ASSESSING THE RISKS OF TRANSPORTING DANGEROUS GOODS
BY TRUCK AND RAIL
(PART 1)

Final Report

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Procor Limited

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Canadian Pacific Railways

Prepared by:

F.F. Saccomanno, J.H. Shortreed and M. Van Aerde

Institute for Risk Research
University of Waterloo
Waterloo, Ontario
N2L 3G1

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ASSESSING THE RISKS OF TRANSPORTING DANGEROUS GOODS BY TRUCK AND RAIL

EXECUTIVE SUMMARY

1. OBJECTIVES OF THE STUDY

Concerns about the risks involved in the transport of dangerous goods, as well as concerns about the perceptions of these risks, initiated the call for a study of the safety of dangerous goods transport by truck and by rail in Ontario. The objectives of the study were to determine the magnitude of the frequency and the consequences of dangerous goods accidents, incidents and risk, and to examine if thesre were differences between shipments by truck and by rail. In addition, concern about the way these incidents were reported in the media resulted in the inclusion of a risk perception component to the study.

2. THE STUDY'S APPROACH

The study examines the risks involved in transporting dangerous goods by truck and rail. Emphasis has been placed on the first step, the analysis of accident rates. The other steps in the risk analysis are calculated using the best information available at this time, but care should be taken in interpreting the results. The steps used in the risk analysis are outlined below.

Risk can be defined in a variety of ways; in terms of accident rates, fatalities from the "maximum possible event", expected number of fatalities per tonne-kilometer, and so on. In this study, the risk is estimated as the number of fatalities per tonne of goods shipped from an origin to a destination. The fatalities include two main groups: persons killed in the accident, and persons killed as a result of the release of the dangerous good carried. Since a per shipment basis is dependent on the characteristics of the road and rail routes, risk is also compared on a tonne-kilometer basis using similar environmental characteristics.

First, estimates of average truck and rail accident rates are determined and the factors that cause deviation from the estimates are quantified. Second, the consequences of dangerous goods releases following the occurrence of an accident are estimated on a per truck- or car-load basis. These two steps provide an overall assessment of the general risk involved. In step 3, the estimates of truck and rail accident rates and the corresponding consequences are compared based on the analysis of a chosen transportation corridor. Finally, in step 4, the perceptions of dangerous goods incidents are examined, using the media as a surrogate of public opinion. Newspaper reports are examined for dangerous goods spill types, quantities, locations, and consequences.

3. TRUCK AND RAIL ACCIDENT RATE ANALYSIS

In order to examine the relative frequency of truck and rail accidents, an analysis was performed of truck accidents within Ontario for 1983, and for rail accidents in Canada from 1980 to 1985. The analysis did not make a distinction between regular trains/trucks and dangerous goods trains/trucks, since the number of dangerous goods cars involved in an accident was not indicated in the Railway Transport Committee (RTC) data base, or in truck accident records for 1983.

a. Analysis Approach

Accident rates for different conditions and situations were examined using a loglinear analysis. This involved a classification of all accident occurrences and corresponding exposure measures into a number of cross tabulations. A loglinear approach was used because it is best suited to determine the relationships between the factors that affect accident rates.

This loglinear analysis assumes that a standardized reference accident rate exists for some prespecified set of accident conditions. In addition, it assumes that all deviations from this standardized rate can be expressed as a product of a series of multiplicative factors. Some of these factors are first order, as they consider only the impact of one variable by itself. However, second and third order factors are also introduced to account for the interaction of factors. The significance of variables is also determined.

The final result is a formula which allows accident rates for any set of conditions to be calculated as the product of the base accident rate multiplied by the various contributing factors. This allows unique accident rates to be calculated for each road or rail link in view of its particular characteristics.

b. Truck Accident Analysis

The analysis of truck accident rates considered a total of 1955 police accident reports for large trucks for 1983 within Southern Ontario. The corresponding exposure traffic volumes were based on the 1983 MTC Commercial Vehicle Survey and the MTC highway traffic volume counts. These accident occurrences and truck flows were categorized using 22 variables which emphasized the road, vehicle and driver characteristics as well as the accident environment. Estimation of detailed truck accident rates were limited to those occurring on the travel links; these represent about 80% of all accidents.

