9. CONCLUSIONS

In this study, the risks associated with transporting dangerous goods by truck and rail have been assessed in terms of accident involvement and the expected impacts of specific material spills on population and property. Several important conclusions can be drawn from the results obtained in this study:

1. For a range of route and traffic conditions, accident rates for large trucks are significantly higher than for rail. Higher truck accident rates were observed for both tonne-kilometer and car-kilometer measures of travel exposure. Rates expressed on a tonne-kilometer basis take into account higher rail car carrying capacities, and as a result fewer shipments for the same total volume being transported. These results differ significantly from Glickman (1988), in which release accident rates on a car-mile basis for rail were estimated to be higher than corresponding rates for trucks. Differences between these results and those reported by Glickman can be attributed to reliance by Glickman on release involvements and more aggregate measures that ignore interaction effects in accident environment. Significant differences were also observed for the estimated exposure levels on both modes.

2. Any comparison of truck and rail accident involvement must take into account a wide spectrum of factors that influence accidents on each mode. Truck and rail accidents are affected by various combinations of track/road, vehicle and traffic conditions. Statistical models of accident rates need to be calibrated to account for various levels of interactions among influencing factors in the accident profiles. Failure to consider factor interactions in accident analysis may give rise to counter-intuitive results, eg., lower accident rates at higher speeds for trucks, where higher speeds tend to be associated with safer freeway transport.

3. Loglinear models of truck and rail accident rates best represent factor interactions affecting accidents on each mode. In general, the calibration of loglinear models of accident rates is inhibited by two problems: a) incompatabilities between categorial and continuous factor inputs in the accident rate expression, and b) paucity of accident involvement data for various combinations of effecting factors. Accident rate in this study has been expressed as the ratio of accident frequency to travel exposure for a given combination of effecting factors. Since the exposure term is a continuous factor input, it is difficult to incorporate this term directly into a loglinear expression of categorical influencing variables in the accident rate expression. This study has adopted a GLIM loglinear approach, that permits the inclusion of exposure as continuous covariate in the accident rate relationship.

4. The truck accident rate loglinear model consists of eight effecting terms including: road type, truck type, truck model year, traffic volume, traffic pattern, load status, age of driver, age of vehicle, and time of day. Rail

accident expressions consist of four factors: region, track volume (quality), track type (single or multiple), and average subdivision operating speed. The only statistically significant models of rail accident rates were obtained for derailments on mainline. Collision accidents and rail accidents taking place in rail yards did not exhibit statistically significant interaction effects. Both truck and rail accident rate expressions reflect statistically significant first, second and third order interaction terms. The presence of third order factor interactions in the truck and rail accident rate models suggests that a thorough comparison of rates must be able to account for a wide-range of factors in the accident profile. A simple comparison of aggregate accident rate values would not provide a complete understanding of the relative safety merits of each mode.

5. The consequences of material spills in the transport of dangerous goods were observed to be more severe for rail than trucks. This is due to higher carrying capacities for rail cars relative to trucks carrying the same material. Assuming a fully loaded LPG rail tanker carrying 80 tonnes and a fully loaded single truck tanker carrying 25 tonnes, the areas of hazard for rail and truck spills are 0.28 Km^2 and 0.11 Km^2, respectively. This is based on a 1% mortality rate and medium instantaneous release rate. Differences in hazard areas for rail and truck spills are affected by the nature of the material, the release rate and the extent of impact under consideration.

6. In general, only a small proportion of rail and truck accidents involving dangerous goods actually result in a release of material. Much of the damage associated with rail and truck accidents involving dangerous goods takes place as a direct result of the accident, and is incidental to the type of material being transported or the extent of spill that may occur. Given the infrequency of spills and their dependence on the severity of accidents in general, closer attention should be paid to strategies aimed at accident reduction.

7. The impacts of materials spills are especially critical for vapour cloud dispersion, where the associated hazard areas are expected to be more extensive. For other types of materials, for example pool fires for gasoline, consequent injuries and fatalities tend to be confined to the immediate area of the accident. Hazard areas associated with materials spills on both modes are affected by the dispersal properties of the material, weather conditions, containment system features and extent of damage being considered. In estimating the consequences of accidents involving the spill of dangerous goods on truck and rail, it is necessary to consider a spectrum of damages. Emphasis on the so-called worst case scenario produces results that are not applicable to all conditions under which dangerous goods are transported. The results of this study suggest that rail by virtue of greater spill sizes result in higher consequent damages for most accident situations.

8. Risk exposure can be expressed as the product function between accident rate, spill probability and consequent

damages. The expected risks on rail from potential material spills are higher than on road, due to higher consequent damages for rail. An application of a comprehensive risk assessment model to a selected road and rail corridor in Southern Ontario suggests that transporting dangerous goods by road will result in lower expected risks than rail per tonne shipment of material. This is especially true for non-expressway sections of the road option, where higher truck accident rates were estimated. For example, the expected fatality rate on the expressway corridor (Route A - singles) is 1.76E-08 compared to 6.07E-08 for rail, where both modes are carrying LPG's. This is due mainly to higher population densities. For comparable population densities, the two modes show similar risks on a per tonne-km basis.

