4. RAIL ACCIDENT ANALYSIS

Most Canadian rail accident analyses, such as the work by Doswell et al. (1986), have been done at an aggregate level where types of accidents are studied, but not the underlying causes of these accidents. Disaggregate analyses have been accomplished in the United States to various extents, using American transportation data (see American Association of Railroads, 1986 for example). These analyses, however, are not readily applicable to Canadian conditions.

In this report, an analysis of rail accident frequencies and rates is carried out at both an aggregate and a disaggregate level. At both levels of analysis all rail accidents are considered, and the special characteristics of incidents involving dangerous goods are distinguished in a few specific situations.

4.1 Rail Accident and Exposure Data

To provide an overview of Canadian rail accident experience, aggregate accident frequencies tabulated annually by the Canadian Transport Commission (CTC) and summarized and reviewed by the Railway Transport Committee (RTC) are used. Statistics Canada car load data are also used.

Table 4.1 provides a summary of the number of derailments, collisions and crossing accidents in Canada from 1980 to 1985 as reported by the RTC (1986). This table indicates the number of accidents that involved dangerous goods and the number of dangerous goods incidents not involving transportation accidents. These data indicate that from 900 to 1200 reportable rail accidents occur per year and that the majority of these are crossing accidents. There also appears to be nearly one derailment every day of the year and one collision every 3 days. While the total number of annual accidents exhibits some random fluctuations, it does appear that a significant downward trend in annual accident occurrences exists.

Dangerous goods involvement has increased significantly since 1980, likely due to the requirement that all incidents involving dangerous goods be reported. It appears, however, that this impact may have stabilized at an average rate of nearly 600 occurrences per year. Approximately 63% of transportation accidents involving dangerous goods occur as a result of derailments; 32% as a result of collisions; and 5% as a result of crossing accidents.

In order to translate the aggregate accident frequencies in Table 4.1 into accident rates per unit of exposure, comparable aggregate rail operating and traffic statistics were required. Such statistics, published by the RTC and annually by Statistics Canada, are summarized in Table 4.2 for the years 1980 to 1985.

Based on aggregate rail accident frequencies and rail operating statistics, aggregate rail accident rates can be determined to provide accident rates per tonne-kilometer and car-kilometer for all of Canada. The results of this analysis are given in Table 4.3.

TABLE 4.1

DERAILMENTS, COLLISIONS AND CROSSING ACCIDENTS 1980-1985

	1980	1981	1982	1983	1984	1985	Avg	Std Dev
- Derailments	292	348	327	254	273	278	295	35.5
DG involvement	65	132	101	94	100	142	106	27.8
- Collisions	97	108	101	92	102	72	95	12.6
DG involvement	44	65	67	56	66	43	57	11.0
- Crossing Accidents	826	763	691	567	596	606	675	103.4
DG involvement	11	4	8	9	10	8	8	2.7
- Total Accidents	1215	1219	1119	913	971	956	1066	136.3
- Total DG accident involvement:	120	201	176	159	176	193	171	28.9
- DG non accident involvement:	107	157	105	288	418	336	235	131.0
- Total DG incidents:	227	358	281	447	594	529	406	142.9

Source: Railway Transport Committee 1986.

TABLE 4.2

OPERATING AND TRAFFIC STATISTICS FOR CN, CP AND VIA
(1980-1985)

a. Freight Car Kilometers (Statistics Canada, 1980-1985)
(x 1,000,000)

	1980	1981	1982	1983	1984	1985	average
Loaded	4622	4615	3649	3960	4274	4079	4200
Empty	3240	3202	2563	2734	2906	2677	2887
Caboose	131	123	93	97	101	98	107
Total	7993	7940	6305	6791	7281	6854	7194

b. Gross Tonne Kilometers (RTC, 1986)
(x 1,000,000)

	1980	1981	1982	1983	1984	1985	average std dev
Total	448700	449700	400900	434200	466900	457700	443000 23300

c. Average Values of Train Characteristics (Statistics Canada, 1980-1985)

	1980	1981	1982	1983	1984	1985	average
# cars/train	72.0	72.9	74.2	76.1	75.6	74.1	74.2
freight car load (tons/car)	49.6	50.8	56.3	53.9	54.9	54.2	53.3
train speed (km/hr)	38.2	38.5	37.1	37.7	37.9	38.5	40.0

d. Gross Freight Car Kilometers (RTC, 1986; Statistics Canada, 1980-1985)

