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RISK COSTS OF TRANSPORTING HAZARDOUS MATERIALS BY RAIL: 1982-1992

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ABSTRACT

Analysis of major hazardous materials releases involving rail transportation during the 1982-1992 period indicates that the railroad industry has dramatically improved its ability to handle this traffic safely compared to the 1971-1981 period covered by a previous study. Risk cost and other data gathered from individual railroads and other sources demonstrate that while railroad hazardous materials traffic nearly doubled during the 11-year period covered by this study, the number of major hazardous materials releases and the risk cost per release declined substantially. The composition of risk costs also changed compared to the previous study, with environmental expenses becoming relatively more important, and legal settlement expenses becoming relatively less important. The percentage of risk costs attributable to switching operations declined compared to the previous study, while the percentage of risk costs attributable to running operations increased. The risk cost per release varied substantially among the seven environmental/safety commodity categories and two types of operation designated in this study. Because it was not possible to obtain complete coverage of all releases and expenses, the study results are best regarded as *minimum* estimates of the total risk costs incurred.

INTRODUCTION

A study previously published in this journal (Wolfe 1984) analyzed the risk costs associated with railroad transportation of hazardous materials from 1971 to 1981. Since that time, accidents per million train miles have been cut nearly in half (USDOT FRA 1982-1992, Table 4).[1] Tank car design (TRB 1994, 28-60), emergency response procedures (US Congress OTA 1986, 217-234), and railroad operating practices for hazardous materials (AAR 1993) have also improved substantially. On the other hand, the amount of hazardous materials shipped by rail has nearly doubled (USICC 1982-1992). Price indexes for legal settlements and environmental remediation, which together represented more than 80 percent of the costs in the previous study, have also increased rapidly (Masterson 1992; Barkan, Glickman, and Harvey 1991). More stringent environmental statutes have been implemented, changing the regulations pertaining to remediation of hazardous materials spills.[2] These two sets of competing trends make it unclear whether the risk costs of transporting hazardous materials by rail increased or decreased subsequent to the previous study. The answer to this question has important implications for railroad costing, operating, and investment with regard to hazardous materials transportation.

This paper uses actual cost data from carriers to estimate the risk costs associated with railroad freight transportation of hazardous materials. The focus of this study is on groups of hazardous materials known to have generated substantial risk costs. The second section of this paper discusses hazardous materials releases in the broader context of railroad safety. This is followed by a section which describes the methodology employed in this study. The next section presents the historical cost results of this study, and compares them, where appropriate, to the results of the previous study. The conclusions of this study are presented in the last section.

TRANSPORTATION OF HAZARDOUS MATERIALS BY RAIL

Risk Costs

Like endeavors of any kind, transportation activities entail some possibility of an

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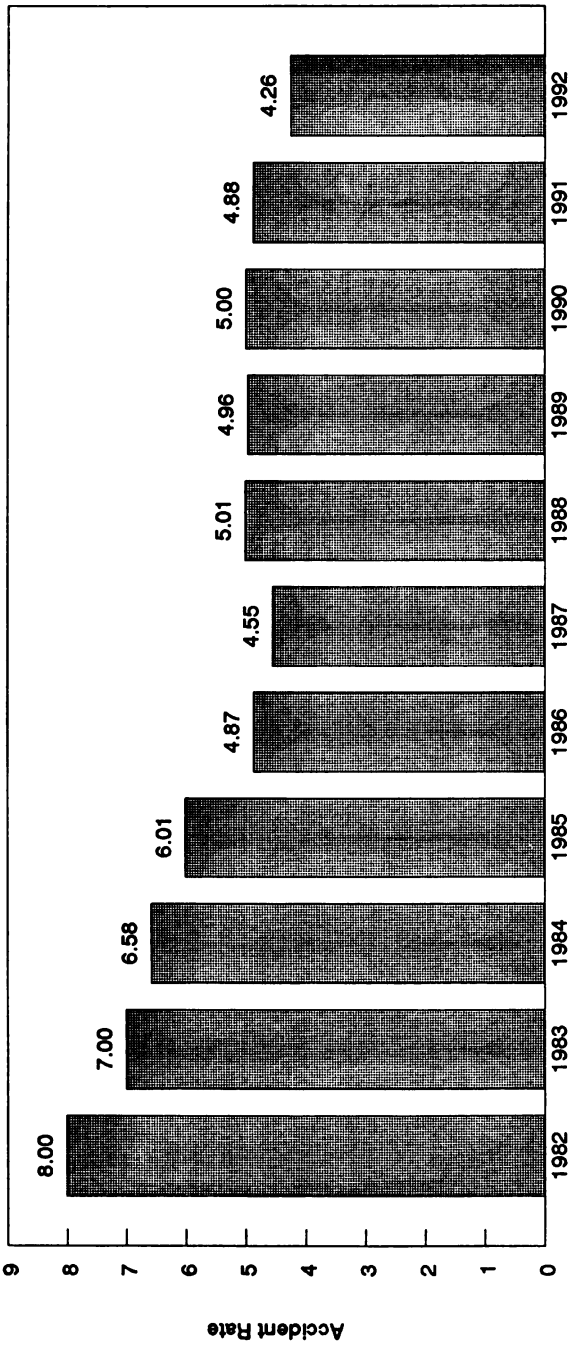
FIGURE 1



Source: U. S. Department of Transportation, Federal Railroad Administration, Office of Safety, Accident/Incident Bulletins, 1982–1992, Table 4.

