ANALYSES OF TRACK-RELATED RAILROAD ACCIDENT DATA

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FINAL REPORT

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16. Abstract

The Federal Railroad Administration (FRA), as part of a comprehensive research program, has sponsored the Improved Track Structures Research Program (ITSRP) at the Transportation Systems Center (TSC). The study, documented in this report, supports the ITSRP through analysis of data contained in the new FRA Railroad Accident Incident Reporting System, established in 1975. This study has led to the identification of leading causes of--and factors contributing to--track-related accidents. These results will be useful in increasing the effectiveness of track safety programs by assisting in the refinement of research priorities and the identification of improved maintenance techniques, operations guidelines, and safety standards for reducing track-related accidents.

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PREFACE

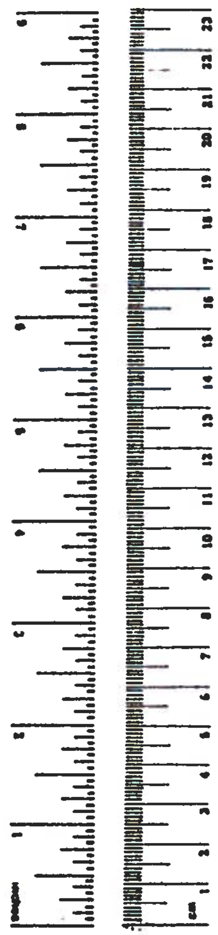
This report describes analyses performed during FY 1977 of railroad accident data contained in the new Federal Railroad Administration (FRA) Railroad Accident/Incident Reporting System, established in 1975. This work was performed at the Transportation Systems Center (TSC) in support of railroad accident reduction research under the Improved Track Structures Research Program (ITSRP). The ITSRP is sponsored by the FRA, Office of Rail Safety Research.

The author wishes to express his appreciation for the contributions made to this project by Robert Montanari, Kentron Hawaii, Ltd., and Dean Muccio, TSC work-study program.

METRIC CONVERSION FACTORS

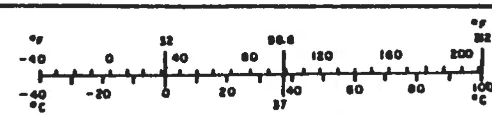
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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SUMMARY

The Federal Railroad Administration (FRA), as part of a comprehensive research program, has sponsored the Improved Track Structures Research Program (ITSRP) at the Transportation Systems Center (TSC). The study, documented in this report, supports the ITSRP through analysis of data contained in the new FRA Railroad Accident/Incident Reporting System, established in 1975. The analysis was confined to accident/incident data contained in this system for the year 1975. This study has led to the identification of leading causes of, and factors contributing to, track-related accidents. These results will be useful in increasing the effectiveness of the ITSRP by assisting in the refinement of priorities for research and the identification of improved maintenance techniques, operations guidelines, and safety standards as a means of reducing track-related accidents.

The most significant study findings are summarized below:

1) Railroad Accident Statistics

Track-related accidents produce 39 percent of the dollar damages resulting from all railroad accidents and incidents. However, they account for only 0.06 percent of the fatalities and 0.22 percent of the injuries. Track-related accident dollar damages occur predominantly on main track (85 percent of damages), of traffic density less than 20 MGT (72 percent of damages) and of FRA track classes 1, 2 and 3 (78 percent of damages). About 80 percent of track-related accidents occur on rail routes handling only 33 percent of freight traffic.

2) Results Relevant to the Track Safety Standards

Several results of the analysis proved relevant to any future evaluations of the Track Safety Standards. The Standards require classification of track into six track classes, reflective of track quality, that form the basis for train speed limits and, together with traffic volumes, track inspection frequencies. The analysis showed that Class 1, 2 and 3 track accounts for about

78 percent of all track-related damages, and was estimated to have an accident rate (accidents per MGT per track-mile) eight times greater than Class 4, 5 and 6 track. In addition, main track of less than 10 million gross tons annual traffic accounts for about 55 percent of all track-related damages.

As part of the analysis, it was also possible to correlate specific sections of the standards with cause codes and thus determine the priority of individual standard sections in terms of the total accident damages to which they apply. The results showed that as few as five sections of the standards concern 74 percent of all track-related accident damages with Section 213.113, defective rails, on main track of Class 1, 2 and 3 alone, accounting for 23 percent of the total.

3) Leading Track-Related Cause Codes

Seventeen leading reported causes of track-related accidents were identified, including roadbed, track-geometry, rail and track appliance defects. These leading causes accounted for over 80 percent of track-related accident damages and should thus be given priority in accident-reduction research. The three leading causes are listed below:

Rank	Cause	Code No.	Percent of Total Track-Related Dollar Damages
1	Cross level of track irregular	119	11.5
2	Wide gauge, ties	110	10.1
3	Transverse/compound fissure	141	7.2

1. INTRODUCTION

1.1 BACKGROUND

In recent years the nation's railroads have been experiencing a worsening accident problem. During the ten-year period from 1965 to 1975, the number of railroad accidents,* exceeding an inflation-adjusted threshold,** increased from 4,952 to 8,041[1,2] or 62 percent, as shown in Figure 1-1. Economic losses*** from these accidents, over the same period, increased from $85.5 million to $177.4 million[1], or 107 percent. Part of the increase in railroad accidents can be attributed to growth in railroad activity; hence, the number of accidents in Figure 1-1 is also normalized by gross ton-miles of traffic.[1,2,3] Even normalized, however, the railroad accident rate increased by 46 percent over the ten-year period. Most of this increase took place between 1972 and 1975. The growing accident problem, with its resulting social impacts, was a significant factor in the enactment of the Federal Railroad Safety Act of 1970 and in the adoption by FRA of the Track Safety Standards and Inspection Requirements of 1973. In spite of these initial steps, the nation's railroads are becoming increasingly accident-prone.

Further understanding of the railroad accident problem can be gained by observing the trend in accident statistics for the four major categories of railroad accidents: (1) Track-Related, (2) Equipment-Related, (3) Human Factors-Related and (4) Miscellaneous, as shown in Figure 1-2. The figure demonstrates that the major contributor to the worsening railroad accident problem is the track-related category. The inflation-adjusted and normalized rate of track-related accidents increased by 198 percent[1,2,3] between 1965 and 1975. In 1965, track-related

*All accidents resulting from the operation of trains as reported to the Federal Railroad Administration.
**Damage threshold is equivalent to $1750 in 1975.
***Track and equipment damage only.

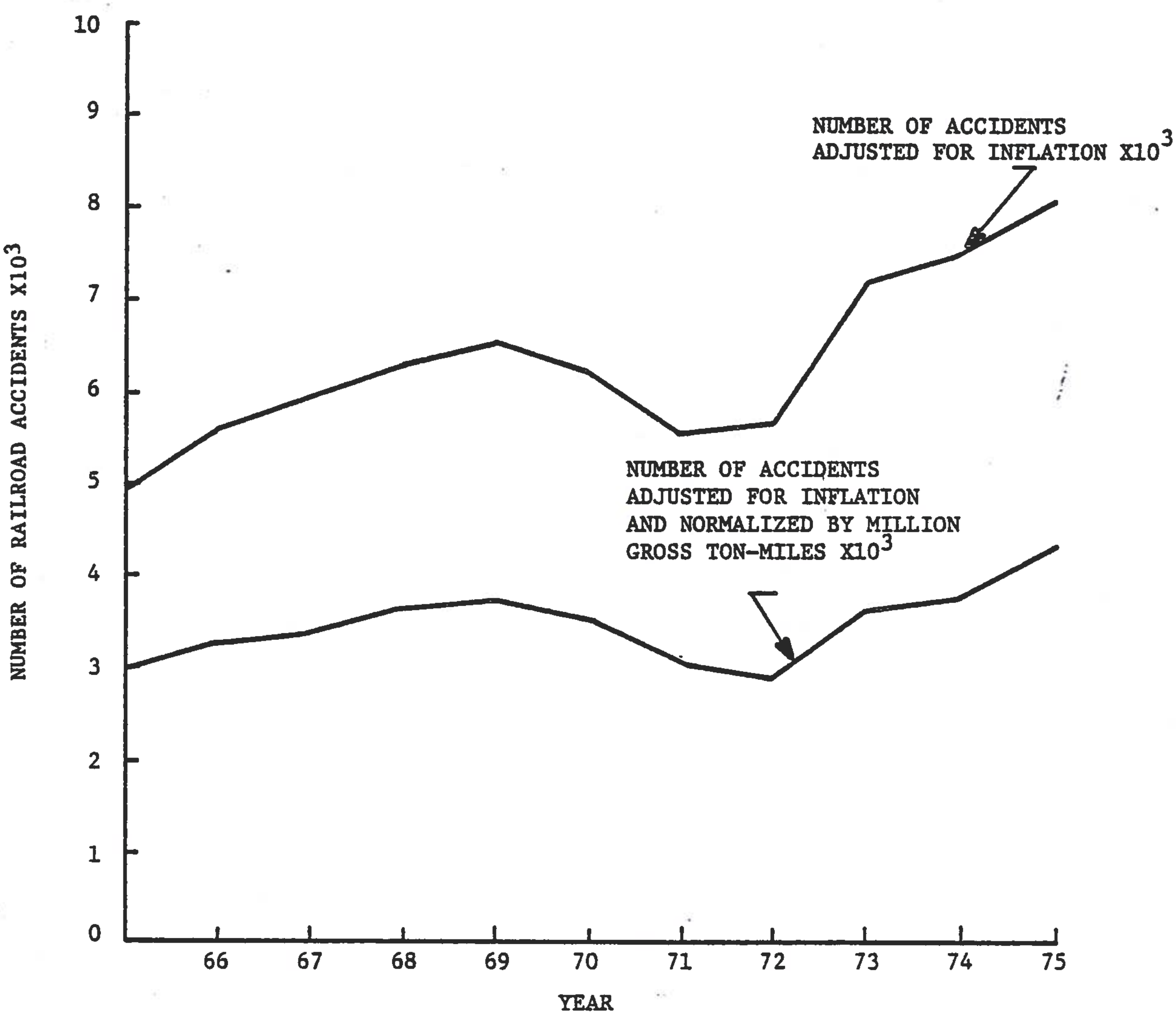


FIGURE 1-1. TREND IN RAILROAD ACCIDENTS, INFLATION-ADJUSTED AND NORMALIZED, 1965-1975[1,2,3]