The results of this analysis indicated that truck accident rates are lower on freeways, on flat terrain and on busier highways. Higher accident rates were found for trucks and tractors as opposed to combination vehicles, for empty trucks versus loaded ones, and for older versus newer trucks (except for trucks less than one year old). The four most common types of defects associated with truck accidents were found to be brake failure, tire puncture/blowout, wheel/suspension defects, and trailer hitch defects. In terms of driver-related factors, accident rates decreased proportionately with increased driver age. Actions associated with accidents were found to be speeding, improper passing and disobeying directions. Finally, driver fatigue was overrepresented but only accounted for 1% of all accidents.

c. Rail Accident Analysis

Rail accident frequencies for all of Canada were analyzed for the period from 1980 to 1985 as reported by the RTC, while accident rates were calculated based on exposure data provided by CN and CP. The accident rates were broken down to compute separate rates for different general accident causes, while the exposure data were utilized to determine separate rates for different types of track, speeds and geographic regions.

In general, it was found that from 900 to 1200 reportable accidents and incidents occur each year, with the majority of these at railroad/highway crossings. Derailments occur at a rate of a little less than 1 every day, while collisions occur at a rate of about 1 every 4 days. However, to offset the overrepresentation of crossing accidents, it should be noted that of the 400 occurrences involving dangerous goods (from all sources, including leakers, in yards, etc.) per year only 5% result from crossing accidents, while 63% result from derailments and 32% result from collisions. A more detailed analysis of rail accident causes indicated that derailments can be attributed to fixed plant, rolling stock and operational causes, approximately 38%, 29% and 26% of the time respectively. However, collisions can be attributed to operational causes alone nearly 84% of the time.

An initial examination of mainline accident rates for different conditions indicated that considerable regional differences exist, that collisions and derailments are 1.4 and 2.0 times more likely on single as opposed to double track, that designated speed has only a small impact on accident rates, and that tracks with higher volumes have lower accident rates per car carried. Yard collision and derailment rates were found to be 22.5 and 2.6 times higher than the corresponding mainline rates, a similar strong regional factor was found, and yard accidents per car were found to decrease for busier yards.

A loglinear analysis was performed to assess any interaction effects for rail accident causation. This analysis only produced a satisfactory result for mainline derailments, due to a lack of data for other accident modes. However, the findings of this model were in general agreement with the initial examination of accident rates. There was a regional factor (highest accident rates were in the Atlantic Region, and the lowest were in the Central Region). For volumes less than 100 million ton-miles, multiple tracks had higher derailment rates for all regions, although single track had higher rates at higher volumes. In general, track with higher volume classes experienced lower accident rates.

d. Comparison of Accident Rates

In both the truck and rail situation, the difficulty in deriving accident rates per measure of exposure is in terms of the classification by exposure type. The loglinear analysis was used to determine interaction effects for rail and road accidents. This analysis was successful for the determination of truck accident rates, but was less successful for rail accident rates. Only mainline derailments could be modelled, due to a lack of data on other accident modes. In the absence of loglinear expressions, accident rates for mainline collisions, and derailments and collisions in yards were estimated directly from the RTC data.

For the Sarnia to Toronto LPG shipment studied, typical truck accident rates were 8.9 accidents per million tonnes shipped, versus 1.6 accidents per million tonnes shipped by rail. Thus, rail is estimated to have only 18% as many accidents as an equivalent truck shipment. The accident rate comparison includes adjustments for non-link accidents for the truck mode, crossing accidents for the rail mode, and other accident causes that were not modelled in detail.

4. CORRIDOR RISK ANALYSIS

In order to place the above findings on truck and rail accident rates into perspective, a specific transportation corridor between Sarnia and Toronto was analyzed. Shipments of LPG were considered in both modes, and accident rates and consequences were analyzed separately.

a. Route and Load Characteristics

Two truck routes were considered. A minimum distance route, which is 285 km long and follows primarily a non-freeway route, and a minimum time route, which is 292 km long and follows a freeway route, were considered. Truck shipments using both single and double trailer trucks were considered. Single and double trailer trucks were assumed to carry 25 tonnes and 30 tonnes respectively.

For rail transport a 274 km long route was selected which passed through London, Brantford, Hamilton and Mississauga. The rail cars were assumed to be carrying a payload of 80 tonnes.

b. Comparison of Accident Experience

Estimated accident rates at truck intersections and ramps, and rail grade crossings were included in the analysis of the corridor accident rates.