(x 1,000,000)

1980	1981	1982	1983	1984	1985
9046	8852	7121	8056	8505	8445

TABLE 4.3

AGGREGATE ACCIDENT RATES
(RTC, 1986; STATISTICS CANADA, 1980-1985)

a. Train Derailments

	1980	1981	1982	1983	1984	1985	Avg
Number per million gross tonne-km	0.0006	0.0008	0.0008	0.0006	0.0006	0.0006	0.0007
Number per million freight car-km	0.0323	0.0393	0.0459	0.0351	0.0321	0.0329	0.0363

b. Train Collisions

	1980	1981	1982	1983	1984	1985	Avg
Number per million gross tonne-km	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
Number per million freight car-km	0.0107	0.0122	0.0142	0.0114	0.0120	0.0085	0.0115

c. Train Crossing Accidents

	1980	1981	1982	1983	1984	1985	Avg
Number per million gross tonne-km	0.0018	0.0017	0.0017	0.0013	0.0013	0.0013	0.0015
Number per million freight car-km	0.0913	0.0862	0.0970	0.0704	0.0701	0.0718	0.0811

d. Transportation Accidents Involving Dangerous Goods

	1980	1981	1982	1983	1984	1985	Avg
Number per million gross tonne-km	0.0003	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004
Number per million freight car-km	0.0133	0.0227	0.0247	0.0197	0.0207	0.0228	0.0206

4.2 Analysis of Rail Accident Causes

For purposes of a detailed analysis of accident causes, separate records for each individual accident occurrence were obtained for the years from 1980 to 1985, and entered into a computerized data base format. The specific fields within each of the original derailment and collision data base files are summarized in Table 4.4, along with those variables that were subsequently added. A detailed data base of highway-railroad crossing accidents was not analyzed, since these accidents have been shown to depend on both highway and railroad factors, of which only the latter have been assessed. Furthermore, the release of dangerous goods on rail is mainly due to non-crossing accidents; approximately 5% of all dangerous goods involvements occur due to crossing accidents (CTC Annual Report, 1986). The nature of accidents taking place at grade crossings for rail and at intersections for trucks will be investigated separately in the next phase of the study, under the URIF.

The data contained in this detailed data base were found to be in general agreement with the preliminary statistics published by the Canadian Transport Commission, except for the fact that invalid accident observations had been removed from the preliminary statistics and were not present in the more up-to-date accident file. The original data base provided descriptions of accident causes in a qualitative form. Consequently, for purposes of classification and analysis, these qualitative causes were assigned a numerical code describing the type of accident cause.

The accident coding scheme is based on the Federal Railway Administration (1985) Accident Record System (FRA system). This not only provides for a comprehensive set of existing standard codes, but also allows for subsequent comparisons to similar American data, although the damage levels for reporting are different. In the U.S., damages over $6700 (US) are required to be reported. In Canada, this figure was $750 (Cdn) until November 1, 1987, when the level of reporting became $7000 (Cdn). As of January 1, 1988, the level of damage for reporting is $7350 (Cdn).

For purposes of illustration, a subset of some of the FRA cause codes and descriptions is provided in Table 4.5. In addition to the original numerical codes, subsequent codes were periodically added to further differentiate within groups of accident causes. Also, a secondary flag was added, depending upon whether the incident was locomotive or non-locomotive related.

While a tabulation of all accident occurrences for 1980 to 1985 using the initial FRA codes provided some initial insights into the detailed causes of accidents, the findings became more significant when grouped according to the aggregate coding system described below.