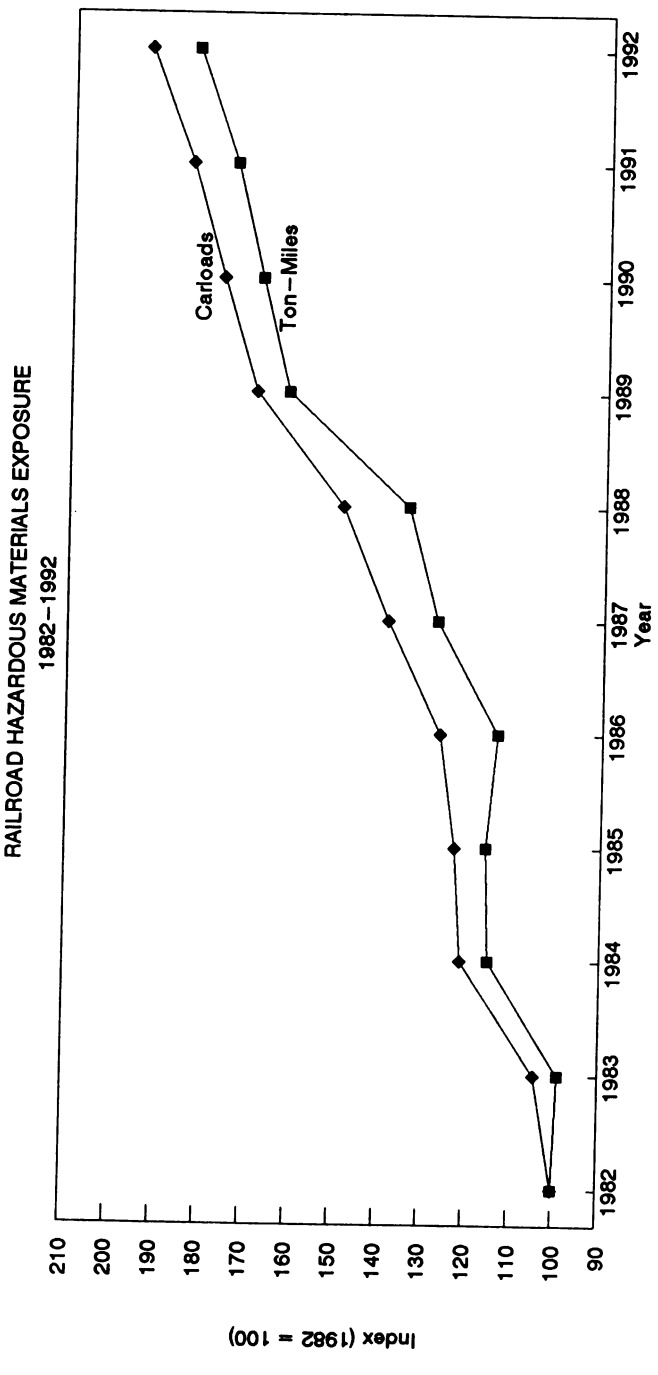


FIGURE 2

Source: ICC Carload Waybill Sample

undesired outcome. In most cases this risk is negligible. Figure 1 shows the number of train accidents per million train miles in the United States for the 1982-1992 period covered by this study (USDOT FRA 1982-1992, Table 4).[3] Train accidents have declined by almost half over the period, reaching a low of 4.26 accidents per million train miles in 1992.

However, some commodities carried by the railroad industry, such as hazardous materials (Standard Transportation Commodity Code (STCC) 49), hazardous waste (STCC 48), and a very small number of other commodities, represent sufficient hazards that they are likely to cause risks beyond the level attributable to typical railroad traffic. These hazards can result in risk to human health, property, or the environment. The costs associated with these risks are termed *risk costs*. The risk costs incurred in a release of hazardous materials depend on both the hazard posed by the commodity and the circumstances of its release (e. g., a hazardous material released in a populated versus unpopulated area; or discharged onto dry land versus into a lake or stream).[4]

This study identifies as risk costs only those costs which were incurred as a result of the presence of hazardous materials. If a train carrying hazardous materials derailed and damaged the track, the cost of repairing the track would not necessarily be attributable to the hazardous materials. However, if the hazardous materials burned or exploded, damaging other commodities and railroad equipment, then the damage to the other commodities and equipment would properly be a risk cost of carrying hazardous materials.

Exposure

The amount of hazardous materials transported by rail, and hence the risk exposure attendant in their transport, can be measured in a variety of ways. While no one measure is likely to capture all the aspects of risk exposure, the most useful measures are probably ton-miles and carloads. Figure 2 shows the exposure of hazardous materials terminated in the United States over the 1982-1992 period covered by this study (1982 = 100 for both exposure indexes). Both the ton-mile and carload measures of exposure nearly doubled since 1982.[5] In 1992, the last year of this study, hazardous materials accounted for more than 70 billion ton-miles, more than six percent of all rail ton-miles, and 1.4 million carloads, almost six percent of all rail carloads.

Hazardous Materials Incidents

A hazardous materials incident is defined as any unintentional release of a hazardous material in railroad transportation (49 CFR Sec. 171.16). This is clearly a very broad definition, which includes releases of any quantity of hazardous materials which occur either on railroad property or at shipper loading facilities. Incidents are often minor spills and leaks. Figure 3 shows that the number of incidents per thousand carloads declined by approximately one third from 1982 to 1992. There were 0.72 hazardous materials incidents per thousand carloads in 1992.

Figure 4 shows the number of hazardous materials incidents per thousand carloads which occurred as a result of railroad *accidents* (USDOT FRA 1982-1992, Table 26). This small subset of incidents reflects a much more narrow definition that is directly related to railroad operations. Hazardous materials incidents which occur as a result of railroad accidents are more likely to result in a large release of hazardous materials than non-accident releases. The number of hazardous materials releases per thousand carloads which occurred as a result of railroad accidents in the United States declined by approximately 75 percent from 1982 to 1992. There were 0.019 such releases per thousand carloads in 1992.