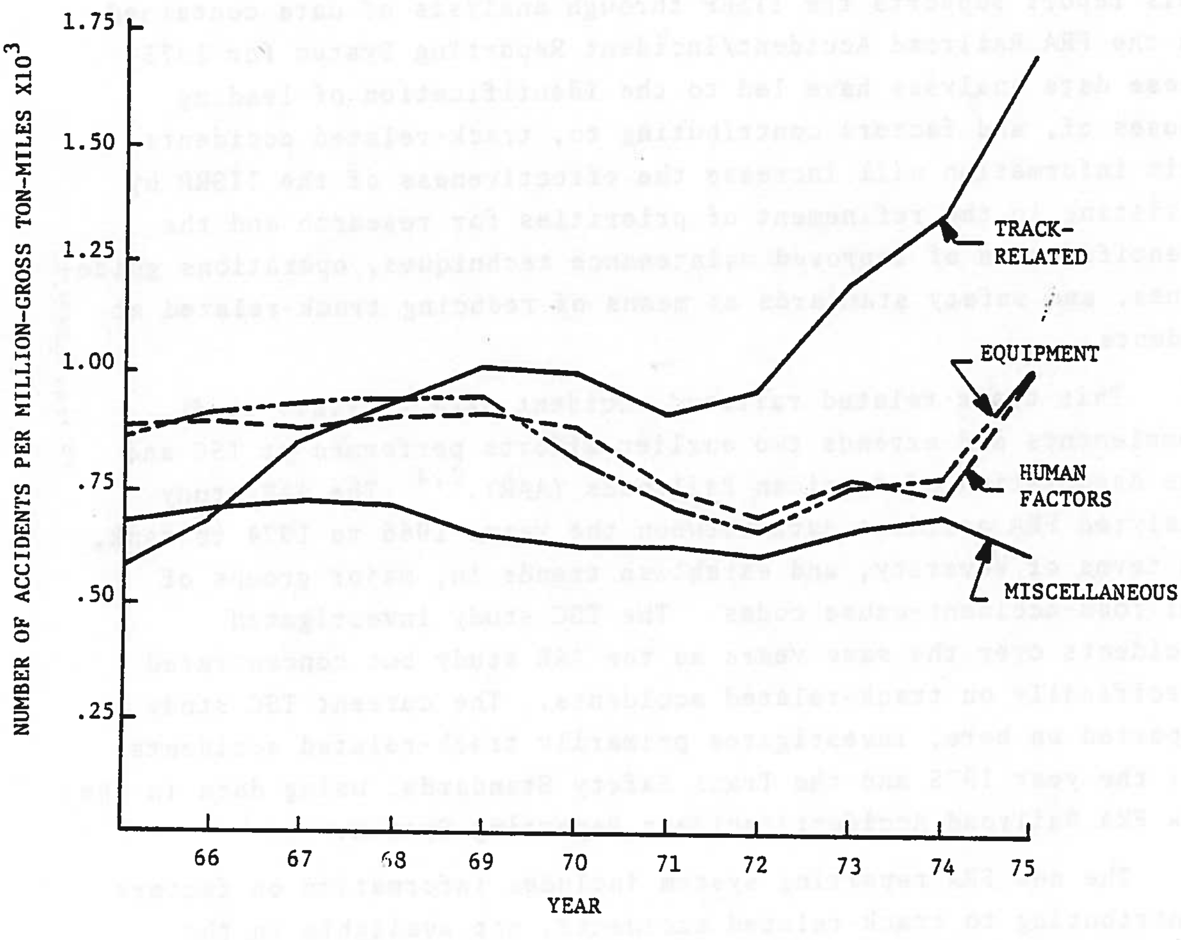


FIGURE 1-2. TREND IN FOUR CATEGORIES OF RAILROAD ACCIDENTS, INFLATION-ADJUSTED AND NORMALIZED, 1965-1975[1,2,3]

accidents accounted for 19 percent of the railroad accidents and resulting economic losses. However, in 1975, the share of these accident impacts attributable to track-related accidents increased to 39 percent. Track-related accidents are thus a significant contributor to the damages resulting from railroad accidents and should be given priority for remedial action.

The FRA, as part of a comprehensive research program, has sponsored the Improved Track Structures Research Program (ITSRP) at The Transportation Systems Center (TSC). The study documented in this report supports the ITSRP through analysis of data contained in the FRA Railroad Accident/Incident Reporting System for 1975. These data analyses have led to the identification of leading causes of, and factors contributing to, track-related accidents. This information will increase the effectiveness of the ITSRP by assisting in the refinement of priorities for research and the identification of improved maintenance techniques, operations guidelines, and safety standards as means of reducing track-related accidents.

This track-related railroad accident data analysis study complements and extends two earlier efforts performed at TSC and the Association of American Railroads (AAR).[2,4] The AAR study analyzed FRA accident data between the years 1966 to 1974 to rank, in terms of severity, and establish trends in, major groups of railroad-accident-cause codes. The TSC study investigated accidents over the same years as the AAR study but concentrated specifically on track-related accidents. The current TSC study, reported on here, investigates primarily track-related accidents for the year 1975 and the Track Safety Standards, using data in the new FRA Railroad Accident/Incident Reporting System.

The new FRA reporting system includes information on factors contributing to track-related accidents, not available in the earlier pre-1975 system, and a new system of accident-cause codes consistent with the Track Safety Standards. A detailed description of the changes made to the accident-reporting system, including a list of the new and old track-related accident cause codes, is provided in Appendix A. Where some problems of data quality may exist in the new FRA reporting system, it was considered beyond the scope of this study to assess the data in this regard.

1.2 STUDY FINDINGS

1.2.1 Track-Related Accidents in Relation to All Railroad Accidents/Incidents

Railroad accidents and incidents are classified into three distinct groups[9]: (1) rail-equipment, (2) grade-crossing and (3) deaths, injuries and occupational illnesses (D, I & OI).

For purposes of this study those groups were defined as follows:

1. Rail-equipment - all accidents involving train operations with equipment damages exceeding $1750, excluding occurrences at grade crossings.
2. Grade-crossing - all accidents and incidents at grade crossings regardless of equipment damages.
3. D, I & OI - all casualty producing incidents not covered by 1 and 2 above.

The impacts of these accident and incident groups for 1975, as measured by total dollar damage, total number of accidents and total number of casualties, are summarized in Figures 1-3, 1-4 and 1-5.

The information in Figures 1-3 to 1-5 demonstrates that each accident group is uniquely characterized by its impacts. Rail-equipment accidents constitute 96 percent of the total dollar damages, grade-crossing accidents a major portion (63 percent) of the fatalities, and D, I & OI incidents 91 percent of the injuries. It should be noted that the dollar damages reported in Figure 1-3 actually underestimate the total economic losses produced by these accidents. Several FRA-sponsored studies[5&6] have shown that the total cost of a train accident is two to three times the reported

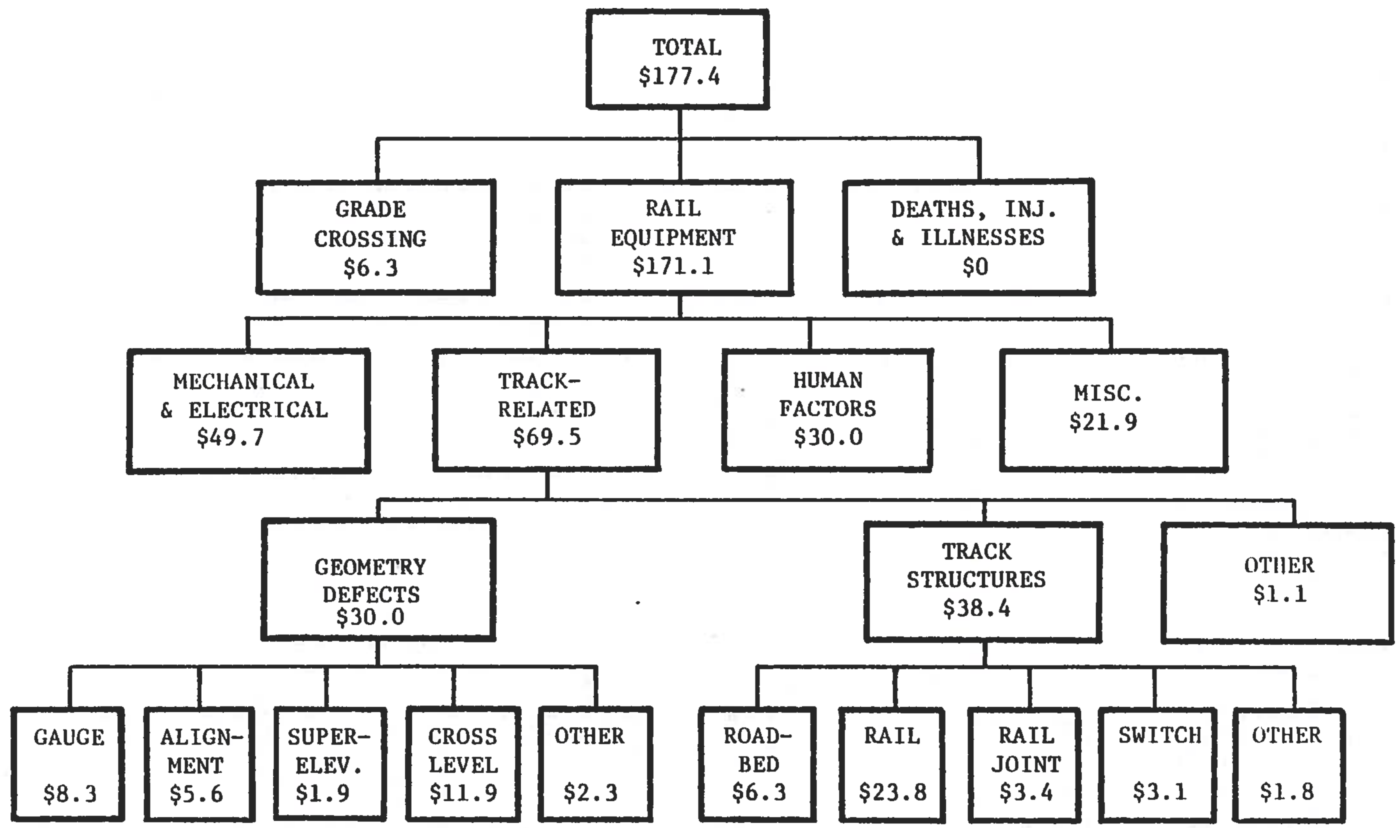
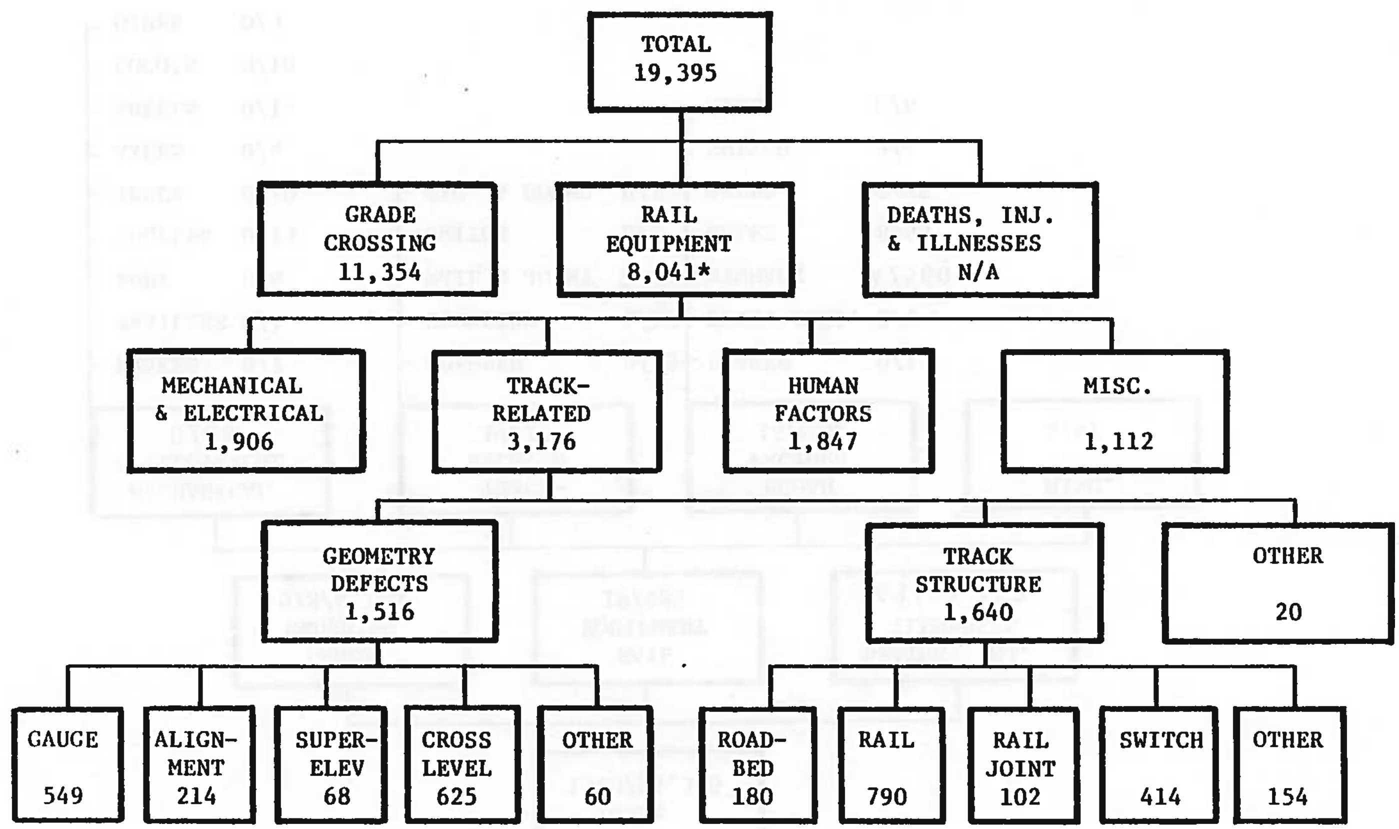