TABLE 4.4

FIELDS CONTAINED IN THE ACCIDENT DATA BASE

Derailment	
Record file number	
Date of Incident	
Subdivision	
Mile post	
Cause of accident	
Number of people killed	
Number of people injured	
Dangerous goods indicator	*
Number of units that derailed	
Train tonnes	
FRA Accident Cause Codes	*
Corresponding Aggregate Code	*
Locomotive indicator	*
Various indicators to identify the derailed unit(s)	*
Collision	
Record file number	
Date of incident	
Subdivision	
Railway	
Mile post	
Cause of accident	
Number of people killed	
Number of people injured	
Type of collision	*
Code for the first rolling stock type in collision	*
Code for the second rolling stock type in collision	*
Dangerous goods indicator	
Indicator if collision caused subsequent derailment	*
Number of units that derailed (if derailment occurred)	
FRA Accident Cause Codes	*
Corresponding Aggregate Cause Code	*
Locomotive indicator	*
Logical indicators for type of rolling stock in collision	*

* indicates variables subsequently coded for analysis purposes

TABLE 4.5

SAMPLE OF US FEDERAL RAILWAY ADMINISTRATION ACCIDENT CAUSE CODES

Code Number	Qualitative Description of Primary Accident Cause
101	Roadbed settled or soft
102	Washout/rain/slide/ice etc., damage to track
109	Other roadbed effects
110	Wide gauge (defective/missing crossties)
111	Wide gauge (defective/missing fasteners)
112	Wide gauge (involving gauge rods)
113	Wide gauge due to worn rail
114	Track alignment irregular
115	Track alignment irregular (buckled)
116	Track profile improper
117	Superelevation incorrect
118	Superelevation runoff improper
119	Cross level irregular at joints
120	Cross level irregular not at joints
125	Wide gauge unspecified
129	Other track geometry defects
130	Bolt hole crack or break
131	Broken base of rail
132	Broken weld, field
133	Broken weld, plant
134	Detail fracture from shelling/head fracture
135	Engine burn fracture
136	Head/web separation (outside joint bar limits)
137	Head/web separation (within joint bar limits)
138	Horizontal split head
139	Piped rail

The original FRA coding scheme was summarized into approximately 80 accident causes which belong in one of the following 4 families:

a. track environment related causes (fixed plant),
b. train related causes on the tracks (rolling stock),
c. operational types of causes (rules of operation), and
d. other miscellaneous factors (not classified above).

A summary of the average frequency of these groups of causes for 1980 to 1985 is provided in Table 4.6 for derailments and collisions. This summary indicates that roughly equal numbers of derailments are caused by fixed plant, rolling stock and operational causes, while collisions are attributed almost exclusively to operational causes. Due to the virtual lack of fixed plant and rolling stock related collisions, the number of collisions is approximately one third of the number of derailments. However, when rail car involvements are considered in each train accident, this ratio is reduced to 1 car collision per 13 car derailments.

The derailment and collision frequencies form a basis from which accident rates could be established, when supplemented with corresponding exposure data. Estimation of exposure measures for rail is discussed in Section 4.3 of the report. It should be noted here that the above frequency analysis does provide a good guide for this analysis. For example, the clear distinction between types of accident causes suggests that separate accident rates need to be determined for track, equipment and operational factors. Specifically, as only one third of all derailments are track-related, it would be inappropriate to develop a model which predicts all derailments as a function of track quality. Similarly, the predominance of operational causes of collisions appears to indicate that an explanation of differences in collision accident rates should be based firmly on variables describing operational differences between various rail sections.

4.3 Analysis of Factors Affecting Rail Accident Rates

An analysis of rail accident rates is predicated on the estimation of accident involvement for compatible measures of exposure. As was the case for the analysis of truck accident rates, rail accident rates were obtained by aggregating derailments and collisions in the data base, with respect to underlying environmental causes for which exposure measures are available.

Accident frequencies were classified according to selected average properties of each subdivision. Specifically, the number of derailments and collisions for an aggregate set of causes (Table 4.6) were totalled for each subdivision for the period 1980-85. Subdivisions for which exposure was not available, were excluded from the analysis. Each subdivision was classified according to various combinations of track-related factors, such as regional affiliation, volume class, track environment, subdivision operating speed, and number of tracks (Table 4.7). Regional affiliation serves to reflect various design and operational features that are unique to networks in specific regions of the country. For example, the Mountain Region is likely to be characterized by different vertical and horizontal

TABLE 4.6

SUMMARY OF DERAILMENT AND COLLISION FREQUENCIES 1980 TO 1985

		Average Frequency			
		Derailment		Collision	
		Count	Percent	Count	Percent
a.	fixed plant	120	38	4	3.5
b.	rolling stock	92	29	3	3
c.	operational causes	81	26	97	84
d.	other/unknown factors	17	5	4	3.5
	not applicable to study	7	2	7	6
	Total	317	100	115	100