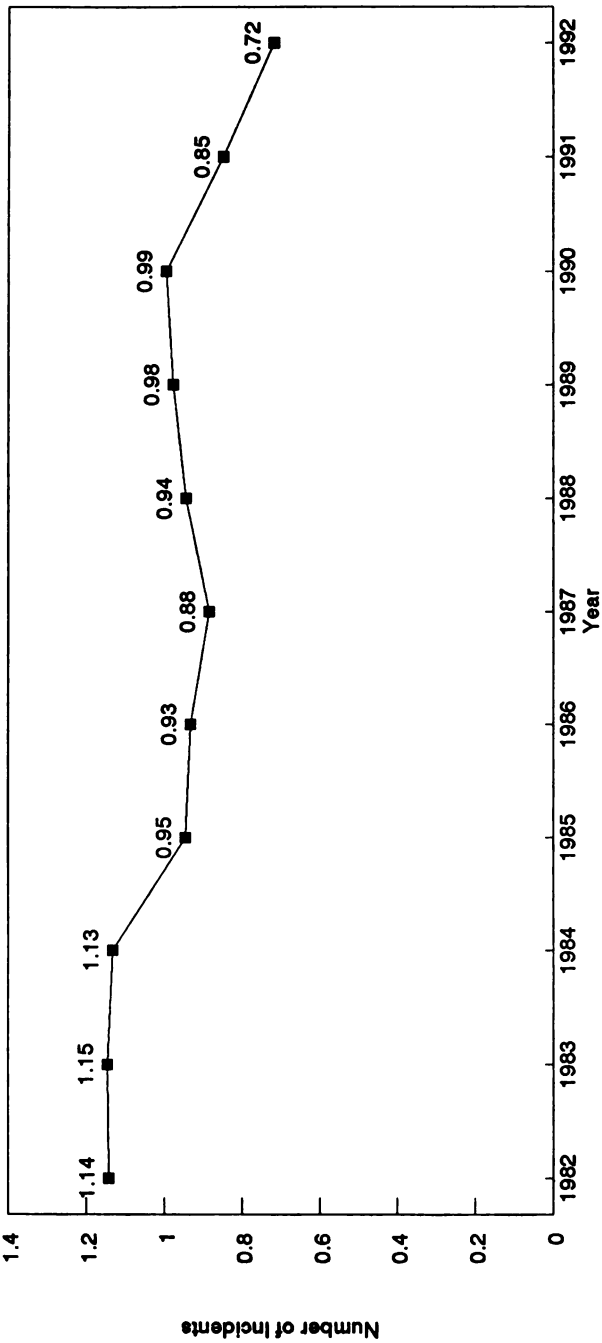
Major releases, which are the focus of this study, involve more than $100,000 in current dollar risk costs incurred as a result of hazardous materials. Major releases can be the result of railroad accidents, or large releases that did not result from accidents. Although major hazardous materials releases are rare events, when they do occur, this small minority of incidents can impose substantial costs on the railroads involved.

METHODOLOGY

Data Collection

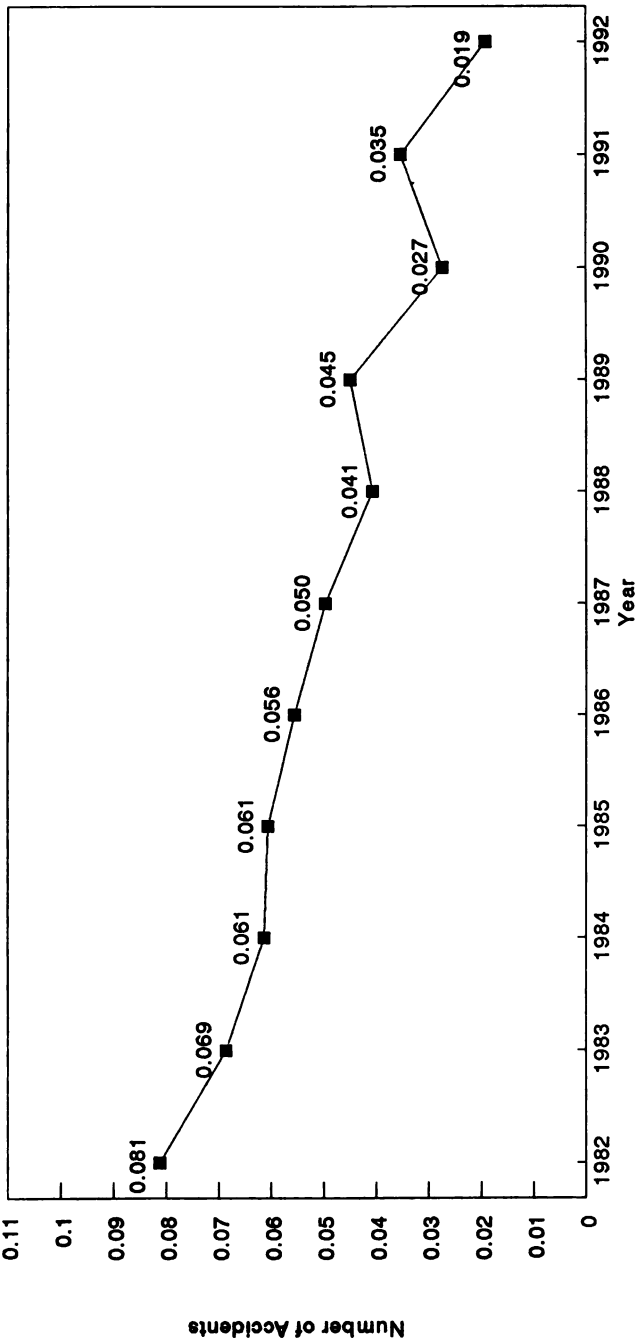
Major Releases. In November, 1992 surveys were sent to each of 32 participating railroads, requesting detailed information about releases which occurred between 1982 and 1992. The Association of American Railroads (AAR) developed a list of potential major hazardous materials releases for review by the individual

FIGURE 3



Source: U. S. Department of Transportation, Research and Special Programs Administration, Annual Report on Hazardous Materials Transportation, 1982–1992, Exhibit 1; ICC Carload Waybill Sample.

FIGURE 4



Source: U. S. Department of Transportation, Federal Railroad Administration, Office of Safety, Accident/Incident Bulletin, 1982–1992, Table 26; ICC Carload Waybill Sample.

railroads as a starting point for the analysis.[6] A release was considered to be potentially major if it included any of the following criteria: $100,000 or more in current dollar damages; one or more deaths; two or more injuries; an evacuation; or a release of 500 gallons or more of hazardous materials.