A comparison of the potential accident experience for each mode indicated that on a per vehicle basis, truck transport was an average of 2 times more accident prone. Lower accident rates were found for single trailers as opposed to double trailers. Relatively small accident rate differences were found when comparing truck route A vs. B, but both routes were consistently more accident prone than the rail route.

The above analysis results considered a single truck and a single rail car. However, for a comparable amount of total material shipped, a multiplier of approximately 80/25 should be applied to the truck accident rate. If such a multiplier is included, the truck accident rate is shown to be 6 times higher than the comparable rail rate.

c. Accident Consequences

It is not sufficient to equate the accident rate directly to the relative safety or risk involved. Since rail car accidents involve a larger payload than trucks, and consequently can result in a larger damage area, this aspect of risk was also considered. Specifically, following the occurrence of an accident, the probability of a release, the size of the release, and the population exposed to the release were considered to provide a more comprehensive estimate of the risk involved.

The components of the risk analysis model that estimate the release of goods in an accident and the development of damage areas are not of the same quality as the accident rate analysis, which was the main focus of this study. Thus, the risk comparisons should be treated with some caution. The model components will be improved in future studies.

The results of the corridor analysis are summarized in Table 7.11, included here as Table E.1. For the corridor shipment of LPG, the risk by truck is estimated as 0.36 fatalities per million tonnes shipped. The comparable risk for rail shipments is 0.1 fatalities per million tonnes shipped. The risk of fatality for rail is only 28% of that for trucks.

Table E.1 illustrates that the vast majority of the truck fatalities are the result of the accident itself, while for rail the fatalities due to the accident and the dangerous goods are similar in magnitude. It should be noted that the risk expressed as fatalities due to the dangerous goods include large events with very low probabilities. These events may never take place, and the risk estimates given in the first column of Table E.1 will generally be considerably greater than historical experience because of this consideration.

Considering the estimated fatalities due to the dangerous goods, given in Table E.1, the rail risk is 3 times that for truck. This difference is due to the characteristics of the corridor, specifically the much higher density of population along the rail route in comparison to the truck route.

Comparing risks due to the dangerous goods movement with similar population densities, Tabel E.1 shows that there was no difference found between truck and rail, and the difference in total risk in this case is even greater.

5. RISK PERCEPTION

As most public reaction to safety issues is not rooted in a scientific analysis of the problem, but rather the media's presentation of the problems, a preliminary analysis was performed of the media's presentation of the risk of transporting dangerous goods. The reporting of different types of accidents was traced in the media to examine the relationship between the amount of reporting and the severity of the incidents.

TABLE E.1

COMPARISON OF TOTAL FATALITIES FOR LPG SHIPMENT FROM SARNIA TO TORONTO BY ROAD AND RAIL

	Estimated Fatalities per Million Tonnes from Sarnia to Toronto		
	Due to LPG	Due to Accident	Total
ROAD Singles Route A	0.02	0.34	0.36
Doubles Route A	0.02	0.35	0.37
RAIL	0.06	0.04	0.10

	Estimated Fatalities per Million Tonnes from Sarnia to Toronto (Assuming equal population densities)		
	Due to LPG	Due to Accident	Total
ROAD Singles Route A	0.02	0.34	0.36
RAIL	0.02	0.04	0.06

The analysis was based on accident records reported to the Transport Canada from January 1986 to August 1987. A search of the Toronto Globe and Mail and the Toronto Star newspapers was performed, to try and match their reports of accidents with the Transport Canada data. Surprisingly, a number of observations from the Globe and Mail and Toronto Star newspaper files were found to be absent from the Transport Canada file.

While it was the original intent to directly compare truck vs. rail accidents for the same commodity, amount released and amount of population exposed, reports of such matches in the newspapers were found to be too few to be statistically significant. However, some initial more aggregate observations were possible. First, there is a direct correlation between the amount of media coverage and the severity of the incident. Second, there is a clear consensus that Class 3 (flammable liquids) incidents are more severe than comparable Class 8 (corrosives) incidents. Third, it appeared that for a newspaper article to contain more than 200 words, the incident had to either involve a death, an evacuation, or more than 3 injuries. Finally, it should be noted that only about 4% of all the incidents in the Transport Canada file were reported in either the Globe and Mail or the Toronto Star. It was not possible to compare the perceptions of truck and rail accidents, due to insufficient data.