Table 4.7

VARIABLES FOR PRELIMINARY ANALYSIS

VARIABLES	CATEGORIES
ACCIDENT TYPE	Collision
	Derailment
ACCIDENT CAUSE TYPE	Fixed Plant
	Rolling Stock
	Operational
	Other/Unknown
TRACK ENVIRONMENT	Mainline
	Yard
VOLUME	< 100 million ton-mi/year
	100- 1000 million ton-mi/year
	1000-10000 million ton-mi/year
	>10000 million ton-mi/year
NUMBER OF TRACKS	Single
	Multiple
AVERAGE FREIGHT SPEED	< 35 mph
	> 35 mph
GEOGRAPHIC REGION	Atlantic
	Central
	Prairies
	Mountain

Note: Speed = Subdivision Operating Speed

alignments than the Prairie Region, all other factors assumed constant. Volume class reflects track quality; high volumes require increased maintenance and better design standards.

Freight movements in terms of car-miles and ton-miles for each subdivision on the rail network were extrapolated from various sources, such as CTC Annual Reports, CN-CP Files and Statistics Canada. These flow estimates represent measures of exposure on the subdivision which, when compared to accident frequencies, gives the corresponding accident rate for the subdivision for a given class of accident. For the purpose of comparing truck and rail accident rates, rail exposure is expressed in terms of car-kilometers. From the perspective of productivity on each mode, accident rates for truck and rail are expressed in terms of tonne-kilometers.

Accident rates for various factors affecting train derailments and collisions are summarized in Tables 4.8 and 4.9 for mainline and yard locations, respectively.

4.3.1 Mainline Collision and Derailment Rates

The mainline data for CN rail only included 223 train collisions and 835 train derailments for the 1980-85 period nation-wide. This translates to about 5.0 cars per train derailment and 1.2 cars per collision.

Table 4.8 indicates that regional differences are exacerbated in derailment rates compared to collision rates, with mean (standard deviation) of 0.025 (0.009) and 0.572 (0.221) for derailment and collisions, respectively. As expected, the Mountain Region experienced the highest collision rate at 0.039 collision per million car-miles. The Atlantic Region, on the other hand, reflected the highest derailment rate at 0.907 per million car-miles. The Prairies reflected the safest record for both collision and derailment experience, at 0.017 and 0.298 per million car-miles, respectively.

Subdivisions consisting of single tracks only registered higher collision and derailment rates than subdivisions containing multiple tracks, with a ratio of 1.4 for collisions compared to 2.1 for derailments.

Speed class did not have a significant effect on accident rates for collisions and derailments. This is very likely due to the strong correlation between speed and track quality.

Significant differences in rates were observed for different volume categories. In general, increasing volumes are characterized by lower collision and derailment rates. This supports the assumption that volume class can serve as a surrogate measure for track quality on mainlines.

TABLE 4.8

MAINLINE COLLISION AND DERAILMENT ACCIDENT RATES
(Classified by Region, Volume and Accident Cause)