Current dollar damages do not necessarily reflect the risk costs associated with transporting hazardous materials. Reported damage to track and equipment may not necessarily be attributable to the hazardous materials. In addition, estimated costs can be substantially different from the actual costs incurred. Reasons for this divergence in cost estimates include the requirement that the forms be filed within weeks of the release, the possibility of protracted or delayed litigation, and potentially lengthy or uncertain environmental remediation. Each railroad was therefore asked to identify which of these releases were *in fact* major releases based on whether there were $100,000 in risk costs of all types *caused by the presence of hazardous materials*. In addition, each railroad was asked to identify any other releases which satisfy the $100,000 criterion but were not on the original listing furnished by the AAR.

Risk Cost Survey. Participating railroads filled out an eight-page survey form for each major release that they could identify. The first part of the survey requested information needed to identify the release, including railroad, date, location, commodities involved, a short narrative description of the circumstances, and type of operation (running or switching). The remainder of the survey addressed information concerning the type and amount of risk costs caused by the presence of hazardous materials. The categories of risk costs included in the survey were equipment damage, lading loss (both hazardous and non-hazardous commodities), way and structures damage, signals damage, wrecking expenses, environmental costs, other costs (evacuation, loss of business), and legal settlement expenses (personal injury, third-party property damage, and legal fees) not already included in other categories.[7]

Participating carriers returned 174 surveys. The AAR then conducted seven separate edit checks on the data, and subsequently held in-depth discussions with the individual carriers to obtain missing information as well as clarification of the data that were furnished. Of the 174 surveys returned, 121 were found to represent major releases on which sufficient information was available to conduct the analysis. It was ultimately determined that another 32 surveys had sufficient information but did not, in fact, represent major releases. These surveys were not used in the analysis. The remaining 21 surveys may represent major releases, but did not contain sufficient information to conduct the analysis. The information available on these 21 surveys, while not used in the analysis, did not appear substantially different in any way from the 121 surveys that were used in the analysis.

Categorization of Hazardous Materials Releases

Conceptual Basis. Conceptually, risk costs should be evaluated based on the loss experience of each individual commodity. However, since major hazardous materials releases are relatively rare, many commodities have yet to experience a major loss. Therefore, calculation of risk costs based on historical losses for individual commodities would result in no costs being assigned to many commodities. Moreover, while hazards are inherent in the characteristics of some commodities, the risk costs resulting from transportation of these commodities depend heavily on the circumstances of their release. A hazardous material released in a populated versus unpopulated area, or discharged onto dry land versus into a lake or stream, generates large random variations in the risk costs of an individual release that cannot be predicted based solely on the characteristics of the commodity. The risk costs attendant to any one release may be either much higher or much lower than the average cost of all releases for a given commodity over time.

One solution to these problems is to analyze the loss experience of groups of commodities which have similar characteristics. While one commodity may have yet to experience a major loss, another commodity or set of commodities with similar characteristics may have experienced several major losses. Similarly, while any one release may seem comparatively expensive or inexpensive compared to releases involving similar commodities, the combined experience over a number of releases involving similar commodities should provide a better indication of the expected losses. In addition to these issues, a number of carriers expressed concerns about confidentiality when asked to report legal settlements pertaining to individual

releases. Dividing commodities into groups and reporting legal settlement expenses for the entire group, instead of for individual releases, helped to alleviate these confidentiality concerns.

Commodity Groupings. Seven commodity groupings were developed by the AAR's Research and Test, Operations and Maintenance, and Economics, Policy, and Statistics Departments. These groupings reflect a balancing of the need to combine the cost experience of commodities with similar safety and environmental hazards versus the need to maintain enough observations in each group to reduce random variation and help preserve confidentiality.

The first step in this process was to identify the commodity primarily responsible for the costs incurred in each major release. This was done with the aid of carrier personnel, many of whom were actually on the scene at the time of the release.[8] Next, each commodity was assigned to one of three safety hazard classes which were developed based on the U. S. Department of Transportation hazard classifications (49 CFR Sec. 173.50-145). The first category includes all commodities which pose a poison inhalation hazard. The rationale for this category definition is that the hazard of poison by inhalation is an overriding potential danger regardless of any other properties of the commodity. The second category consists of flammable or combustible commodities. The primary hazards posed by these commodities are fire or explosion. The third category consists of all other commodities. From a safety standpoint, these commodities present mainly a hazard that is confined to the immediate area of the release. Hazardous waste (STCC 48) and other non-STCC 49 commodities are not rated in the DOT system. These commodities were assigned to a safety category based on STCC 49 commodities with similar characteristics.

Each commodity was also assigned to an environmental hazard category based on analysis conducted by Eder Associates (1992) for CSX Transportation, Inc..[9] This analysis suggested three categories representing high, medium, and low environmental hazard. Hazardous waste and other non-STCC 49 commodities are not rated in the Eder system. These commodities were assigned to an environmental category based on STCC 49 commodities with similar characteristics.

Combining three safety categories with three environmental categories results in nine possible commodity groups. However, because most poison inhalation commodities evaporate, the environmental hazard is not an important consideration for these commodities. The poison inhalation hazards were, therefore, consolidated into one group regardless of their environmental score.

The seven commodity groups resulting from this process are shown in Table 1, along with typical commodities in each group. The poison inhalation hazard, flammable/combustible hazard, and all other safety hazards in the DOT hazard classification are read down the table. This classification represents different *kinds* of safety hazard for any given environmental hazard. Chlorine poses a poison inhalation hazard over a wide area; fuel oil can burn; and caustic soda can cause injury from immediate contact. High, medium, and low environmental hazards are read across the table. This classification represents different *degrees* of environmental hazard for any given safety hazard. Styrene, fuel oil, and liquefied petroleum gas (LPG) all burn. However, styrene can easily soak into the soil, fuel oil tends to form surface pools, and LPG tends to evaporate, hence their different environmental hazards. Asphalt is included in the analysis because there have been cases where it has been costly to clean up in spite of its low safety and environmental hazards.[10]

Estimation of Constant Dollar Costs

The cost data on the risk cost surveys represent the actual costs incurred at the time they were paid. These costs must be converted to a common basis in order to calculate risk costs over a period of time. Two kinds of effects should be taken into account. The first effect, price inflation, adjusts for increases in prices over the period of time covered by the study. The second effect, social inflation, adjusts for changes in the legal and regulatory climate over the period of time covered by this study.