FIGURE 1-3. TOTAL REPORTED DAMAGES RESULTING FROM RAILROAD ACCIDENTS, 1975 IN MILLIONS OF DOLLARS



*Only Accidents Exceeding $1,750

FIGURE 1-4. NUMBER OF RAILROAD ACCIDENTS BY CAUSE CATEGORIES, 1975

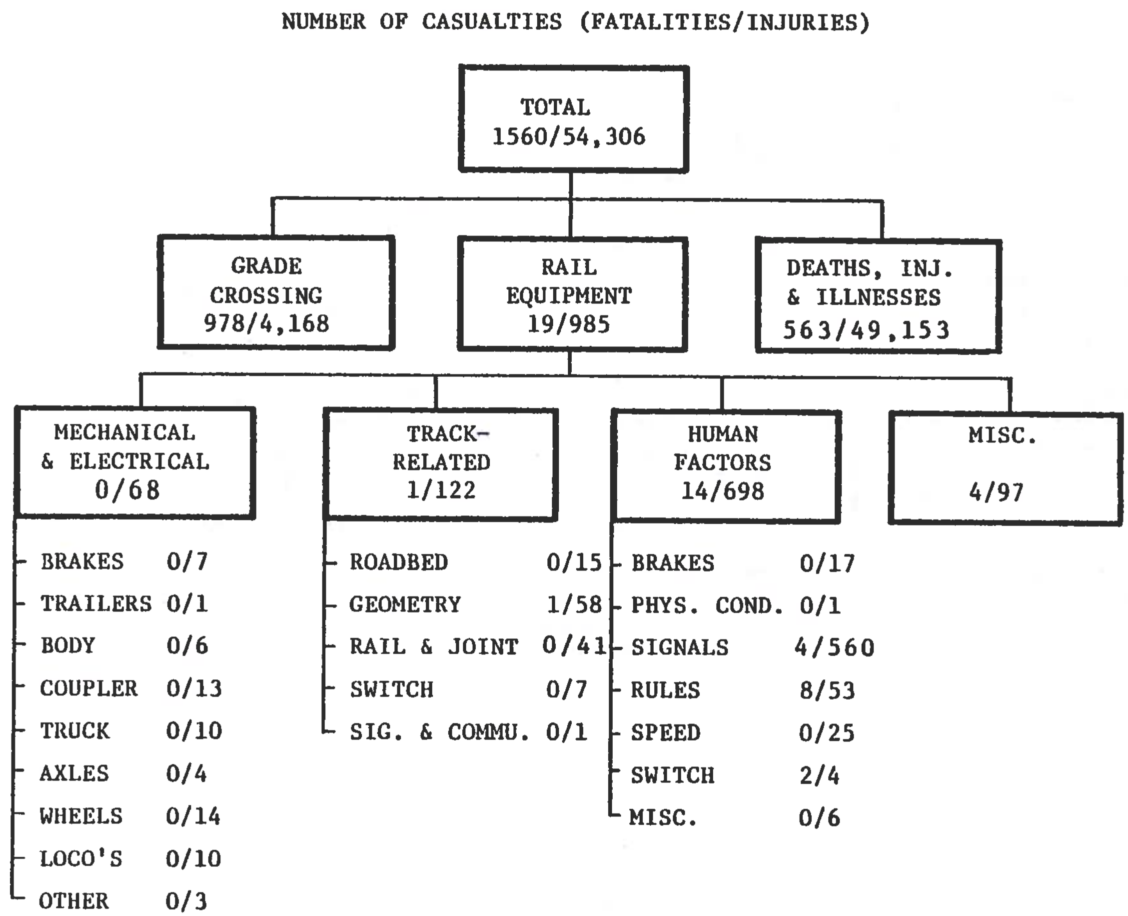


FIGURE 1-5. CASUALTIES RESULTING FROM RAILROAD ACCIDENTS, 1975

costs, which include only track and train damages. The costs of clearing wrecks, losses and damage to lading, and delays and service disruptions are not recorded. Track-related accidents produce 39 percent of the reported economic losses resulting from all railroad accidents.

Track-Related accident damages are about equally divided between track geometry and track structures causes. The largest single group of causes is rail defects, which account for over 34 percent of total track-related accident damages.

1.2.2 Effect of Track Factors on Track-Related Accidents

The information contained in the FRA accident files since 1975 permits grouping of accidents by a number of factors useful in defining track conditions under which track-related accidents occur. Figures 1-6, 1-7 and 1-8 show the number and total damage of track-related accidents by type of track, FRA track class and track traffic density. These figures illustrate that track-related accidents are concentrated on main track of low FRA class and traffic density of less than 20 million gross tons (MGT). In fact, using data from the FRA Track Classification Project[8] on route miles of track in various traffic density categories, it can be shown that the accident rate (accidents per gross ton of traffic per track-mile) is at least 8 times greater on track carrying less than 20 MGT than over 20 MGT. As a result, almost 80 percent of track-related accidents occur on rail routes which handle only 33 percent of the traffic.

The accident rate by class of track is more difficult to determine because less is known about the mileage of track by class. However, a conservative estimate is that the mileage of class 3 track and less is the same as that for track with less than 20 MGT of traffic. This would mean that the accident rate per gross ton per mile of track on class 1, 2 and 3 track is about 8 times greater than on class 4, 5, and 6 track.