REGION VOLUME	EXPOSURE car-mi	NUMBER OF ACCIDENTS Collisions (car) TOTAL	FP	OE	Derailments (car) TOTAL	FP	EQ	OE	UNK	ACCIDENT RATES Collisions per mil car-mi TOTAL	FP	OE	Derailments per mil car-mi TOTAL	FP	EQ	OE	UNK
ATLANTIC																	
> 100	8990384	0	0	0	67	59	0	8	0	0.000	0.000	0.000	7.452	6.563	0.000	0.890	0.000
100- 1000	26751020	0	0	0	33	28	0	5	0	0.000	0.000	0.000	1.234	1.047	0.000	0.187	0.000
1000-10000	202954516	10	0	10	254	129	65	53	7	0.049	0.000	0.049	1.252	0.636	0.320	0.261	0.034
>10000	294814016	1	0	1	130	66	48	10	6	0.003	0.000	0.003	0.441	0.224	0.163	0.034	0.020
TOTAL	533509936	11	0	11	484	282	113	76	13	0.021	0.000	0.021	0.907	0.529	0.212	0.142	0.024
CENTRAL																	
> 100	12709195	5	0	5	62	47	2	13	0	0.393	0.000	0.393	4.878	3.698	0.157	1.023	0.000
100- 1000	75013915	23	0	23	131	88	37	6	0	0.307	0.000	0.307	1.746	1.173	0.493	0.080	0.000
1000-10000	806657458	20	0	20	578	251	167	151	9	0.025	0.000	0.025	0.717	0.311	0.207	0.187	0.011
>10000	1706100429	10	0	10	492	190	183	80	39	0.006	0.000	0.006	0.288	0.111	0.107	0.047	0.023
TOTAL	2600480997	58	0	58	1263	576	389	250	48	0.022	0.000	0.022	0.486	0.221	0.150	0.096	0.018
PRAIRIES																	
> 100	10185371	1	0	1	68	57	9	0	2	0.098	0.000	0.098	6.676	5.596	0.884	0.000	0.196
100- 1000	66915963	4	0	4	208	149	29	28	2	0.060	0.000	0.060	3.108	2.227	0.433	0.418	0.030
1000-10000	313474346	4	0	4	204	133	56	15	0	0.013	0.000	0.013	0.651	0.424	0.179	0.048	0.000
>10000	1878098928	29	2	27	195	91	61	43	0	0.015	0.001	0.014	0.104	0.048	0.032	0.023	0.000
TOTAL	2268674608	38	2	36	675	430	155	86	4	0.017	0.001	0.016	0.298	0.190	0.068	0.038	0.002
MOUNTAIN																	
> 100	38661393	7	0	7	191	108	60	18	5	0.181	0.000	0.181	4.940	2.793	1.552	0.466	0.129
100- 1000	71356714	22	0	22	51	34	3	13	1	0.308	0.000	0.308	0.715	0.476	0.042	0.182	0.014
1000-10000	436624991	31	0	31	476	331	78	43	24	0.071	0.000	0.071	1.090	0.758	0.179	0.098	0.055
>10000	2394361698	56	0	56	1043	590	233	219	1	0.023	0.000	0.023	0.436	0.246	0.097	0.091	0.000
TOTAL	2941004796	116	0	116	1761	1063	374	293	31	0.039	0.000	0.039	0.599	0.361	0.127	0.100	0.011
TOTAL	8343670337	223	2	221	4183	2351	1031	705	96	0.027	0.000	0.026	0.501	0.282	0.124	0.084	0.012

EGEND
FP - Fixed Plant
EQ - Rolling Stock
OE - Operational
UNK - Other/Unknown

TABLE 4.9

YARD COLLISION AND DERAILMENT ACCIDENT RATES
(Classified by Region, Volume and Accident Cause)

REGION VOLUME	EXPOSURE car-mi	NUMBER OF ACCIDENTS collisions (car) TOTAL	FP	OE	derailments (car) TOTAL	FP	EQ	OE	UNK	ACCIDENT RATES Collisions per mil car-mi TOTAL	FP	OE	Derailments per mil car-mi TOTAL	FP	EQ	OE	UNK
ATLANTIC																	
> 100	11307	0	0	0	0	0	0	0	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
100- 1000	570437	0	0	0	13	8	0	5	0	0.000	0.000	0.000	22.790	14.024	0.000	8.765	0.000
1000-10000	8059360	0	0	0	2	0	2	0	0	0.000	0.000	0.000	0.248	0.000	0.248	0.000	0.000
>10000	5010674	7	4	3	31	8	18	5	0	1.397	0.798	0.599	6.187	1.597	3.592	0.998	0.000
TOTAL	13651778	7	4	3	46	16	20	10	0	0.513	0.293	0.220	3.370	1.172	1.465	0.733	0.000
CENTRAL																	
> 100	13869	0	0	0	13	0	0	13	0	0.000	0.000	0.000	937.342	0.000	0.000	937.342	0.000
100- 1000	763913	0	0	0	6	1	0	5	0	0.000	0.000	0.000	7.854	1.309	0.000	6.545	0.000
1000-10000	19648359	35	0	35	22	11	3	8	0	1.781	0.000	1.781	1.120	0.560	0.153	0.407	0.000
>10000	76340204	33	0	33	39	12	12	14	1	0.432	0.000	0.432	0.511	0.157	0.157	0.183	0.013
TOTAL	96766345	68	0	68	80	24	15	40	1	0.703	0.000	0.703	0.827	0.248	0.155	0.413	0.010
PRAIRIES																	
> 100	93345	0	0	0	0	0	0	0	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
100- 1000	350121	0	0	0	2	0	0	2	0	0.000	0.000	0.000	5.712	0.000	0.000	5.712	0.000
1000-10000	2506392	1	0	1	4	3	0	1	0	0.399	0.000	0.399	1.596	1.197	0.000	0.399	0.000
>10000	26619533	15	0	15	14	9	5	0	0	0.563	0.000	0.563	0.526	0.338	0.188	0.000	0.000
TOTAL	29569391	16	0	16	20	12	5	3	0	0.541	0.000	0.541	0.676	0.406	0.169	0.101	0.000
MOUNTAIN																	
> 100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
100- 1000	279346	0	0	0	0	0	0	0	0	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
1000-10000	7366841	4	0	4	48	10	23	15	0	0.543	0.000	0.543	6.516	1.357	3.122	2.036	0.000
>10000	61558737	32	1	31	84	44	8	31	1	0.520	0.016	0.504	1.365	0.715	0.130	0.504	0.016
TOTAL	69204924	36	1	35	132	54	31	46	1	0.520	0.014	0.506	1.907	0.780	0.448	0.665	0.014
TOTAL	209192438	127	5	122	278	106	71	99	2	0.607	0.024	0.583	1.329	0.507	0.339	0.473	0.010