Estimates of Price Inflation. Constant dollar costs were estimated in 1992 dollars, since this was the most recent year for which all necessary inflators could be calculated. In each case every effort was made to use inflators which would result in conservative estimates of constant dollar costs.

TABLE 1

HAZARDOUS MATERIALS COMMODITY GROUPS
(Example Commodities)

Safety Hazard	Environmental Hazard: High	Medium	Low
Poison Inhalation Hazard	Anhydrous Ammonia Chlorine Ethylene Oxide		
Flammable/Combustible	Phosphorus Styrene Toluene	Acetaldehyde Fuel Oil Hexane	Butadiene LPG Methanol
All Other	Chloroform Metam Sodium Perchloroethylene	Acrylic Acid Caustic Soda Sulfuric Acid	Acetic Acid Asphalt Molten Sulfur

Railroad equipment costs were converted into constant dollar expenses using the Producer Price Index for railroad equipment (USDOL BLS 1982-1992, Table 4). Lading loss, way and structures damage, signals damage, wrecking expenses, and other costs were converted into constant dollars using the Gross Domestic Product (GDP) implicit price index (Executive Office of the President 1994, Table B-3). Environmental costs were converted using the GDP implicit price index, since environmental remediation was viewed as requiring a market basket of goods and services similar to those produced in the economy as a whole. Legal settlement expenses were converted into constant dollars using appropriate components of Masterson's Claims Cost Index (1992).[11]

Estimate of Social Inflation. In addition to an increase in prices over time, there may also have been changes in the legal environment which would increase the number or likelihood of lawsuits resulting from any given release. An increase in the number or likelihood of lawsuits resulting from any given release should be expected as the result of population growth, increasing litigiousness, or an expansion of liability as defined by the courts.[12] This last effect, known as social inflation, results in more people who are considered to be adversely affected in some way by a particular release. Social inflation should be taken into account when calculating risk costs over a period of time, since it is the source of additional legal settlement expenses.[13]

A number of possible measures of social inflation are presented in the Appendix.[14] The measure of social inflation used must reflect a mix of personal injury, property damage, and environmental damage, and must also take into account whether the case is appealed, and other factors. For these reasons, no one number can provide a completely accurate measure of social inflation. As will be shown later in this paper, legal settlement expenses comprise a little over one half of total risk costs in this study, and environmental expenses just under one third. An expense-weighted average of the growth in personal injury, property damage, and environmental cases would result in a growth rate of four percent per year. Given these considerations, a conservative social inflation estimate of two percent per year was adopted for purposes of this study.[15]

The inflators used to convert nominal cost data into 1992 dollars are shown in Table 2. The inflators for environmental expenses, bodily injury, and property damage all include the combined effect of price inflation and the two percent per year adjustment for social inflation. Each cost inflator for a given year shows how many times greater that type of expense would have been had a release which occurred in that year occurred in 1992.

RESULTS

Both this study and the previous 1971-1981 study sought to obtain as broad a coverage of major hazardous materials releases as possible. In neither case was it possible to obtain complete coverage of all releases and all expenses. Bankruptcies, substantial reductions in the "institutional memory" of many carriers due to mergers and rationalization of the employee base, and the dispersal of hazardous materials data among a variety of departments within the individual railroad organizations combined to restrict the number of major releases studied to something less than the complete population; and accurate data for some cost components were simply not available for some releases. Neither study contains information about releases which fall below the $100,000 threshold. Information on these releases would require a significant increase in the amount of data collection effort while providing little additional coverage of expenses.

For these reasons, the number of releases analyzed in this study (and the 1971-1981 study) is best regarded as a substantial sample of major releases, not as the complete population of major releases. Costs in both studies are, therefore, most properly characterized as *minimum* estimates, not as the full value actually experienced over the period. It is reasonable to assume that the completeness of coverage in each study is approximately the same, and that the releases that we do not have information about are similar in terms of commodities, circumstances, and expense to the releases that we do know about. With these qualifications in mind, several conclusions about the risk costs associated with railroad freight transportation of hazardous materials can be observed.

TABLE 2

CONSTANT DOLLAR INFLATORS NORMALIZED TO 1992

Year	GDP Index	Rail Equipment PPI Index	Environmental Index	Bodily Injury Index	Property Damage Index
1982	1.445	1.237	1.762	2.399	1.963
1983	1.389	1.224	1.660	2.169	1.787
1984	1.331	1.206	1.559	2.013	1.654
1985	1.283	1.180	1.474	1.821	1.507
1986	1.250	1.174	1.407	1.643	1.422
1987	1.211	1.181	1.337	1.530	1.352
1988	1.166	1.151	1.262	1.392	1.242
1989	1.116	1.085	1.184	1.265	1.185
1990	1.069	1.043	1.112	1.165	1.142
1991	1.029	1.012	1.049	1.075	1.055
1992	1.000	1.000	1.000	1.000	1.000

Total Number and Cost of Releases

The first study (1971-1981) resulted in 195 major releases for which enough information existed to conduct analysis. The current study (1982-1992) resulted in 121 major releases for which enough information existed to conduct analysis, a 38 percent decline from the previous study. The number of releases per year contained in the studies declined from an average of almost 18 per year in the first study to 11 per year in the current study. Information was more readily available in the later years of each study than in the early years due to the legal requirements for record retention. For this reason, the later years of each study are likely to be more representative of the population, as a whole, than the earlier years. Looking at the last four years of each study, the number of major releases declined to approximately one third of its previous level, from 31 per year in 1978-1981 to 11 per year in 1989-1992. This provides further, stronger evidence of a decline in the number of releases over time.