6. CONCLUSIONS

The closer look at the relative safety of shipping dangerous goods by truck vs. rail indicates that the problem involves a number of rather diverse factors. The systematic approach presented in this report provides one avenue for addressing these issues in an objective manner, but still includes a considerable amount of subjective interpretation of results.

However, despite its limitations, the approach provides several useful insights into the problem by quantifying a variety of the measures that can be utilized to measure relative safety or risk. Preliminary results indicate that the risk of transporting dangerous goods by truck is greater than the risk of transporting them by rail. The follow-up study to be performed under the URIF contract will be used to confirm these results.

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ASSESSING THE RISKS OF TRANSPORTING DANGEROUS GOODS BY TRUCK AND RAIL

1. INTRODUCTION

1.1 Background

While incidents involving dangerous goods occur infrequently, their consequent damages to people and property can in many cases reflect very high social costs. Public perceptions of risks associated with the transport of dangerous goods by truck and rail are generally influenced more by the consequences of potential spills than by their frequency of occurrence. The situation is especially critical for the railways, where consequent damages from potential spills are perceived to be more serious on rail than on roads, by virtue of the volume of dangerous goods being carried by rail. The Canadian Transport Commission (CTC) has reacted to these perceptions by imposing strict regulations on the shipment of dangerous goods by rail for those situations where the potential for damage is most severe, for example spills taking place in populated areas.

Commonly held perceptions on the relative risks of transporting dangerous goods by truck and rail may not be supported by strong empirical evidence. In fact, it is unlikely that regulations based solely on perceptions of modal risks will prove to be efficient from a safety perspective. Marginal gains in safety are frequently achieved at the expense of major increases in transport costs. In some situations, regulations have resulted in significant risk transfer from one jurisdiction to another, without any net gain in public safety. A distorted view of the risks associated with transporting dangerous goods by various modes can result in regulations that produce significant misallocations of resources, unnecessary interference in the efficient flow of goods, and high externality costs.

The essential concern for the transport of dangerous goods is that policies are currently being established in the absence of a comprehensive understanding of the risks involved. While shifts in dangerous goods shipments from rail to truck could affect higher accident rates, the specific nature of these relationships and their effect on overall transport risks is not well understood. Statistical evidence on the nature of accidents involving truck and rail shipments is incomplete. Where information on safety exists, each mode is treated separately in the analysis making a comparison of statistical results between modes very difficult. Comprehensive information on the relative risks of transporting dangerous goods by truck and rail is generally biased by inadequate data and incompatibilities in risk measures between the two modes.

This study addresses the relative safety of transporting dangerous goods by truck and rail. It adopts a comprehensive view of risk analysis that considers both the likelihood of incidents involving truck and rail shipments, and their consequent damages. The sensitivity of risk to changes in various mitigating factors is considered explicitly in the analysis to yield a risk spectrum for each mode and various shipment characteristics. Such a consideration of a risk spectrum provides a more comprehensive view of the safety implications of shipping dangerous goods by a given mode than is possible by considering a more confined "worst-case scenario". The results of this analysis should provide a strong empirical basis for developing effective and stable policies for the safe transport of dangerous goods in various situations.

1.2 Objective of the Study

The objective of this study is to assess the relative risks of transporting dangerous goods by truck and rail using a comprehensive risk analysis model developed by the Institute for Risk Research (IRR). The model is able to account for a wide range of factors that affect the cause of accidents, the probability of release from containment, the hazard areas associated with the spillage of certain commodities and the consequent damages to population, property and the environment.

The objective can be expressed in terms of four distinctive procedures:

1. Multivariate Analysis of Factors Affecting Truck and Rail Accidents

   Conduct a comprehensive analysis of factors affecting accident rates for truck and rail. Accident frequencies for each mode are considered in terms of compatible measures of travel exposure. This analysis permits an efficient evaluation of the statistical significance of main and higher order effects in accident causation, and serves as a basis for calibrating comprehensive accident rate expressions for truck and rail shipments. Since truck and rail accidents are affected by different factors, the multivariate analysis of accident and exposure data will be carried out separately for each mode.

2. Calibration of Accident Causation Models

   Calibrate statistical models of truck and rail accident rates. The coefficients in these models give aggregate measures of truck and rail accident rates for various combinations of mitigating factors. These modifiers permit estimates of accident rates for truck and rail that are sensitive to a wide range of conditions, such as road and track conditions, vehicle and driver characteristics and operating environment. The resultant statistical expressions can be used to estimate accident rates for truck and rail for individual links in the road and rail network taking into account various conditions of shipment and roadside environment.