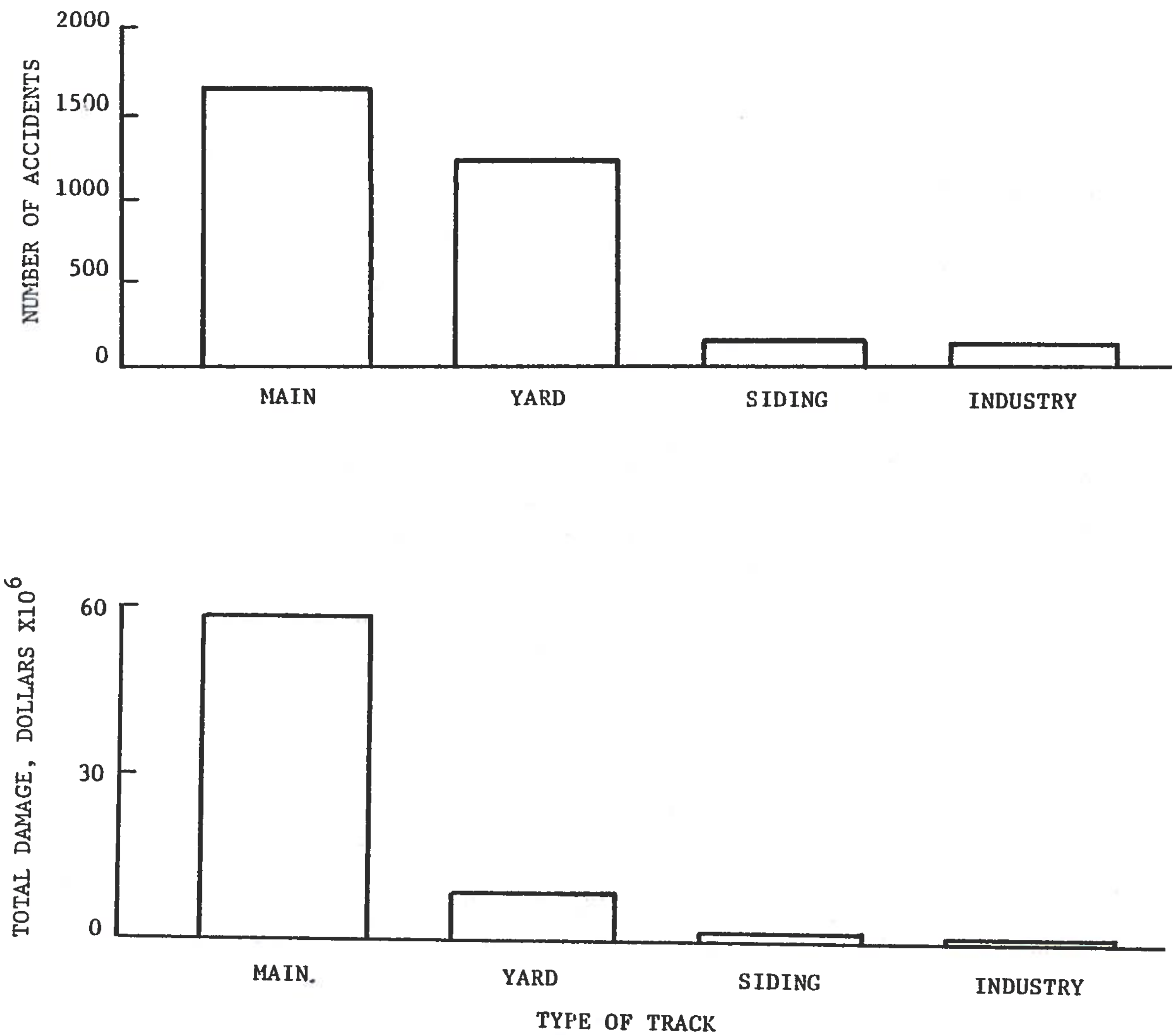


FIGURE 1-6. NUMBER AND TOTAL DAMAGE OF TRACK-RELATED ACCIDENTS BY TYPE OF TRACK

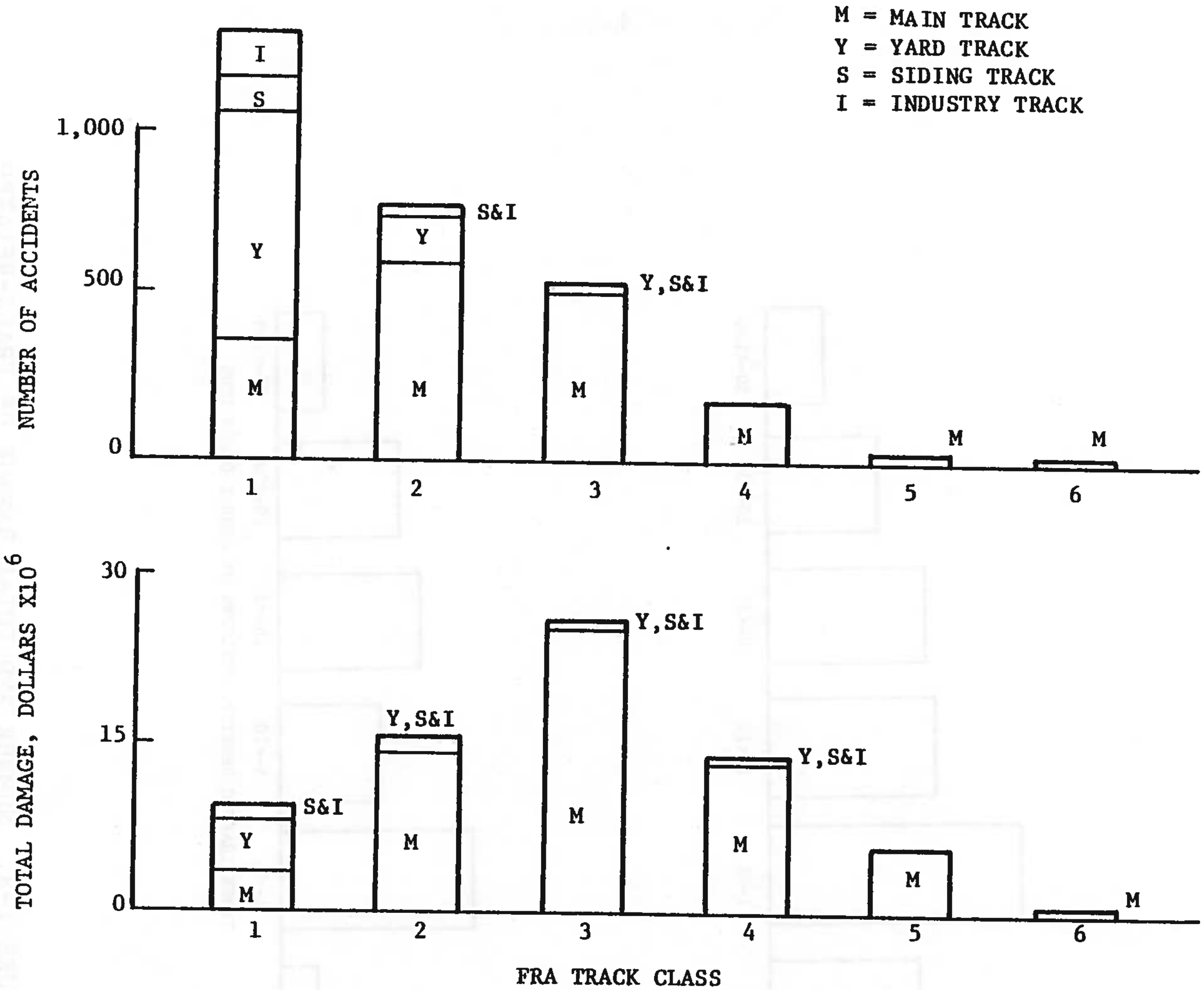


FIGURE 1-7. NUMBER AND TOTAL DAMAGE OF TRACK-RELATED ACCIDENTS BY FRA TRACK CLASS

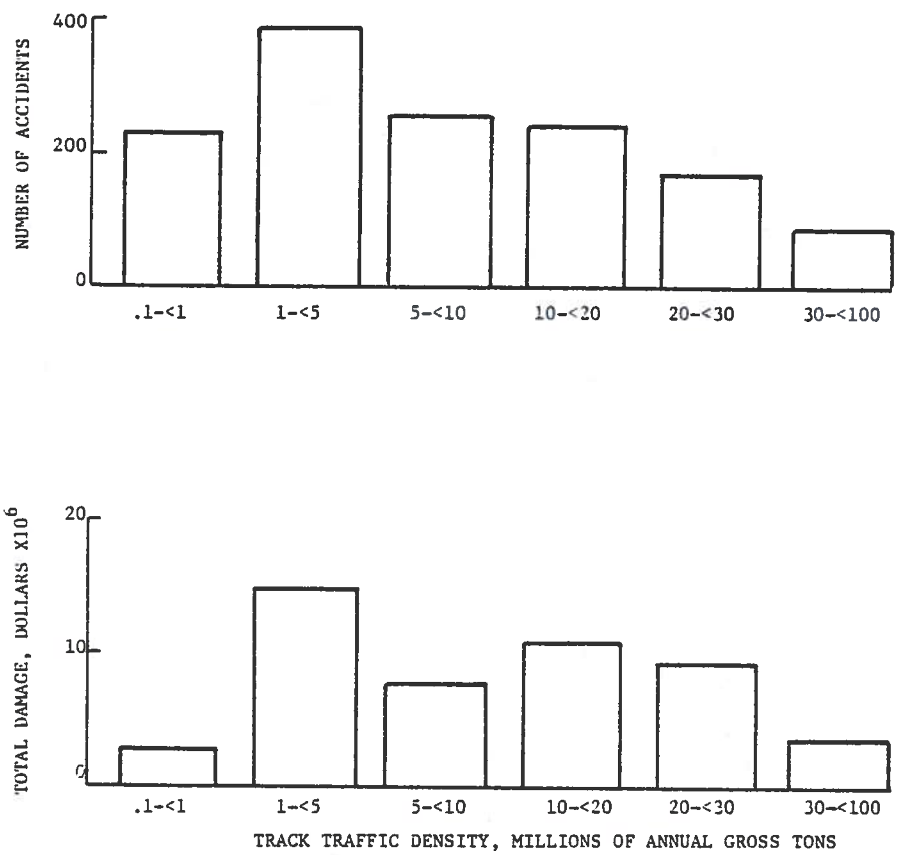


FIGURE 1-8. NUMBER AND TOTAL DAMAGE OF TRACK-RELATED ACCIDENTS BY TRACK TRAFFIC DENSITY, MAIN TRACK ONLY

1.2.3 Results Relevant to the Track Safety Standards

Several results of the analysis proved relevant to any future evaluations of the Track Safety Standards. The Standards require classification of track into six track classes, reflective of track quality, that form the basis for train speed limits and, together with traffic volumes, track inspection frequencies. For example, Class 1, 2 and 3 track is permitted to have greater track geometry tolerances and to be inspected less frequently than Class 4, 5 and 6 track when the traffic volume is less than 10 MGT (with the exception of Class 3 track over which passenger trains operate). However, train speeds on Class 1, 2 and 3 track are required to be commensurately less than on Class 4, 5 and 6 track. The analysis determined accident statistics by class of track and traffic volume. The results showed that Class 1, 2 and 3 track accounts for about 78 percent of all track-related damages, and was estimated to have an accident rate (accidents per MGT per track-mile) eight times greater than Class 4, 5 and 6 track. In addition, main track of less than 10 million gross tons annual traffic accounts for about 55 percent of all track-related damages.

In addition to the above, it was found that defective rails, Section 213.113, resulting largely from flaws detectable by inspection for internal defects, is the most critical standard, accounting for 31 percent of track-related accident damages, and occurs predominantly on class 3 track and less, as summarized for mainline track below (See also Figure 1-10):

	FRA TRACK CLASS					
	1	2	3	4	5	6
PERCENT OF DEFECTIVE RAIL-CAUSED ACCIDENT DAMAGES BY CLASS ON MAINLINE TRACK	3.1	26.0	45.2	25.2	0.5	0.0

The cause code structure in the new 1975 Accident Reporting System was revised, making the cause codes consistent with the Track Safety Standards; e.g., for Standard Section 213.109, crossties, there is a corresponding accident cause code, wide gauge (defective or missing crossties). An evaluation of the standards can thus be performed to determine the ranking of individual standard sections in terms of the total accident damages to which they apply. Such an analysis was performed and shows that as few as five critical sections of standards concern 74 percent of track-related accident damages as summarized below:

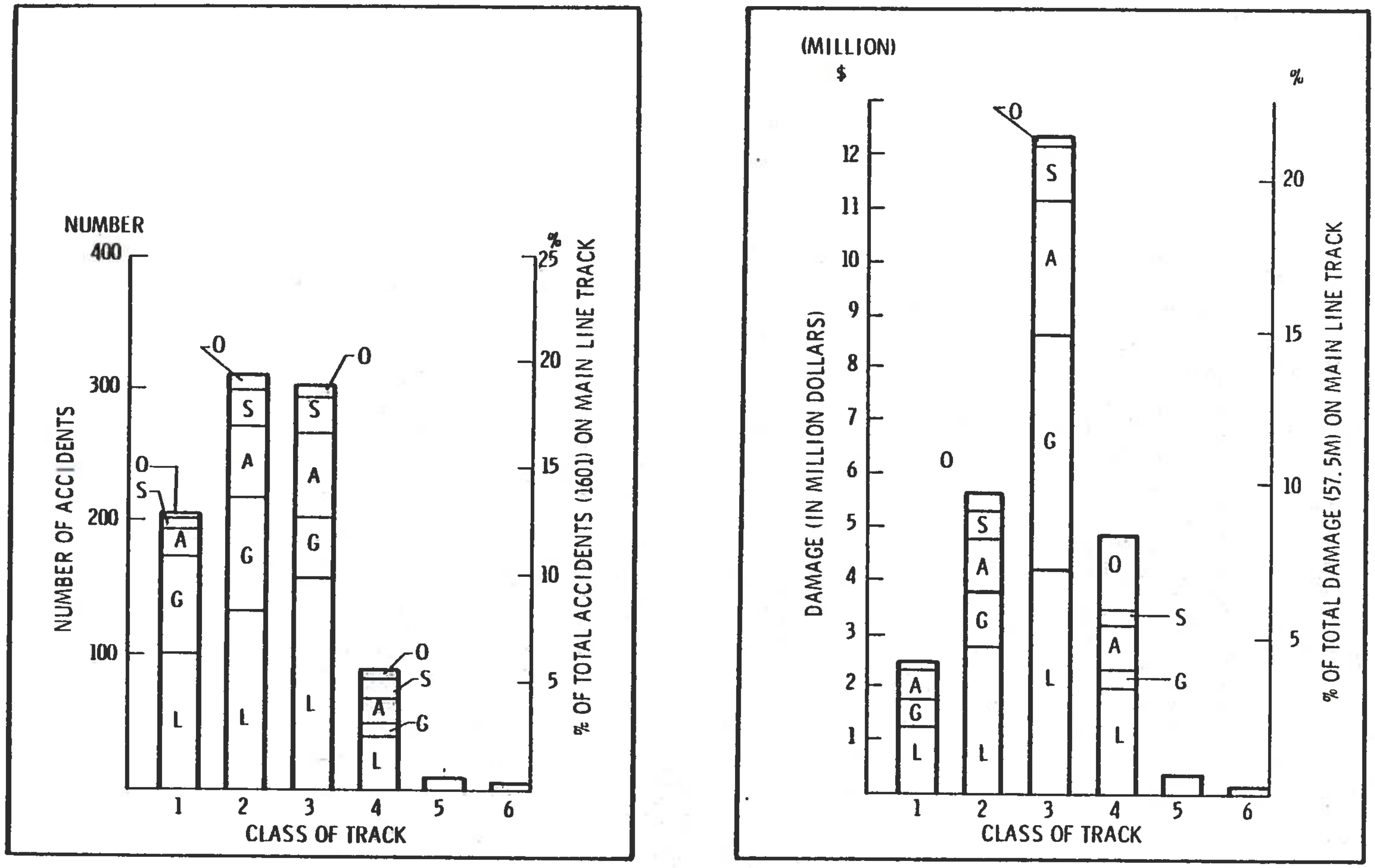
Rank by Total Damage	Section of Track Safety Standards	Percent of Total Track-Related Accident Damages
1	213.113 Defective Rail	31.0
2	213.63 Track Surface	17.9
3	213.109 Crossties	10.1
4	213.103 Ballast/213.33 Drainage	8.0
5	213.55 Alignment	7.2
		74.2

1.2.4 Leading Track-Related Accident Causes

The accident data was analyzed to determine leading causes of track-related accidents. The results of this analysis, summarized in Table 1-1, show that 17 specific causes of track-related accidents account for over 80 percent of the dollar damages. The distribution of accidents and damages attributable to these leading causes by class of track is shown in Figures 1-9 and 1-10, grouped by track geometry and structures causes, respectively.