LEGEND
FP - Fixed Plant
EQ - Rolling Stock
OE - Operational
UNK - Other/Unknown

4.3.2 Yard Collision and Derailment Rates

Yard movement considers a block of rail cars being marshalled through a yard. Yard engine movements without cars are not considered. Yard accidents are defined as accidents involving cars in railway yards. Yard collision and derailment rates are summarized in Table 4.9. These rates were classified according to regional affiliation, volume and primary accident cause. Track and speed variables were not included in the analysis as the raw data did not reflect the conditions in the yard environment. For example, yard environment is always multiple track and characterized by operating speeds in the less than 35 mph category.

There were 133 yard movement collisions and 123 yard movement derailments for 1980-1985. However, only 127 car collisions were listed in the data, indicating that in some collisions only locomotives (not cars) were involved. About 2.3 cars were involved per derailment in the yard. This is considerably less than the 5.0 cars per train derailment estimated for mainlines.

Total accident rates in rail yards were observed to be several orders of magnitude higher than on mainlines. The yard collision rate of 0.607 cars per million car-miles is about 22.5 times the mainline collision rate. For derailments, however, the total rate observed in yards (1.329 cars per million car-miles) is only 2.6 times the mainline rate. Miles in this case refers to the length of the yard.

As with the mainline data, yard collision and derailment rates differed significantly between the various regions. Central and Atlantic Regions registered the highest collision (0.703 cars per million car-miles) and derailment (3.370 cars per million car-miles) rates, respectively.

Increasing volumes are reflected in decreasing accident rates for both collisions and derailments for all regions. A cross-tabulation of rates by region and volume in Table 4.9 indicates that the relationship between accident rate and volume is strongly affected by regional affiliation.

4.4 Accident Severity

To provide an indication of the severity of rail accidents in Canada, a summary of the impact of these accidents based on the total number of people killed and injured, as well as the total number of units derailed in Canadian rail accidents from 1980 to 1985 is presented below. Fatality and injury rates are also produced and expressed as a function of the accident frequency. The frequencies and rates were produced for four groups of accident causes:

1. All fixed plant related
2. All equipment related
3. All operational related
4. All other or unknown

The results are presented for collisions and derailments in rail yards and on mainlines in Tables 4.10 and 4.11 respectively.

TABLE 4.10

SEVERITY OF COLLISIONS ANALYZED BY CAUSE: 1980 - 1985

	FR	NK	NI	ND	NK/FR	NI/FR	ND/FR
Yard - Fixed Plant	16	0	1	18	0.000	0.063	1.125
- Equipment	3	0	0	2	0.000	0.000	0.667
- Operational	147	3	81	158	0.020	0.551	1.075
- Unknown	7	0	1	2	0.000	0.143	0.286
Subtotal	173	3	83	180			
Main - Fixed Plant	11	0	2	3	0.000	0.182	0.273
- Equipment	15	0	13	3	0.000	0.867	0.200
- Operational	444	19	572	580	0.043	1.288	1.306
- Unknown	10	0	2	0	0.000	0.200	0.000
Subtotal	480	19	589	586			
TOTAL	653	22	672	768			

LEGEND:

FR - The total number of accidents occurring in 1980-1985 inclusive.
NK - The total number of people killed in these accidents.
NI - The total number of people injured in these accidents.
ND - The total number of units that derailed in these accidents.

