fact that most of the United Kingdom rail system was built over 100 years ago and was intended to go from town to town while most of the major roads were built over the past 20 years and were specifically routed to take traffic away from the centres of population. This indicates that the results of this study would not necessarily be valid in another location with different rail and roadway systems.

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**Saccomanno, F. F. and Shortreed, J. H. *Hazmat Transport Risks: Societal and Individual Perspectives*. (missing full citation, but article was also in: Abkowitz, Mard and Zografos, Kostas, editors. *State and Local Issues in Transportation of Hazardous Waste Materials: Towards a National Strategy*. Proceedings of the National Conference on Hazardous Materials Transportation. Sponsored by the Urban Transportation division of the American society of Civil Engineers. In cooperation with the Transportation research board and the U.S. Department of Transportation. American Society of Civil Engineers. 1990**

The objective of this paper was to compare societal and individual risks for the bulk transport of pressure liquefied chlorine gas by truck and rail tanker. For illustrative purposes, the risks considered in this analysis are estimated for road and track conditions found along the Sarnia-to-Toronto corridor in southwestern Ontario, Canada. Chlorine was used because it represents the extremes of risk for hazardous materials in general, from both a societal and individual perspective. Societal risks reflect the expectation of all possible damages posed by an activity of an extended period of time, for all locations that are adversely affected. Individual risks are concerned with potential threats to individuals residing at specific distances from a given transportation corridor or route. The study finds that the order of consideration for individual and societal risks is important. Since individual risks best reflect the concerns of adjacent residents and workers, and since they are traditionally the first consideration in risk assessment, the study recommends that individual risks be considered first in the evaluation process. If these risks are unacceptable, then it is not necessary to evaluate the broader societal risks. If individual risks are acceptable, then it would be necessary to consider the larger societal risks, particularly as they relate to the occurrence of very low frequency, very high consequence events.

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**Leeming, D. G., and Saccomanno, F. F., *Use of Quantified Risk Assessment in Evaluating the Risks of Transporting Chlorine by Road and Rail*. Transportation Research Record. No. 1430. (missing rest of citation)**

This study, based in the United Kingdom, uses the Health and Safety Executive computerized quantified Risk Assessment Tool (RISKAT) to evaluate a hypothetical scenario regarding the transport of more frequent truck loads of chlorine to an industrial facility versus the continued use of less frequent rail deliveries that require the storage of

higher quantities of chlorine on site. Many data sources were utilized to help reduce error. The study notes that the credibility of quantitative risk assessment is often undermined by the degree of uncertainty in the estimates. The results of the study indicate that the use of trucks to deliver the chlorine will reduce the risk to populations surrounding the industrial facility. The results also show that the risk to populations along the route might be higher for the rail scenario because the tracks pass through populated areas. The study authors emphasize that the degree of accuracy of this study depends on the accuracy of the estimates, which vary widely.

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**Phani Raj, P. K.** *A risk assessment study on the transportation of hazardous materials over the U.S. railroads*, Phani K. Raj (Technology and Management Systems, Inc.). Washington, D.C. U.S. Dept. of Transportation, Federal Railroad Administration, Office of Research and Development, [1988] 164 p.

The goal for this research was to determine what is the annual probability of exposing a specified number of people in the United States to the harmful effects of a hazardous material released from a tank car involved in a rail accident and how does this probability vary with different tank cars. Mainline rail accident (derailment) and tank damage data for the years 1985-1990 were obtained from accident statistics maintained by the Federal Railroad Administration. Risk calculations were made for each type of tank car or product combination. First the annual probability of a tank car suffering a derailment and damage was determined. The conditional probability of suffering a particular size puncture was determined, followed by the release rate of the chemical for the given size hole. The exposure area for the particular chemical, hole size, and weather condition was calculated. The population exposed to different types of hazards was calculated, noting at the same time the conditional probabilities of occurrence of the type of hazard (fire, toxic concentration, blast effects, etc.), the weather type assumed, and the population density area.

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**Saccomanno, F.F., Shortreen, J.H., Van Aerde, M., and Higgs, J.** *Comparison of risk measures for the transport of dangerous commodities by truck and rail.* Transportation research record. No. 1245 (1989) p. 1-13.

This article focuses on the issue of inconsistencies between predictive risks and risks that are observed in the available data. The issue of truck and rail safety in transporting dangerous commodities cannot be resolved through a review of historical data alone—primarily because of low-probability, high-consequence events. The objectives of this study were to; 1) assess the relative risks of transporting dangerous goods by truck and rail using accident rates, spill probabilities, hazard areas and expected impacts to population, and environment, and; 2) for different measures, assess the sensitivity of risk to changes in the transportation environment for each mode and material shipped. Data from Canada between 1982 and 1986 were utilized. The results show that for chlorine fatalities per tonne-kilometer are higher for rail than for truck. For shipments of LPG, truck fatalities on a per tonne-kilometer basis may be higher than for rail. The authors

note that there is a margin of error of at least one order of magnitude for these results. This analysis demonstrates that for both chlorine and LPG, the risk consequences of the accident itself are an important component of the entire risk analysis process.

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**Glickman, Theodore S. *Benchmark estimates of release accident rates in hazardous materials transportation by rail and truck* /, Theodore S. Glickman. Washington, D.C. National Research Council, Transportation Research Board, 1988.**

The research in this paper was designed to respond to the question of the relative safety of transporting hazardous materials via rail versus truck. This research was nationwide, based on 1982 data. The research indicated that there is no simple answer to the question of which mode is safer, since it depends on the size of the releases, the carriers that are performing the transportation, the vehicles that are being used, and the types of track or roadway that are involved. Data was taken from the DOT's Office of Hazardous Materials Transportation. With the exception of battery spills and spills of paint and other consumer products in retail packages of five gallons or less, any unintentional release occurring during loading, unloading, transportation or temporary storage associated with any mode of transportation (except pipelines) is supposed to be reported and reflected in this database. When all types of rail cars and trucks were taken into account, the estimated release accident rate for rail was higher than the truck rate. If only tank cars and tank trucks were considered, then the estimated railroad rate is lower than the respective estimated for-hire truck rates for all incidents and for significant spill incidents only. The report notes that ideally, separate release accident rates should be estimated for each of the three major activities that are addressed by the hazardous materials incident reports; 1) loading and unloading; 2) transportation; and 3) temporary storage. This report is based on national figures, while in practice, most risk assessments deal with relatively localized situations, where the characteristics of the rail route can be readily identified and taken into account. One clear difference between localized situations is the class of track involved. Table 5, page 17 notes the accident rates (in billion gross ton-miles) for the six track classes identified by the Federal Railroad Administration.

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