TABLE 1-1. LEADING TRACK-RELATED ACCIDENT CAUSE CODES, 1975

RANK	CAUSE CODE	(CODE NO.)	PERCENT OF TRACK-RELATED ACCIDENT DAMAGES
1	Cross Level of Track Irregular at Joint	(119)	11.5
2	Wide Gauge, Ties	(101)	10.1
3	Transverse/Compound Fissure	(141)	7.2
4	Head & Web Separation, Outside Joint	(136)	5.7
5	Cross Level of Track Irregular, not at Joint	(120)	5.6
6	Washout/Rain/etc. Damage to Track	(102)	5.1
7	Broken Base of Rail	(131)	4.3
8	Track Alignment Irregular, Buckled	(115)	4.1
9	Other Track Geometry	(129)	3.3
10	Vertical Split Head	(142)	3.3
11	Track Alignment Irregular	(114)	3.2
12	Other Rail & Joint-Bar Defect	(149)	3.1
13	Joint Bar Broken, Non-Insulated	(147)	3.1
14	Roadbed Settled or Soft	(101)	2.9
15	Bolt Hole Crack or Break	(130)	2.9
16	Switch Point Worn or Broken	(165)	2.7
17	Superelevation Improper	(117)	2.5
			80.6



LEGEND: G = GAGE
L = CROSS LEVEL
A = ALIGNMENT
S = SUPERELEVATION
O = ALL OTHER GEOMETRY CODES

FIGURE 1-9. DISTRIBUTION OF TRACK GEOMETRY-CAUSED ACCIDENTS AND DAMAGES BY CLASS OF TRACK, 1975

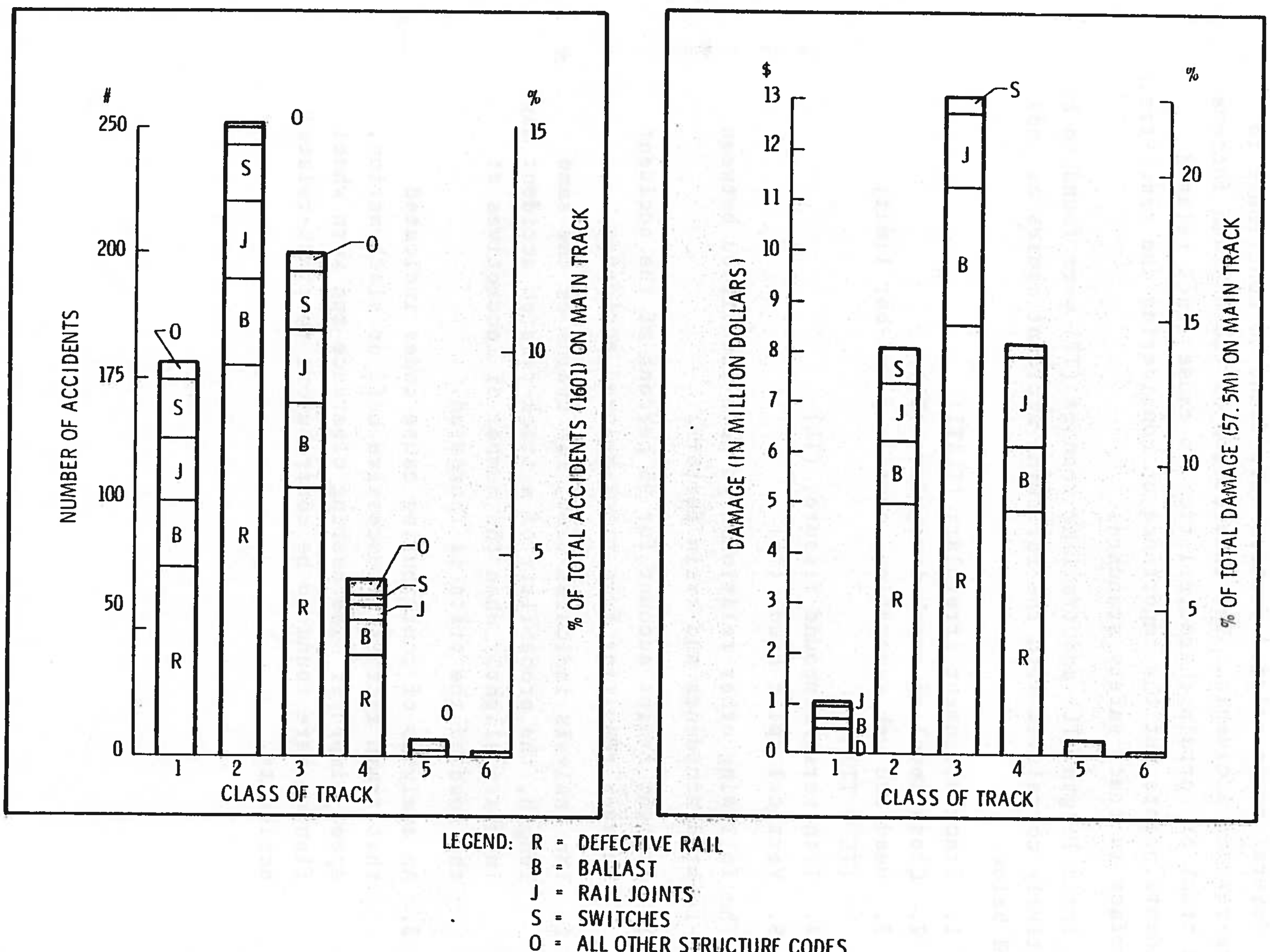


FIGURE 1-10. DISTRIBUTION OF TRACK STRUCTURES-CAUSED ACCIDENTS AND DAMAGES BY CLASS OF TRACK, 1975

1.2.5 Effect of Train Factors on Track-Related Accidents

Several train-related factors were found to contribute to track-related accidents. The interaction of these train factors with track of certain characteristics to cause track-related accidents points out the importance of considering the track-train interface in track safety standards.

Train length (TL) and trailing tonnage (TT) were found to be positively correlated with the following accident causes as indicated below:

1. Track alignment irregular; (TL&TT)
2. Cross level of track irregular; (TL)
3. Head and web separation, outside joint-bar limit; (TL & TT)
4. Transverse/compound fissure; (TL)
5. Vertical split head. (TT)

The following other relationships were identified between track-related accidents and train factors:

1. Freight trains account for 93 percent of the accident damages resulting from track-related accidents.
2. The analysis indicates that, for trains of the same length, the probability of a track-related accident may increase slightly when the number of locomotives at the head of the train is increased.
3. An analysis of contributing cause codes indicated that train factors of excessive buff or slack action, speed, improper side bearing clearance and worn wheel flanges were found to be contributors to track-related accidents.

1.2.6 Effect of Operations Factors (Speed) on Track-Related Accidents

There was no clear evidence that speed was a contributing factor in track-related accidents in general. However, on track of class 3 and less, 13 percent of the track-related accident damages resulted from accidents where the track-class speed limit on main track was exceeded. Furthermore, the speed of trains involved in accidents caused by irregular track alignment and bolt hole cracks or breaks was significantly higher than for most track-related accidents and indicated a possible causal relationship. As would be expected, it was also found that average damages resulting from track-related accidents generally increased with speed.

1.2.7 Effect of Environmental Factors (Temperature) on Track-Related Accidents

Ambient temperature was found to be correlated with the following track-related accident causes:

1. Washout/rain/slide/flood/snow/ice damage to track - low temperatures in yards, most likely causing ice and snow damage to track appliances;
2. Track alignment irregular - high temperatures;
3. Cross level of track irregular - high temperatures;
4. Bolt hole crack or break - low temperatures;
5. Broken base of rail - low temperatures;
6. Transverse/compound fissure - low temperatures; and
7. Vertical split head - low temperatures.

1.3 ANALYSIS APPROACH AND REPORT CONTENT

The overall objective of this study was to determine, through analysis of accident data, possible means of reducing track-related accidents and their impacts. A necessary first step in achieving this objective was to establish an appropriate measure of the overall effect or impact of such accidents. A variety of methods for ranking the impacts of accidents was reviewed, as described in Appendix H; and a preferred measure was developed, defining track-related accident impacts as the total dollar damages resulting from the accident as reported to FRA.

The investigation then proceeded to a general analysis of track-related accidents, as described in Section 2, to determine their relationship to a variety of track, train, operations and environmental factors. The results of these analyses provide a detailed characterization of the relative impacts of track-related accidents, the conditions under which they occur and factors which potentially contribute to their occurrence.

An investigation was then performed of specific track-related cause codes to determine in more detail causes of track-related accidents. Section 3 describes a determination of the seventeen leading cause codes measured in terms of the total accident damages for which they were accountable. An attempt was also made to determine the damage trends in these leading cause codes compared with earlier years.

These leading cause codes were then analyzed, as described in Section 4, to determine the relationship of their frequency and average damages to track, train, operations and environmental conditions. With these relationships established, it was possible to define in more detail the conditions under which the leading causes occurred and, thus, potential reasons as to why they occurred.

Lastly, as described in Section 5, the Track Safety Standards were reviewed to determine their most critical sections in terms of accident impact covered.

2. ANALYSIS OF FACTORS CONTRIBUTING TO TRACK-RELATED ACCIDENTS

2.1 MEASUREMENT OF ACCIDENT IMPACTS

Before an investigation of track-related accidents could be performed, a consistent measure of the impact on society of such accidents was needed. A variety of accident impact measures was evaluated, as documented in Appendix H. In summary, these methods included measuring accident impacts by the following indices:

1. The total number of accidents;
2. The average damage (dollar damage, casualties, etc.) per accident;
3. The total number of casualties; and
4. The total damage of accidents, i.e., the product of the number of accidents times the average damage of accidents.

It was concluded that, for track-related accidents, the most appropriate measure of accident impacts was total damage expressed in units of dollars (accident number times average dollar damage). The following factors were considered in arriving at this conclusion:

a. The measure of total damages permits accident impacts to be expressed as the combined effect of two factors, accident frequency and average damage per accident, both of which can be affected by remedial actions.

b. Consideration of accident frequency alone ignores any measure of damages, and vice versa. Thus, for example, an infrequent but severe accident type with high resulting social impacts may be rated as unimportant if only accident frequency were considered.

c. In contrast to other types of railroad accidents, track-related accidents produce few casualties (see Figure 1-5); hence, dollar damages alone were considered a sufficient measure of these accident effects. Measuring damages by casualties alone ignores some track-related accident types that are either high in frequency or dollar damage and ignores many other track-related accidents altogether. However, all major casualty-producing track-related accidents are included within a methodology that measures damages by their dollar costs. Furthermore, combining casualties with dollar damages did not change the ranking of track-related accidents by dollar damages alone unless casualties had been given an unrealistically high weighting.