The total amount of risk costs included in the original study amounted to $1.35 billion in 1992 dollars, an average of approximately $6.9 million per release. The total amount of risk costs included in the current study amounts to $379 million in 1992 dollars, an average of approximately $3.1 million per release. Therefore, the severity of major releases, as measured by risk costs, is less than half of what it was in the previous study.

In spite of increasing exposure, and in spite of the $100,000 event threshold, (which, due to inflation, allows inclusion of releases in the current study that would not have been included in the previous study), the number of major releases appears to have decreased. Some part of this decline is likely the result of a general improvement in the railroad accident rate over the period covered by this study, as discussed above. Better emergency response procedures have probably helped to reduce the severity of major releases.[16] In addition, shelf couplers, head shields, thermal protection, improved placement of hazardous materials cars within trains, and changes in switching practices for hazardous materials cars within yards were all being phased in at this time.[17] These improvements in equipment, procedures, and operating practices are likely to be responsible for at least some portion of the reduction in both the number and severity of releases.

Deaths and Injuries

The number of deaths declined dramatically from 40 in the first study to only one in the current study.[18] Similarly, the number of injuries declined from 1,303 in the first study to 923 in the current study. Both decreases came in spite of increasing hazardous materials rail traffic exposure over time. It is unlikely that any missing information would reverse the observed decline in deaths and injuries, since, in either study, releases which cause deaths or a large number of injuries are unlikely to fade from institutional memory.

In addition to a substantial decline in the number of injuries, descriptions of major releases indicate that there has also been a change in the type of injury incurred. Most injuries in the previous study were burns or major trauma as a result of fires or explosions. Most injuries in the current study involved inhalation as a result of large releases. The change in the type of injury appears to be the result of a reduction in the number of fires and explosions in major releases.

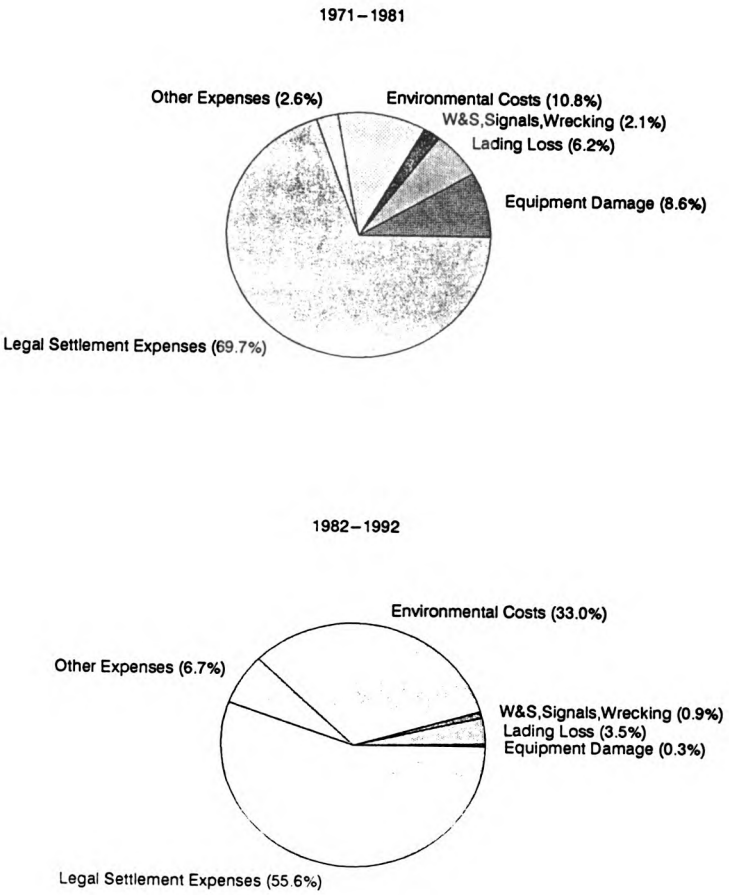
Composition of Risk Costs

Figure 5 shows the composition of risk costs incurred in major hazardous materials releases. Legal settlement expenses accounted for a large majority (70 percent) of risk costs in the 1971-1981 period covered by the previous study. Environmental expenses, equipment damage, and lading loss, in that order, were the next most important categories of expenses. Way and structures, signals, wrecking, and other expenses were of fairly minor importance. The proportion of risk costs attributable to environmental expenses increased three-fold in the 1982-1992 period covered by the current study. The proportion of risk costs attributable to legal settlement expenses declined by 14 percentage points to a little over half of total risk costs, and the proportion of risk costs attributable to equipment damage also fell. The proportion of risk costs attributable to other cost categories (way and structures, signals, wrecking, lading loss, and other expenses) remained roughly the same as in the previous period.

The change in the composition of risk costs between the two periods reflects a variety of trends. The greater proportion of environmental expenses in the current study likely reflects both the expanding liability under the various

FIGURE 5

COMPOSITION OF RISK COSTS



environmental laws previously discussed, and the added expense of increasingly stringent remediation requirements.[19] In both periods, about half of the releases have legal settlement expenses. However, the average legal settlement expense per release has declined during the more recent period. This may be the result of the lower number of deaths and injuries involved, which may in turn reflect fewer fires or explosions. This change in the type of major release may also be a factor in the decline in equipment damages and the slight decline in lading losses.