3. Estimate Risks for Representative Dangerous Goods for Truck and Rail Shipments

   Conduct a comprehensive risk assessment of transporting dangerous goods by truck and rail using the risk analysis model developed by the Institute for Risk Research. The purpose of this assessment is to develop an appreciation and understanding of the relative risks associated with shipping certain types of dangerous goods by truck and rail for varying conditions. The risk analysis is carried out in two stages: 1) For a representative number of dangerous goods, several "look-up" tables of accident rates, release probabilities, release rates and hazard areas are developed for different classes of potential damage. Since these values are not location specific they can be applied on any section of the road and rail network. 2) Given a corridor where truck and rail compete for market share, link-specific risks to adjacent population and property are obtained for both modes for various mitigating factors and damage types.

4. Comparison of Risk Perception with Objective Risk Criteria

   For a selected number of incidents involving dangerous goods on truck and rail, objective measures of accident severity are obtained and compared with corresponding media coverage of each incident. This analysis should provide an understanding of the perception of risks associated with specific incidents on each mode relative to the actual hazards posed by these incidents.

1.3 Outline of Risk Analysis Process and Scope of Study

Figure 1.1 shows the organization of the risk analysis model. The risk analysis process adopted in this study consists of five major components:

1. Analysis of factors affecting truck and rail accident rates.
2. Estimating release probabilities and rates by fault type.
3. Estimating hazard areas for various types of release.
4. Obtain link-specific population and land use distributions.
5. Estimate link-specific risk spectrum for individual shipments.

Accident data are gathered from a number of sources, anc broken down into different causal classes. Truck and rail flow data (exposure) are used to determine accident rates, expressed as the number of accidents per unit of travel exposure for a number of causal factors. These causal factors are then analyzed using a form of the loglinear statistical model called the Generalized Linear Interactive Model (GLIM). GLIM uses maximum likelihood techniques for estimating Lambda parameters in the loglinear model of accident rates.

The nature and frequency of accidents involving dangerous goods shipments are major features affecting the probability of release from containment. In the risk model, release probabilities for a given containment system are obtained from a fault tree analysis of the release process. The nature of release from containment affects the quantity and rate of release in a given accident situation. A series of damage propagation relationships for various material properties are used to obtain hazard areas for any spill situation and damage class. Damages are considered in terms of fatalities, personal injuries, property impacts and environmental impacts. The various risk implications of accidents involving certain types of dangerous