2.2 ANALYSIS OF FACTORS CONTRIBUTING TO TRACK-RELATED ACCIDENTS

The first accident-data analyses to be performed were to relate all track-related accidents to a variety of factors describing the circumstances surrounding such accidents. The intent of these analyses was to:

1. Characterize the track-related accident problem, in terms of these factors, thus quantitatively defining priority areas for research and remedial action.
2. Determine those conditions where the variance of track-related accident frequency as a function of these factors was not typical of normal (non-accident) operations, thus suggesting possible causes of such accidents.
3. Determine the variance of track-related accident average damages as a function of these factors, to identify particularly severe accidents which should receive priority.

The new FRA accident-reporting system established in 1975 includes a wide variety of factors relevant to track-related accidents which were unavailable in the earlier system. The following factors were chosen for this analysis:

1) Track Factors

Track type: main, yard, siding, industry;

FRA track class: 1 through 6;

Annual traffic density: .1 to < 100 million gross tons.

2) Train Factors

Type of equipment consist: 8 types;

Trailing tons: <.5 to > 10 thousand gross tons;

Train length: Number of cars, <25 to >225;

Initial car/unit involved: position in train, 1st to >225th;

Number of head locomotives: 1 to >3.

3) Operations Factors

Train Speed: .1 to >110 mph.

4) Environmental Factors

Temperature: <-.20 to >100°F.

Computer programs were prepared to compute the following statistics from the accident files (a sample computer output is provided in Appendix F):

1) For all track-related accidents and for each track-related cause code (see Appendix A for cause code listing) the following data were produced as a function of levels of the factor being investigated:

   a. Number of accidents;

   b. Percent distribution of accidents;

   c. Total dollar damages;

   d. Percent distribution of total dollar damages; and

   e. Average dollar damages.

2) For all values of the factor the following total statistics were produced:

   a. Number of accidents;

   b. Mean value of the factor based on the distribution of the number of accidents;

   c. Standard deviation of the factor;

   d. Total dollar damages; and

   e. Average dollar damages.

3) The statistics developed were also stratified for type of track and, in the case of speed, by FRA track class.

There were two basic problems which arose in analysis of the accident data. Some of the accidents reported contained erroneous data (e.g. traffic densities greater than 1 billion gross tons), missing data or only partial information on accidents involving more than one train. These accident records were not used, resulting in a less than complete data base of all track-related accidents. However, in no case was less than 81 percent of relevant data used. The data base was otherwise assumed to be accurate for purposes of this study. The other problem resulted from there being only a few accidents reported, in some cases, having extreme values of the factor being investigated. This produced biased statistics from which reliable results could not be inferred. For example, average damage statistics were often biased because of the strong influence of one unusual accident among only a few reported accidents.

A summary analysis of the relationships between track-related accidents and the factors investigated is provided in Table 2-1, and a discussion of the significant findings follows below.

2.2.1 Track Factors

The track-related accident problem, as measured by total accident damages, can be characterized as occurring predominantly on main track (85 percent of damages) of traffic density less than 20 MGT and low FRA track class (class 3 or less). The dominance of main track is expected and is due both to the large number of accidents on main track and the high average damages of these accidents. The second largest category of accidents occurs in yards (only 11.4 percent of track-related accident damages), where there is a substantial number of accidents of low average damages.

The occurrence of 79 percent of track-related accidents on main track of less than 20 MGT and 95 percent of track-related accidents on track of FRA class 3 or less suggests that track-related

TABLE 2-1. SUMMARY ANALYSIS OF FACTORS AFFECTING TRACK-RELATED ACCIDENTS (1 of 4)

FACTOR	SUMMARY ANALYSIS
TRACK FACTORS	
Type of Track	o 85% of track-related (T-R) accident damages occurs on main track, 11.4% on yard track. Damages on siding and industry tracks are negligible (3.8%).
	o High total damages on main track are due both to high frequency and average damages of accidents. Yard truck accidents are frequent (39% of accident frequency) but are low in average damages.
FRA Track Class	o 78% of T-R accident damages occurs on track classes 1, 2 and 3.
	o The frequency of T-R accidents decreases with higher classes of track.
	o 46% of T-R accidents occurs on class 1 track.
	o Average damages of T-R accidents increase with track class 1 thru class 4 track. The data indicates a drop in average damages beyond class 4 track, but the scarcity of data makes this observation unreliable.
Annual Traffic Density	o 51% of T-R accident damages on main track occurs on track of relatively low density (<10 million gross tons) and decreases as traffic density increases beyond 20 million gross tons.
	o 62% of T-R accident frequency on main track occurs on track of less than 10 million gross tons.
	o T-R accident average damages on main track increase with traffic density up to 30 million gross tons. Beyond this point a consistent trend is not observed.

Note: See Appendix D, Figures D-1 to D-19, which relate accident frequency average damages per accident and total damages to various levels of these factors.

TABLE 2-1. SUMMARY ANALYSIS OF FACTORS AFFECTING TRACK-RELATED ACCIDENTS (2 of 4)

FACTOR	SUMMARY ANALYSIS
TRAIN FACTORS	
Type of Equipment Consist	o 93% of T-R accident damages occurs on freight trains, 05% on yard/switching.
	o 76% of T-R accident frequency occurs on freight trains, 19% on yard/switching.
	o T-R accident average damages are greatest on freight trains; yard/switching average damages are relatively low (22% of freight-train severity).
Trailing Tons	o T-R accident damages as a function of trailing tons follow roughly a normal distribution, but it is skewed to the right (mean gross tonnage ~ 5 thousand).
	o T-R accident frequency is also a right-skewed distribution (mean gross tonnage = 5 thousand, standard deviation = 4.15 thousand). This distribution appears to be about the same as for normal (non-accident) operations, suggesting no causal relationship between trailing tons and accident frequency. This observation was also noted in Reference 9.
	o T-R accident average damages tend to increase directly with trailing tons. This is as would be expected since more equipment would be damaged with longer trains. This observation is also noted in Reference 9.
Train Length	o The observations made for trailing tons apply similarly for train length. The mean train length for T-R accidents is 61 cars; standard deviation, 37 cars.

Note: See Appendix D, Figures D-1 to D-19, which relate accident frequency, average damages per accident and total damages to various levels of these factors.

TABLE 2-1. SUMMARY ANALYSIS OF FACTORS AFFECTING TRACK-RELATED ACCIDENTS (3 of 4)

FACTOR	SUMMARY ANALYSIS
Position of Initial Car/Unit Involved	o T-R accident damages as a fucntion of position of initial car involved are normally distributed, but they are skewed to the right. o T-R accident frequency distribution is also skewed to the right (mean position, 29th car; standard deviation, 30 cars). o T-R accident average damages decrease slightly as the initial car/unit changes from the head to end of the train.
Number of head locomotives	o T-R accident damages increase with the number of head locomotives, considering more than 3 locomotives as the largest group. o T-R accident frequency as a function of head locomotives is normally distributed (mean head locomotives = 3). However, based on the criterion of 1 locomotive per 50 cars and using the train length data, we find that the mean number of locomotives should be 2. This suggests that increasing the number of locomotives may have an influence on increasing the probability of a T-R accident. o T-R accident average damages increase with the number of locomotives, as would be expected, because of the positive correlation between locomotives and train length.
Number of mid- and rear-end locomotives	o The number of accidents involving mid- and rear-end locomotives was insufficient to produce reliable results.

Note: See Appendix D, Figures D-1 to D-19, which relate accident frequency, average damages per accident and total damages to various levels of these factors.

TABLE 2-1. SUMMARY ANALYSIS OF FACTORS AFFECTING TRACK-RELATED ACCIDENTS. (4 of 4)

FACTOR	SUMMARY ANALYSIS
OPERATIONS FACTORS	
Train Speed	o 71% of T-R damages occurs at speeds of less than 40 mph.
	o T-R accident frequency occurs primarily at low speeds (mean speed, 13 mph, standard deviation, 11 mph) typical of normal (non-accident) operations; hence, speed does not, in general, appear to be a causal factor.
	o T-R accident average damages increase sharply with speed, as expected, up to at least 60 mph. Beyond 60 mph, the data is insufficient to draw reliable conclusions.
ENVIRONMENTAL FACTORS	
Temperature	o T-R accident damages are a normally distributed function of temperature around a mean of about 50°F.
	o T-R accident frequency is similarly distributed (mean temperature, 52°F°, standard deviation, 22°F), typical of normal operations and indicative of no general causal relationship.
	o T-R accident average damages do not appear to vary signficantly as a function of temperature.

Note: See Appendix D, Figures D-1 to D-19, which relate accident frequency, average damages per accident and total damages to various levels of these factors.

accident propensity is strongly affected by overall track condition as reflected by FRA track class and traffic density (assuming lower density track is typically lower class). As a part of this study, it was possible to estimate the relative track-related accident rate (accidents per MGT per track-mile) on track of less than and greater than 20 MGT based on information from the FRA Track Classification and Designation Project[7] combined with FRA accident statistics. The important statistics used in this determination and the calculations are summarized in Appendix E. Even on the basis of several conservative assumptions, it was determined that the number of track-related accidents per ton of traffic per track-mile is more than 8 times greater on track of less than 20 MGT than on track of greater than 20 MGT.

The track-related accident rate by class of track is more difficult to determine because less is known about the mileage track by class. However, a reasonable assumption may be that the mileage of track carrying less than 20 MGT traffic is roughly equal to the mileage of Class 1, 2 and 3 track. This assumption is supported by the fact that at least 86 percent of the accidents on track of less than 20 MGT traffic also occurred on class 3 track or less and appears conservative since it results in class 3 track or less mileage constituting about 65 percent of all track miles. The accident rate (accidents per gross ton per mile of track), based on this assumption, for class 3 track and less would be about 8 times that of class 4 track and higher (see Appendix E for calculations). This result strongly suggests that achieving a high track-class rating is a primary deterrent to track-related accidents.

2.2.2 Train Factors

Freight trains on main track account for eighty-four percent of total track-related accident damages. It was found that the distribution of track-related accidents as a function of train length (mean length, 61 cars) and trailing tonnage (mean tonnage, 5,000 tons) was similar to that of typical non-accident operations (average freight train length = 68.6 cars,[14] average gross ton-miles per train mile = 4,600 tons[3]) and thus indicates that the factors do not contribute generally to track-related accidents. This observation regarding the effect of train length and trailing tons was also made in a study of the economics of short trains.[8] The accident statistics also indicated that additional head locomotives may increase slightly the probability of a track-related accident for trains of the same length.

2.2.3 Operations Factors

Train speeds of less that 40 mph on main track account for 71 percent of track-related accident damages. Since track-related accidents occur at low speeds (mean speed, 13 mph) typical of normal operations on low-class track, speed does not, in general, appear to be a cause of such accidents. In some cases, however, the speed of the train exceeded the speed limit for the class of track. Table 2-2 lists statistics for those accidents in which the speed limit was exceeded. In the case of class 1, 2 and 3 track, the number of violations resulted in 13 percent of total track-related accident damages. It was also found, as expected, that average accident damages increased with speed.