Average Risk Cost of Major Releases by Commodity Group and Type of Operation

Table 3 shows the average risk cost of major releases in 1992 dollars for each commodity group by type of railroad operation. Running operation, the first column of numbers, includes those releases which occurred while trains were moving over the road. Switching operation, the second column of numbers, includes releases which occurred either in yards or during road switching. Reading down either column of the table indicates that, other factors being equal, greater environmental hazards translate into higher risk costs.[20] (As mentioned previously, environmental hazards are not an important consideration for the Poison Inhalation Hazard commodities.) The difference in risk costs is especially noticeable in comparing the high environmental hazard commodities to the other two environmental categories. Furthermore, the All Other commodities with high environmental hazard are exceptionally expensive on a per release basis. This group includes two of the most expensive releases, and a number of releases involving halogenated organic compounds (HOC's) which must be removed from the environment to very low tolerances.[21] Reading down the table indicates that risk costs also vary depending on the kind of safety hazard. The risk costs of Poison Inhalation Hazard commodities are similar to those of the Flammable/Combustible commodities with medium environmental hazard for running releases, and low environmental hazard for switching releases. For medium and low environmental hazard commodities, which represent most of the observations in this study, the safety hazards posed by Flammable/Combustible commodities result in greater risk costs than those of the All Other commodities. However, the All Other commodities with high environmental hazard are much more expensive than the Flammable/Combustible commodities with high environmental hazard. This may be due to the fact that major hazardous materials releases are rare. The All Other-High commodities have experienced a number of exceptionally expensive releases, while the Flammable/Combustible-High commodities have only experienced one. Another possible explanation is that environmental considerations greatly outweigh safety considerations for the high environmental risk commodities.

One feature worth noting is the change in the proportion of total risk costs attributable to running and switching operations. The 1971-1981 study contained 12 switching releases, which accounted for six percent of the releases and 41 percent of the risk costs.[22] The current 1982-1992 study contains 25 switching releases, which account for 21 percent of the releases and 12 percent of the risk costs. This reduction in the proportion of risk costs attributable to switching again appears to be the result of a reduction in the number of fires and explosions in major releases. Fires and explosions in yard areas were especially damaging in the previous study.

CONCLUSIONS

A study previously published in this journal analyzed the risk costs associated with railroad transportation of hazardous materials from 1971 to 1981. Since that time, railroad safety in general has greatly improved, and changes in tank car design, operating practices, and emergency response procedures have improved the safety of hazardous materials transportation in particular. On the other hand, the amount of hazardous materials shipped by rail has nearly doubled, environmental remediation requirements have become more stringent, and price indexes for legal settlements and environmental remediation have also increased rapidly. These trends have resulted in substantial changes in the risk costs of transporting hazardous materials by rail.

This study's analysis of major hazardous materials releases during the 1982-1992 period, using actual cost data from carriers, indicates that the railroad industry has dramatically improved its ability to handle this traffic safely compared to the previous period. The number of major releases, cost per release, and total amount of risk costs associated with hazardous materials transportation

TABLE 3

AVERAGE RISK COST OF MAJOR RELEASES BY COMMODITY GROUP AND TYPE OF OPERATION

Commodity Group	Type of Operation	
	Running	Switching
Poison Inhalation Hazard	$1,950,838	$779,049
Flammable/Combustible:		
High Environmental	$6,219,709	$1,248,196
Med. Environmental	$1,314,617	$3,674,104
Low Environmental	$997,127	$664,839
All Other:		
High Environmental	$21,199,933	$5,101,833
Med. Environmental	$876,812	$1,057,250
Low Environmental	$818,325	$287,029

all declined substantially. Legal settlement expenses declined, but environmental expenses now account for a much greater proportion of total risk costs. In addition, the percentage of risk costs attributable to switching operations declined, while the percentage attributable to running operations experienced a corresponding increase. Also, the average risk cost of major releases was shown to vary widely depending on the type of commodity involved. Because it was not possible to obtain complete coverage of all major releases and expenses, the study results are best regarded as *minimum* estimates of the total risk costs incurred.

Improvements in railroad safety, tank car design, operating practices, and emergency response have probably all contributed to the substantial decline in risk costs. However, changes in the type of major release relative to the previous study suggest that environmental costs, which can vary substantially by commodity, and running releases now account for a much greater percentage of risk costs than they previously did. These kinds of releases are likely to assume increasing importance in further efforts to reduce or control risk costs.

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ENDNOTES

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1. Railroad accidents reportable to the Federal Railroad Administration (FRA) include any event involving over $6,300 in damage to railroad property or equipment. (See Appendix A, pp. A3-A4.)

2. The Resource Conservation and Recovery Act (RCRA) was passed in 1976 and began to be implemented in 1980. Under the authority of RCRA, the Environmental Protection Agency identifies hazardous waste and promulgates regulations governing the generation, transportation, storage, treatment, and disposal of hazardous wastes. The Comprehensive Environmental Responsibility Compensation and Liability Act (CERCLA) was passed in 1980. CERCLA, also known as Superfund, imposes liability for sites where hazardous substances have been released.

3. The reduction in the accident rate applied to a large number of railroads in the industry, and cannot be attributed solely or in large part to carriers which had been financially troubled.

4. Cohrssen and Covello (1989) pp. 1-26 provide a more extensive discussion of risk analysis concepts and issues.

5. Some small amount of the increase in these exposure measures is due to the expanding number of commodities considered to be hazardous materials. The increase in hazardous materials traffic over the period has not resulted in any discernable change in the mix of hazardous materials carried.

6. The list was formulated using U. S. Department of Transportation (DOT) Hazardous Materials Incident Reports (DOT 5800 forms), the Federal Railroad Administration (FRA) Accident/Incident Database (FRA 6180 forms), and the Railway Progress Institute (RPI)/AAR Tank Car Safety Project's Damaged Tank Car Database.

7. Each carrier's legal settlement expenses were reported for groups of releases, as discussed below, not for individual releases. This was done in order to help preserve the confidentiality of individual legal settlements. Due to pending litigation and other circumstances, legal expenses in a limited number of releases were estimated based on legal costs incurred in releases involving similar commodities. The cost of hazardous materials departments, operational changes, special handling of hazardous materials, and other risk costs that were not specific to particular releases were excluded from the study due to the difficulty inherent in identifying these costs. These categories may represent substantial risk costs in addition to those included in this study.