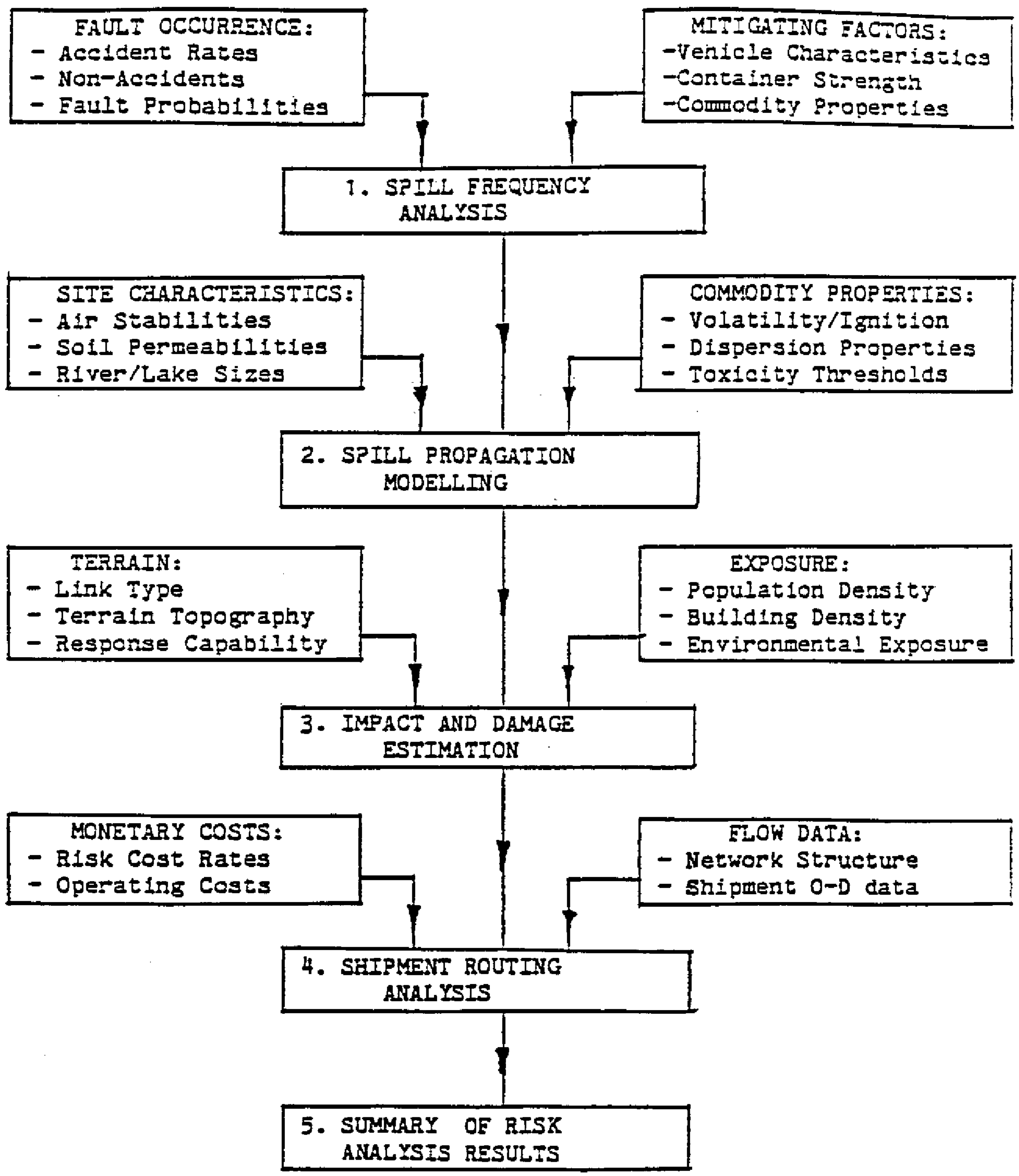

Figure 1.1. Major Elements of the Risk Analysis Model.

goods are determined by applying the risk model to specific links of the rail and road network. Based on the length and type of link, its population and property characteristics, and information on its environment, the expected damages associated with specific shipments of dangerous goods can be obtained on a "per truck" or a "per rail car" basis.

It should be noted that this study focuses on the determination of accident rates as the first step in the risk analysis model. The other parts of the risk analysis model are estimated using the best information available at this time. The methodology for the risk model was developed under a contract with Transport Canada, but many parts of the model require refinement and calibration. It is expected that the follow-up to this study (sponsored by matching dollars from the University Research Incentive Fund) will concentrate on improvements to other components of the risk analysis model.

Table 1.1 presents a summary of Canadian intercity freight transport activity and the associated risks for 1986. While the rail data is reasonable accurate, the truck data represents estimates with a range of ± 15 to 20%. Truck data is based on information from Ontario (Ontario Ministry of Transportation and Communications, 1985) and Alberta (Alberta Transportation and Utilities, 1986), and data from the Insurance Bureau of Canada (Insurance Bureau of Canada, 1985). Note that there were 22,060 heavy truck (over 10,000 lb gross vehicle weight) accidents in Canada, excluding Alberta and Quebec (Transport Canada, 1988).

Unlike rail, road data do not allow for the separation of deaths by employees and others. However, it is thought that the vast majority of the 400 truck accident related deaths each year in Canada are non-employees.

Table 1.1 indicates that the accident itself represents the most important risk faced as a result of transportation. Comparisons between rail and road are limited because of the high degree of uncertainty with the truck data.

TABLE 1.1 SUMMARY OF ESTIMATED INTERCITY FREIGHT TRANSPORT ACTIVITY AND RISKS IN CANADA FOR 1986

	ROAD	RAIL
Billion tonne kilometers	90 +	450
Number of Accidents	9000 +	886
Accidents Involving Dangerous Goods	350 +	200 *
Fatalities in Accident		
Transport Employees	no estimate	19
Others	no estimate	81
Total	400 +	100
FATALITIES DUE TO DANGEROUS GOODS	9 ^	0

+ Estimates ± 15-20%

^ Data from CANUTEC - includes fatalities related to both DC release and accident

* DC related train accidents - only a small portion of these accidents involve a dangerous goods car