TABLE 2-2. TRACK-RELATED ACCIDENTS INVOLVING SPEEDS IN EXCESS OF THE FRA TRACK-CLASS LIMIT, MAIN TRACK

TRACK CLASS	NUMBER OF ACCIDENTS	PERCENT OF ACCIDENTS PER CLASS	PERCENT OF DAMAGES PER CLASS
1	36	11%	23%
2	37	7%	14%
3	13	3%	11%
4	1	1%	1%
5	0	0	0
6	0	0	0

2.2.4 Environmental Factors

The mean temperature at which all track-related accidents occur is 52°F. Since this appears to be typical of normal train operations, it indicates that temperature does not generally contribute to track-related accidents. However, as discussed in Section 4.1, temperature was found to contribute to the initiation of several specific track-related cause codes.

3. DETERMINATION OF LEADING TRACK-RELATED ACCIDENT CAUSE CODES

For each rail-equipment accident that occurs, a cause for that accident is reported, as selected from a standard list of cause codes. The track-related accident cause codes are listed in Appendix A for both the pre-1975 and 1975 reporting systems. The purpose of this part of the analysis was to determine the leading cause codes in terms of total accident damages for which they are accountable. The results of this analysis identify the most critical causes of track-related accidents and thus provide valuable guidance in establishing priorities for research and in identifying potential means of reducing track-related accident damages.

3.1 LEADING TRACK-RELATED CAUSE CODE GROUPS

The track-related cause codes, listed in Appendix A for 1975, are combined into six major groups: (1) roadbed defects, (2) track-geometry defects, (3) rail and joint-bar defects, (4) frogs, switches and track appliances, (5) other way and structures, and (6) signal and communication failures. Prior to analyzing the individual cause codes, these major groups were ranked according to damages and compared between the years 1974 and 1975 as a means of reconciling the new and old reporting systems.

The rank of the major cause code groups, based on accident damages, is shown in Table 3-1. Also shown is the percent distribution of the cause code groups by dollar damages, casualties, and number of accidents. The leading cause code group is Track Geometry, closely followed by Rail and Joint-Bar Defects. These two groups combined account for over 82 percent of the dollar damages, 78.4 percent of the casualties and 75 percent of the total number of track-related accidents in 1975.

TABLE 3-1. SEVERITY RANKING OF MAJOR TRACK-RELATED CAUSE GROUPS

RANK	CAUSE GROUP (CODE NOS.)		PERCENT OT TOTAL TRACK-RELATED DOLLAR DAMAGES	PERCENT OF TOTAL TRACK-RELATED CASUALTIES*	PERCENT OF TOTAL TRACK-RELATED ACCIDENTS	
					1975	1974
1	Track Geometry	(110-129)	43.1	45.2	47.6	48.3
2	Rail and Joint-Bar Defects	(130-149)	39.0	33.2	28.0	27.8
3	Roadbed Defects	(101-109)	9.1	16.6	5.7	3.4
4	Frogs, Switches & Track Appliances	(160-179)	7.2	2.5	17.8	20.2
5	Other Way and Structures	(180-189)	1.4	0	0.6	0.1
6	Signal and Communications	(200-209)	0.2	2.5	0.3	0
TOTAL			100.0	100.0	100.0	100.0

*Includes only injuries

At the aggregated level of these major cause code groups, it was possible to assemble similar statistics for 1974 by summing eqivalent cause codes. The percent distribution of the number of accidents by the cause code groups for 1974 is also shown in Table 3-1. A comparison of the two years shows that there was little change in the ranking of the cause groups. This comparison should be considered approximate in view of the possible errors introduced by aggregating specific cause codes that were not identical for the two years.

3.2 LEADING TRACK-RELATED CAUSE CODES

Within the cause code groups cited above, there is a total of 57 individual track-related cause codes in the new reporting system. Computer programs were developed to provide the following summary statistics on each of these cause codes (Appendix C contains a sample computer print-out):

1. Number of accidents;
2. Number of accident reports (some accidents contained several reports);
3. Total dollar damages;
4. Mean (average) dollar damage per accident;
5. Median dollar damage per accident;
6. Product of the number of accidents times the median dollar damage (termed "severity index");
7. Number of injuries;* and
8. Number of fatalities.*

*These casualty statistics, developed from the rail-equipment accident data base, differ slightly from the data contained in the railroad-injury and illness summary data base, which is considered the official report on casualties. The errors are primarily due to the double reporting of about 35 injuries on multiple accidents.

These statistics were analyzed to develop a ranked list of all cause codes and then to select a reduced list of the 17 leading cause codes. These leading cause codes are listed in Table 3-2 ranked by total damages. The following additional statistics for each cause code are also provided in Table 3-2:

1. Damages - measures the damages produced by the specific cause code.
2. Cumulative damages, percent - measures the percent of total track-related accident damages captured by that cause code when combined with all higher-ranking cause codes.
3. Cumulative number of accidents, percent - measures the percent of accidents captured by that cause code when combined with all higher-ranked codes.
4. Cumulative number of casualties, percent - measures the percent of casualties captured by that cause code when combined with all higher-ranked codes.

The purpose in developing a reduced list of cause codes was to identify those codes of most significance to the track-related accident problem and also to narrow the problem definition to permit concentration of research effort. The 17 cause codes selected thus served as the basis for more detailed analyses of factors contributing to track-related accidents described in Section 4 of this report. The following considerations were taken into account in establishing the reduced list of 17 leading cause codes:

1. A sufficient number of cause codes was included so that most of the total damages and casualties were captured. The 17 leading cause codes selected account for almost 81 percent of the damages and 83 percent of the casualties produced by track-related accidents.

TABLE 3-2. RANKING OF THE 17 LEADING TRACK-RELATED CAUSES, 1975

RANK	CAUSE CODE	(CODE NO.)	DAMAGES $ MILLION	CUMULATIVE PERCENT OF DAMAGES	CUMULATIVE PERCENT OF ACCIDENTS	CUMULATIVE PERCENT OF CASUALTIES
1	Cross Level of Track Irregular at Joint	(119)	8.0	11.5	12.9	7.6
2	Wide Gauge, Ties	(110)	7.0	21.6	26.9	10.8
3	Transverse/Compound Fissure	(141)		28.8	31.8	14.6
4	Head & Web Separation, Outside Joint	(136)	4.0	34.5	34.8	19.7
5	Cross Level of Track Irregular, not at Joint	(120)	3.9	40.1	41.5	24.8
6	Washout/Rain/etc. Damage to Track	(102)	3.6	45.2	43.5	36.3
7	Broken Base of Rail	(131)	3.0	49.5	47.9	38.9
8	Track Alignment Irregular, Buckled	(115)	2.8	53.6	50.6	44.6
9	Other Track Geometry	(129)	2.3	56.9	52.5	60.5
10	Vertical Split Head	(142)	2.3	60.2	55.9	63.7
11	Track Alignment Irregular	(114)	2.2	63.4	59.3	66.2
12	Other Rail & Joint-Bar Defect	(149)	2.2	66.5	61.7	68.2
13	Joint Bar Broken, Non-insulated	(147)	2.2	69.6	63.3	70.7
14	Roadbed Settled or Soft	(101)	2.0	72.5	66.2	75.8
15	Bolt Hole Crack or Break	(130)	2.0	75.4	68.3	79.6
16	Switch Point Worn or Broken	(165)	1.9	78.1	77.9	80.9
17	Superelevation Improper	(117)	1.8	80.6	79.9	82.8

2) The list was made long enough to include all cause codes that produced a significant incremental increase in the cumulative number of accidents, damages or casualties. For this reason, the 16th-ranked cause code was included, Switch Point Worn or Broken, since it produced a significant 9.6 percent increase in the cumulative number of accidents even though the cumulative damage increase was only 2.7 percent.

3) The list was extended to the 17th cause code, Superelevation Improper, since this was a unique code which did not have a related code higher in the list. The next several cause codes, Head and Web Separation, and Other Frogs, Switches and Track Appliances, were not included since they had related codes that ranked 4th and 16th respectively in the list.

The 17 cause codes listed in Table 3-2 represent a range of track-related accident causes encompassing track-geometry, rail and joint, switch, and roadbed defects. These leading cause codes account for the following percentages of the track-related accident impacts:

	Damages	Casualties	Number of Accidents
Track-Geometry Defects	39.3	41.9	43.6
Rail and Joint Defects	29.6	23.0	21.8
Roadbed Defects	8.0	16.6	4.9
Switch Defects	2.7	1.3	9.6
TOTAL	80.6	82.8	79.9

A comparison of the above data with the information in Table 3-1, which shows total damages resulting from all cause codes within these groups, indicates that the 17 leading cause codes account for 91 percent of the geometry, 76 percent of the rail and joint, 88 percent of the roadbed and 38 percent of the switch and appliance-caused damages.

3.3 PREVIOUS YEARS' TRENDS IN 1975 LEADING CAUSE CODES

As is evidenced by a comparison of the track-related cause codes prior to 1975 with those of the new reporting system (Appendix A), there is little direct compatibility of specific codes. For example, a comparison of the 16 leading cause codes for 1974 (Table 3-3), with the leading cause codes for 1975 (Table 3-2), shows there is little continuity. However, knowledge of the trends in accident cause codes is extremely useful in establishing priorities for research. An attempt was therefore made to reconcile the cause code systems for the years 1974 and 1975.

The approach used was to group several individual codes for one year to create equivalent codes similar to those for the previous year. With the 16 leading cause codes for 1974 as a basis, various 1975 cause codes were grouped to create equivalent codes. In some cases, several 1974 codes were grouped to become equivalent to one 1975 code. The results are shown in Table 3-4, which provides the percent of track-related accidents produced by each equivalent group of causes. In many cases, the cause code titles matched well (e.g., Improper Alignment of Track in 1974 equals the two 1975 codes for Track Alignment Irregular), but the percent of accidents accounted for shows large discrepancies (e.g., 2.5 percent in 1974 versus 6.2 percent in 1975 for alignment defects). The difference in percentages between the years is large enough in most cases to suggest that the discrepancy is due in part to inconsistencies in cause code definitions rather than any actual change in accident cause trends. One explanation for this problem is that, prior to 1975, FRA employees selected the cause codes from written descriptions of the accidents prepared by the railroads, whereas, after 1975 the cause codes were selected by the railroads. A further discrepancy, which can be seen in Table 3-4, is that several of the 17 leading cause codes in 1975 (102, 131, 129 and 115) are not included in the equivalent cause codes based on the 16 leading 1974 cause codes. These problems

TABLE 3-4. COMPARISON OF OLD AND NEW CAUSE CODES FROM 1974 TO 1975 (2 of 2)

"OLD" CAUSE CODES NO.	"OLD" CAUSE CODES CODE	EQUIVALENT "NEW" CAUSE CODES NO. (1975 RANK)	EQUIVALENT "NEW" CAUSE CODES CODE	PERCENT OF TRACK-RELATED ACCIDENTS 1974	PERCENT OF TRACK-RELATED ACCIDENTS 1975
3212	Rail Joints, Bars or Bolts	145	Joint Bar, Broken (comp.)	2.8	2.8
		146	Joint Bar, Broken (insul.)		
		142(13)	Joint Bar, Broken (non insul.)		
		148	Joint Bolts		
3205	Rails, Split Head	138	Horizontal Split Head	2.7	4.1
		142(10)	Vertical Split Head		
3212	Rails, Giving Way	143	Worn Rail	3.9	1.7
3508	Soft Track	101(14)	Roadbed, Settled or Soft	3.3	2.9
3313	Switch Point, Worn	165(16)	Switch Point, Worn or Broken	8.5	9.6
3312	Switch Point, Broken				
3309	Switch, Lost Motion or out of Adjust	161	Switch, Damaged or not Adjusted	4.3	1.8
3505	Improper Gauge	111	Wide Gauge, Spikes	5.1	3.3
		112	Wide Gauge, Gauge Rods		
		113	Wide Gauge, Worn Rails		
			TOTALS	84.4	81.1

suggest that, other than at aggregated cause code levels, such as in Table 3-1, it will be difficult to make accurate comparisons of, or define trends in, specific cause codes prior to and after 1975.