8. Some releases involved more than one commodity. In most cases, one of the commodities could be clearly identified as being primarily responsible for the costs incurred based on either the type of hazard, degree of hazard, or the amount of the commodity involved. In only a very few cases was there more than one commodity contributing substantially to the costs incurred. In about half of these

cases it was not important to determine which commodity was primarily responsible, since each commodity contributing to the costs belonged to the same group. In the other half of these cases, costs were attributed to one primary commodity, since there was no objective way to allocate the costs among various commodities.

9. The Eder Associates analysis assigns each STCC 49 commodity a score from 0 to 15 based on that commodity's environmental hazard. This hazard assessment takes into account such factors as potential to adversely affect groundwater, surface water, or soil; EPA reportable quantities; biodegradability; likely method of remediation; and chemical structure. The Eder environmental scores for each of the commodities were plotted, resulting in a symmetric, narrow, bell-shaped distribution. The shape of this distribution suggested three environmental categories. Scores of 0 to 6 were interpreted as low environmental hazard; 7 to 9 was interpreted as medium, and 10 to 15 was interpreted as high environmental hazard.

10. Other commodities included in the study because they have been costly to clean up in spite of their low safety and environmental hazards are polyethylene pellets, paraffin, and latex.

11. The components of the Claims Cost Index measure the increase in the price of market baskets of goods and services which comprise typical elements of insurance claims. Examples of these goods and services include physicians' and other medical services, hospital care and rehabilitation, lost time and wages, building materials, plate and safety glass, lawyers' services, and other legal and court costs. The weight accorded to each of these components in the market basket depends on the kind of claim paid. Plaintiff attorney fees and punitive damages are not included in the market basket. The "Other Bodily Injury" index, which represents personal injury claims that do not result from automobile accidents or workman's compensation, was used to convert personal injury settlements. The "Other Property Damage" index, which represents property damage claims that do not result from burglary, fire, or theft, was used to convert property damage settlements.

12. Both RCRA and CERCLA are examples of expanded liability. See note 2 above.

13. See Wolfe (1992) for a more extensive discussion of social inflation. Changes in the legal or regulatory environment may also increase the value of legal settlements or the expense of environmental remediation above and beyond the rate of price inflation. This, too may be considered part of social inflation. However, this study did not attempt to quantify these effects due to lack of reliable data and an interest in obtaining conservative estimates.

14. Environmental damages, personal injuries, and property damages are all civil cases. Plaintiffs could file such cases in either federal or state courts. Consistent estimates of the number of state court cases are not available for all states for the entire period covered by the study. Therefore, the number of federal civil court cases was used as the basis for estimating the rate of social inflation.

15. An alternative specification using five percent per year social inflation increased the risk costs presented below by approximately 10 percent, while an alternative specification using zero percent per year social inflation decreased the risk costs by approximately 10 percent. These alternative specifications had virtually no effect on the percentage distribution of risk costs, and did not affect the number of deaths, injuries, or other results.

16. See US Congress OTA (1986) for a description of emergency response procedures and training.

17. TRB (1994) pp. 28-60 provides a discussion of tank car design. Shelf couplers, which became a common design feature for hazardous materials cars in the late 1970's and early 1980's, have steel plates or "shelves" located above and below the couplers. The shelves help prevent the couplers from disengaging during a derailment or collision. Head shields, which were installed between 1978 and 1984, consist of ½ inch steel plates installed inside or outside the tank car shell. Head shields help prevent the tank from being punctured by the couplers of other railroad cars, broken rails, or other objects. Thermal protection, which was introduced at about the same time as head shields, consists of an insulating jacket around the tank. This reduces the exposure of the contents to heat from a fire, reducing the chances of an explosion.

AAR (1993) provides a listing of railroad operating practices for hazardous materials. Speed restrictions for trains carrying hazardous materials and installation of wayside defect detectors at regular intervals help reduce the chance of derailments on the road. Limitations on car cut size and switching speed help reduce the chance of a derailment in yard or switching operations.

18. The number of deaths in the current study agrees with that reported in USDOT RSPA (1982-1992), Exhibit 1.

19. Barkan, Glickman, and Harvey (1991) discuss the rapidly increasing costs of remediating releases involving a limited number of hazardous materials that are especially difficult to clean up when spilled.

20. The sole exception to this pattern is the medium environmental category for Flammable/Combustible switching, which includes one rather expensive release.

21. Halogenated organic compounds (HOC's) are commonly used as degreasing agents. They are difficult to remediate because they are denser than water and penetrate deeply into aquifers. In addition, the standards for remediation are stringent, since some HOC's are suspected carcinogens.

22. The previous study counted only yard and siding releases as switching releases. This is a somewhat more narrow definition than used in the current study.

APPENDIX
MEASURES OF SOCIAL INFLATION, 1982-1992

	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	CAGR
United States Population	232.188	234.307	236.348	238.466	240.651	242.804	245.021	247.342	249.900	252.671	255.462	0.96%
US District Court Cases												
Civil	206,193	241,842	261,485	273,670	254,828	239,185	239,634	233,529	217,879	207,690	226,895	0.96%
Tort	34,218	36,484	37,522	41,593	42,326	42,977	44,961	42,090	43,759	37,287	36,469	0.64%
Personal Injury	30,134	32,152	33,473	37,560	38,248	39,173	41,148	38,361	40,593	34,007	33,147	0.96%
Property Damage	4,084	4,332	4,049	4,033	4,078	3,804	3,813	3,729	3,166	3,280	3,322	-2.04%
Environmental	394	465	671	652	641	703	889	938	958	1,075	1,252	12.26%
US Court of Appeals Cases												
Civil	18,784	20,249	21,725	23,571	24,291	25,538	26,674	26,975	27,116	27,461	29,975	4.78%
US	5,517	5,820	6,259	6,744	6,415	6,292	6,210	6,349	6,626	6,663	7,113	2.57%
Private	13,267	14,429	15,466	16,827	17,876	19,246	20,464	20,626	20,490	20,798	22,862	5.59%

CAGR = Compound annual growth rate.

Source: Administrative Office of the U.S. Courts, Annual Report of the Director, 1982-1992