TABLE 4.11

SEVERITY OF DERAILMENTS ANALYZED BY CAUSE: 1980 - 1985

	FR	NK	NI	ND	NK/FR	NI/FR	ND/FR
Yard - Fixed Plant	65	1	8	236	0.015	0.123	3.631
- Equipment	36	0	34	97	0.000	0.944	2.694
- Operational	73	0	5	187	0.000	0.068	2.562
- Unknown	4	0	1	3	0.000	0.250	0.750
Subtotal	178	1	48	523			
Main - Fixed Plant	656	0	244	4163	0.000	0.372	6.346
- Equipment	518	1	78	2042	0.002	0.151	3.942
- Operational	402	0	49	1529	0.000	0.122	3.803
- Unknown	4	0	6	158	0.000	0.130	3.435
Subtotal	1580	1	377	7892			
TOTAL	1758	2	425	8415			

LEGEND:

FR - The total number of accidents occurring in 1980-1985 inclusive.

NK - The total number of people killed in these accidents.

NI - The total number of people injured in these accidents.

ND - The total number of units that derailed in these accidents.

4.5 Loglinear Analysis of Rail Accident Rates

As for trucks, loglinear analysis is used to assess interaction effects in rail accident causation, and to determine modifiers for rail accident rates on individual sections of track while controlling for various mitigating factors. As indicated in Section 4.4, separate loglinear expressions have been calibrated for different track environments (mainline and yard) and different accident types (derailment and collisions). It was found, however, that only mainline derailment contain enough information on which a meaningful model can be calibrated. About 87% of the rail accidents in the 1980-85 data base are mainline derailment accidents.

From Section 4.4, four factors were established for the calibration (Table 4.12). These categorical factors form a contingency table with 64 cells, of which 12 were defined as structurally empty. The "best fit" accident rate expression for mainline derailment using exposure as an offset is:

$$\log(DAR) = 1 + R + T + S + V + RT + RS + RV + TS + TV + SV + RTS + RTV + RSV \quad [4.1]$$

where DAR = expected rate in number of derailments per car-mile,

R = geographic region
T = number of tracks
S = average freight speed
V = volume.

The selected model contains all the main and second order interaction effects and three third order interaction effects. All the third order interaction terms include "regional affiliation", indicating the importance of regional characteristics in rail accident rate estimation.

Table 4.13 summarizes the estimates of the parameters for the derailment model. These estimates reflect the degree of association for the different levels of interactions among the categorical factors that influence mainline derailment rates. The magnitude of the third level order interactions for the different regions are presented in Table 4.14.

The third order interaction effects of region, track type and volume shows that while for volumes less than 100, multiple tracks register higher derailment rates for all regions, the opposite is true for higher volume classes. In general, lower accident rates were experienced for the high volume categories. Increasing volume also reflects decreasing rates in the region, speed and volume combinations. For these combinations, the Central Region (Ontario and Quebec) registered lower derailments on mainlines than other regions of the country.

TABLE 4.12

VARIABLES IDENTIFIED FOR RAIL
LOGLINEAR CALIBRATION

VARIABLE	SYMBOL	CATEGORY DESCRIPTION
GEOGRAPHIC REGION	R	(1) Atlantic
		(2) Central
		(3) Prairies
		(4) Mountain
RAIL TRACK	T	(1) Single
		(2) Multiple
WEIGHTED FREIGHT SPEED	S	(1) < 35 mph
		(2) > 35 mph
VOLUME CLASS PER YEAR	V	(1) < 100 million ton-miles/mile
		(2) 100 - 1000 million ton-miles/mile
		(3) 1000 - 10000 million ton-miles/mile
		(4) > 10000 million ton-miles/mile