9. A comparison of truck accident rates on the Sarnia - Toronto corridor between single and double combination vehicles suggest higher rates for the latter configuration. Doubles appear to be less prone to accidents on routes consisting of expressway links (Route A) than on non-freeways (Route B). Although the accident rates for doubles are still higher than for singles on Route A, the differences between the two truck types are not great. When exposure is expressed in million tonnes, the cumulative accident rates on the Sarnia - Toronto corridor were estimated to be 8.5 accidents for doubles compared to 8.3 accidents for singles on Route A. This can be compared to a difference between 8.8 accidents for doubles and 7.1 accidents for singles on the non-expressway Route B for the same corridor. All truck accident rates are considerably higher than rail on the same corridor. The rail rate expressed per million tonnes is 1.6 for the Sarnia - Toronto corridor.

10. Preliminary results obtained from the application of the Transport Canada risk analysis model indicate that expected impacts of spills of a representative dangerous good (LPG) in terms of fatalities for the Sarnia - Toronto corridor are approximately three times higher for rail than trucks. Further work on the damage propagation relationships is required, however, before these results can be confirmed.

11. Newspaper articles found in Canada's major newspapers were examined over a limited period (1986 to 1987), in order to compare accident reports with those found in the CANUTEC data base for the same period. It was found that only about 4% of all incidents in the CANUTEC file were reported in either the Globe and Mail or the Toronto Star. The newspaper coverage in terms of number of articles and number of words appears to be related to the severity of the incident, as measured by population density, type of commodity spilled, the size of the spill and the consequences of the incident. There was a lack of data to perform a direct comparison of the reporting of rail and road accidents; it will be necessary to sample newspapers over a longer time period than was originally chosen to perform this comparison.

12. This study has been hampered by the availability of

suitable accident and exposure data. The problem has been especially critical for truck accident analysis. Accident data for trucks are based on police reports. In many cases these reports lack technical specifications. More problematic is the unavailability of good exposure data in most jurisdictions. Where these data have been collected, the nature of the exposure information tends to be incompatible with accident data. For example, accident rates for different truck types on certain types of roads require information on travel by truck type on each type of road. This information is simply unavailable. In order to estimate exposure for compatible accident information regarding the vehicle and traffic environment, it has been necessary in this study to obtain adjustment factors for exposure based on independent site counts from Weighing Station surveys. Vehicle count data are not always available in most jurisdictions, and where they are available the information is not always compatible with the requirements of safety studies. For rail, both accident and exposure information is more readily available. The basic problem, however, is the lack of information on the post-accident phenomenon. This information is required to calibrate release models of the truck and rail containment system, necessary to estimate the probability of material release in a given accident situation and the corresponding hazard area.

In conclusion, it should be emphasized that the results of this study show that the major risk in the transportation of dangerous goods is the accident itself. Analysis of CANUTEC data showed that most fatalities and injuries were directly attributable to the accident, rather than to exposure to the dangerous good. Thus, a reduction in risk for dangerous goods transport involves reduction in the number of accidents.

10. RECOMMENDATIONS

The recommendations for future work to be performed under the University Research Incentive Fund (URIF) extension to this project fall into three areas: accident analysis, the risk analysis model, and risk perception. The details of these recommendations are given below.

i. Accident Analysis

The accident data base for trucks should be extended to the years 1984 to 1986, in order to perform a time series accident analysis. The source of these data for Ontario is the 1984-1986 Police Accident files. These files also contain information on causes of accidents; extracting this information will allow an analysis of situational factors.

An investigation of rail accidents, considering the make-up of the train (location of dangerous goods cars in the train and the presence of buffer cars), and the likelihood of dangerous goods car involvement in an accident would allow a more accurate estimation of the likelihood and consequences of rail accidents, eliminating possible biases involving the overestimation of dangerous goods car involvement. The causes of accidents should also be examined to analyze the situational factors involved in accidents. A more detailed analysis of rail intersections, ramps and grade crossings should be done.

ii. Risk Analysis Model

A number of improvements and refinements in the risk analysis computer model can be made. An investigation of the damage areas incorporated into the risk analysis model can be performed by analyzing consequences of accidents for rail and road, and comparing these to the consequences obtained by the model.

The commodity considered in this report (LPG) was chosen as representative of different types of damage and consequences. The inclusion of an additional representative commodity, such as gasoline, will allow a comparison of truck and rail accident consequences for other damage types.

iii. Risk Perception

An extension of this work involves a computer search of all newspapers, covering a longer time period than was originally considered. A detailed content analysis of selected articles can then be performed, and compared against objective measures of risk as obtained from the risk analysis model.

GLOSSARY OF TERMS

AAR	American Association of Railroads
AADT	Average Annual Daily Traffic
Beta	Parameters in the Accident Rate Calculation
CANUTEC	Canadian Transport Emergency Centre
CN	Canadian National
CP	Canadian Pacific
CTC	Canadian Transport Commission
CVS	Commercial Vehicle Survey (Ontario)
DC	Dangerous Commodities
DG	Dangerous Goods
FRA	Federal Railway Administration (U.S.)
GLIM	Generalized Linear Interactive Model
IRR	Institute for Risk Research
Lambda	Modifiers to the Mean Accident Rate
LPG	Liquefied Petroleum Gas
MTC	Ministry of Transportation and Communications (Ontario)
PDO	Property Damage Only
PIN	Product Identification Number (for Dangerous Commodities)
RTC	Railway Transport Committee (Canada)
URIF	University Research Incentive Fund (Ontario)
VMT	Vehicle Miles Travelled

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