Note: Speed = Subdivision Operating Speed

TABLE 4.13

PARAMETER ESTIMATES OF DERAILMENT
RATE MODEL

PARAMETER SYMBOL	LEVEL	PARAMETER ESTIMATE	STANDARD ERROR	PARAMETER SYMBOL	LEVEL	PARAMETER ESTIMATE	STANDARD ERROR
GRAND MEAN		-13.3300	0.3014				
R	2	2.0790	0.3321	SV	22	-4.7690	0.4824
R	3	1.3630	0.3329	SV	23	-1.5450	0.3733
R	4	0.9106	0.3362	SV	24	0.4178	0.2380
T	2	5.4430	0.6499	RTS	222	1.9480	0.6438
S	2	2.7460	0.3297	RTS	322	-1.9170	0.4851
V	2	1.0560	0.3787	RTS	422	-0.3764	0.3267
V	3	-0.2882	0.3335	RTV	222	2.4800	0.9552
V	4	-4.2290	0.2875	RTV	223	1.7290	0.5433
RT	22	-3.0520	0.7557	RTV	224	0.0000	aliased
RT	32	0.2331	0.5487	RTV	322	-3.4950	0.9016
RT	42	-1.8030	0.4565	RTV	323	3.2140	0.6117
RS	22	-4.8350	0.4667	RTV	324	0.0000	aliased
RS	32	-2.5370	0.4292	RTV	422	0.0000	aliased
RS	42	-2.4720	0.3711	RTV	423	0.0000	aliased
TS	22	-0.3079	0.2709	RTV	424	0.0000	aliased
RV	22	-3.2400	0.4281	RSV	222	6.7940	0.6170
RV	23	-2.2390	0.3660	RSV	223	3.3480	0.5081
RV	24	1.1020	0.6795	RSV	224	0.8868	0.7209
RV	32	-2.4680	0.4245	RSV	322	6.1130	0.5761
RV	33	-2.9140	0.3840	RSV	323	3.0300	0.4927
RV	34	-1.1070	0.3702	RSV	324	0.0000	aliased
RV	42	-2.6230	0.4311	RSV	422	4.2760	0.8491
RV	43	-1.0870	0.3688	RSV	423	1.7650	0.4287
RV	44	1.7850	0.2132	RSV	424	0.0000	aliased
TV	22	-2.4210	0.8412				
TV	23	-6.3710	0.6871				
TV	24	-3.4400	0.4509				

MODEL: SEE EQ. 4.1.

LEGEND
- R Geographic Region
- T No. of Tracks
- S Weighted Freight Speed
- V Volume Class (per year)

TABLE 4.14

RAIL ACCIDENT RATES
(Rail Derailment Model)

VARIABLE/ CATEGORIES	REGION ATLANTIC	CENTRAL	PRAIRIES	MOUNTAIN
	(Accident rates are per million car km)			
TRACK				
- SINGLE				
SPEED				
- < 35 mph	1.63	13.01	6.33	4.04
- > 35 mph	25.42	1.61	7.81	5.29
- MULTIPLE				
SPEED				
- < 35 mph	374.47	141.96	1854.76	153.78
- > 35 mph	4296.30	90.51	246.04	102.05
TRACK				
- SINGLE				
VOLUME				
- < 100	1.63	13.01	6.33	4.04
- 100 - 1000	4.69	1.46	1.55	0.84
- 1000 - 10000	1.22	1.04	0.26	1.03
- > 10000	0.02	0.57	0.03	0.35
- MULTIPLE				
VOLUME				
- < 100	374.47	141.96	1854.76	153.78
- 100 - 1000	96.11	16.87	1.22	2.84
- 1000 - 10000	0.48	0.11	3.21	0.07
- > 10000	0.17	0.20	0.29	0.43
SPEED				
- < 35 mph				
VOLUME				
- < 100	1.63	13.01	6.33	4.04
- 100 - 1000	4.69	1.46	1.55	0.84
- 1000 - 10000	1.22	1.04	0.26	1.03
- > 10000	0.02	0.57	0.03	0.35
- > 35 mph				
VOLUME				
- < 100	25.42	1.61	7.81	5.29
- 100 - 1000	0.62	1.37	7.28	0.67
- 1000 - 10000	4.04	0.78	1.40	1.67
- > 10000	0.56	0.26	0.06	0.70

Note: Speed = Subdivision Operating Speed