4. ANALYSIS OF LEADING TRACK-RELATED ACCIDENT CAUSE CODES

This phase of the analysis establishes the relationships between the 17 leading cause codes, identified in the previous section, and various track, train, operations and environmental factors for the purpose of:

1. More precisely defining the conditions under which the leading cause codes occur and thus indicating possible reasons why they occur;
2. Determining how the severity of track-related accidents (measured by average damage per accident) caused by these cause codes varies as a function of the factors investigated.

The factors investigated and the basic data used in the analysis are the same as those described in Section 2.2.

4.1 ANALYSIS OF FACTORS CONTRIBUTING TO CAUSE CODE OCCURRENCE

The analytical approach used to characterize and explain cause code occurrence was to determine whether the relationship of accidents caused by a particular code to a factor was different from the relationship of all track-related accidents to the same factor. If there was no difference, then the influence of that factor on the particular cause code was the same as that described for all track-related accidents in Section 2.3. On the other hand, a unique relationship indicates conditions where the factor contributes to an increased probability of that particular cause occurring given that the general conditions are conducive to a track-related accident. Furthermore, a comparison of the unique relationship to that of normal, non-accident operations will indicate whether the factor contributes to the initiation of that cause. Since non-accident data is not available in the form required for this analysis, only qualitative conclusions can be made regarding the causal influence of factors based on reasonable assumptions of the nature of non-accident operations.

An example of the analysis approach can be provided using temperature as the environmental factor and transverse/compound fissure (141) as the cause code. The analysis shows that the relationship of this cause code to temperature is significantly different from that of all track-related accidents to temperature. When this cause code occurs, the average temperature is not only lower than for other track-related accidents, it is also lower than would be expected for normal, non-accident operations. This, then, indicates that low temperature will generally contribute to accidents caused by transverse/compound fissures particularly on track likely to have track-related accidents (i.e., track characterized by low traffic density and track class).

The approach used to determine wnether a unique relationship existed between a cause code and a factor investigated, relative to all other cause codes, was to compare the mean values of their distributions. A series of distributions were developed of the number of accidents caused by each cause code as a function of levels of the factors investigated. A criterion was developed to establish whether the mean value of a factor for accidents by a specific cause code was different from the mean value for all track-related accidents. It was assumed that the accidents due to a particular cause code constituted a subset, or sample, of the total population of track-related accidents. The central limit theorem was then applied to determine the probability of selecting a sample of accidents from all track-related accidents with a mean value equal to that of the particular cause code. If the probability was less than 5 percent then the mean value was considered significantly different. An example of a computer output that provided the data for this analysis is shown in Appendix F.

The results of this analysis are contained in Appendix G, which includes a series of tables listing the mean values of the distribution of accidents caused by the 17 leading cause codes versus various levels of the factors investigated. Those mean values which are significantly greater than, or less than, the mean for all track-related accidents are designated with a (+) or (-), respectively. Table 4-1 in this section includes a summary analysis of the mean values with annotations of all relationships in which differences occurred. A discussion of the significant findings follows.

4.1.1 Roadbed Group

4.1.1.1 Roadbed, Settled or Soft (101)

- The only significant factors associated with this cause code are that train trailing tonnage and speed are relatively low. The association with smaller trains and lower speeds could be reflective of poor quality track if train size, train speed and condition of track are assumed to be positively correlated.

4.1.1.2 Washout/Rain/Slide/Flood/Snow/Ice Damage to Track (102)

- This cause code occurs primarily on main track. The exception is that low temperature occurrences of this code are prevalent in yards where track appliances may be readily damaged by ice and snow. Because damages by this cause code are largely the result of environmental or natural causes, there may tend to be less discrimination as to the condition of track that is affected; i.e., well maintained high-class track may be the victim of a slide or flood just as easily as low-class track. This would explain the tendency of this cause to occur on higher class track and at higher train speeds. Also, assuming class of track, train speed and train length are positively correlated, it follows that longer trains are primarily affected by this code. The first car of a train affected by this code is more toward the head of the train than is the case for the other track-related accidents. One explanation for this is that track damages caused by this code would tend to occur prior to train arrival.

TABLE 4-1. SUMMARY ANALYSIS OF THE EFFECTS OF FACTORS ON THE 17 LEADING TRACK-RELATED CAUSE CODES (1 of 4)

CAUSE CODE	(CODE NO.)		RELATIONSHIP OF FACTOR TO CAUSE CODE
1. ROADBED GROUP			
1.1 Roadbed, Settled or Soft	(101)	1.1a	Trailing Tons: tends* to be low, significantly** on main track
		1.1b	Speed: significantly less on main track
1.2 Washout/Rain/Slide/etc. Damage to Track	(100)	1.2a	Type of Track: tends to be main
		1.2b	Track Class: tends to be higher, significantly for yard track
		1.2c	Train Length: significantly longer on main track
		1.2d	Principal Position of Initial Car: significantly more towards head of train
		1.2e	Speed: significantly higher on main track
		1.2f	Temperature: tends to be low, significantly in yards
2. TRACK-GEOMETRY GROUP			
2.1 Wide Gauge, Ties	(110)	2.1a	Type of Track: significant occurrence in yards
		2.1b	Track Class: significantly lower
		2.1c	Traffic Density: tends to be low
		2.1d	Trailing Tons: significantly low on main track
		2.1e	Train Length: significantly shorter
		2.1f	Speed: significantly less on main track

*"tends" implies an inferred relationship that was less than statistically significant.
**"significant" implies a statistically significant relationship.

TABLE 4-1. SUMMARY ANALYSIS OF THE EFFECTS OF FACTORS ON THE 17 LEADING TRACK-RELATED CAUSE CODES (2 of 4)

CAUSE CODE		(CODE NO.)	RELATIONSHIP OF FACTOR TO CAUSE CODE	
2.2	Track Alignment, Irregular	(114)	2.2a	Track Type: significant occurrence on main track
			2.2b	Principal Position of Initial Car: significantly more towards rear of train on main track
			2.2c	Temperature: tends to be higher, significantly on main track
2.3	Track Alignment, Irregular (Buckled)	(115)	2.3a	Track Type: significant occurrence on main track
			2.3b	Track Class: tends to be higher, significantly on main track
			2.3c	Trailing Tons: significantly greater in yards
			2.3d	Train Length: significantly longer in yards
			2.3e	Principal Position of Initial Car: significantly more towards rear of train
			2.3f	Temperature: significantly higher
			2.3g	Speed: significantly higher
2.4	Superelevation, Improper	(117)	2.4a	Track Type: significant occurrence on main track
			2.4b	Trailing Tons: significantly less on main track
2.5	Cross Level of Tracks, Irregular (At Joints)	(119)	2.5a	Track Type: significant occurrence on main track
			2.5b	Track Class: significantly higher on main track
			2.5c	Train Length: significantly longer on main track
			2.5d	Principal Position of Initial Car: tends to be more towards rear of train, significantly on main track

TABLE 4-1. SUMMARY ANALYSIS OF THE EFFECTS OF FACTORS ON THE 17 LEADING TRACK-RELATED CAUSE CODES (3 of 4)

CAUSE CODE		(CODE NO.)	RELATIONSHIP OF FACTOR TO CAUSE CODE	
2.5	Cross Level of Tracks, Irregular (Continued)	(119)	2.5e	Temperature: significantly higher in yards
2.6	Cross Level of Tracks, Irregular (not at Joint)	(120)	2.6a	Track Type: significant occurrence on main track
			2.6b	Principal Position of Initial Car: tends to be more toward rear of train, significantly on main track
			2.6c	Temperature: tends to be higher, significantly on main track
2.7	Cause Code not Listed	(129)	2.7a	Track Class: significantly higher on main and siding track
			2.7b	Train Length: significantly longer on main and siding track
			2.7c	Speed: significantly higher on main track
			2.7d	Temperature: significantly higher on siding and industry track.
3.	RAIL AND JOINT-BAR GROUP			
3.1	Bolt Hole Crack or Break	(130)	3.1a	Track Class: significantly higher on main track
			3.1b	Temperature: tends to be lower, significantly on main track
			3.1c	Speed: significantly higher on main track
3.2	Broken Base of Rail	(131)	3.2a	Track Class: Tends to be lower
			3.2b	Trailing Tons: significantly less on main track
			3.2c	Temperature: significantly lower on main track

TABLE 4-1. SUMMARY ANALYSIS OF THE EFFECTS OF FACTORS ON THE 17 LEADING TRACK-RELATED CAUSE CODES (4 of 4)

CAUSE CODE		(CODE NO.)	RELATIONSHIP OF FACTOR TO CAUSE CODE	
3.3	Head and Web Separation (Outside Joint-Bar Limits)	(136)	3.3a	Traffic Density: tends to be low
			3.3b	Trailing Tons: tends to be higher, significantly on main track
			3.3c	Train Length: tends to be longer, significantly in yard
3.4	Transverse/Compound Fissure	(141)	3.4a	Train Length: significantly longer in yards
			3.4b	Temperature: significantly less on main track
3.5	Vertical Split Head	(142)	3.5a	Trailing Tons: tends to be greater, significantly in yards
			3.5b	Temperature: tends to be lower, significantly on main track
3.6	Joint Bar, Broken, Noninsulated	(147)	3.6a	Traffic Density: Tends to be low
3.7	Cause Code not Listed	(149)	3.7a	Traffic Density: significantly higher
			3.7b	Train Length: significantly shorter on main track
			3.7c	Temperature: tends to be lower, significantly in yards
			3.7d	Speed: significantly higher on main track
4.	<u>FROG, SWITCHES AND TRACK APPLIANCE GROUP</u>			
4.1	Switch Point, Worn or Broken	(165)	4.1a	Track Type: significant occurrence in yards
			4.1b	Trailing Tons: significantly less
			4.1c	Speed: significantly less on main track

4.1.2 Track Geometry Group

4.1.2.1 Wide Gauge (Defective or Missing Crossties) (110) - A very clear indication is provided that this cause code occurs predominantly on track of unusually low class, traffic density, train trailing tons, train length and train speed. The primary occurrence of this cause code is in yards.

4.1.2.2 Track Alignment, Irregular (114) and (115 Buckled) - These cause codes, like all other leading track geometry codes, excluding crossties (110) above, occur primarily on main track, which indicates that this is a problem associated with entrainment. This observation is supported by the evidence that code 115 occurs in yards only when the train length is significantly longer than is the case in other track-related yard accidents; i.e., the numerous short trains in yards tend not to be involved with this cause code. High temperatures also play a critical role in contributing to irregular track alignment, presumably through thermal expansion. The position of the first car involved tends to be more towards the rear of the train, again suggesting that the cumulative effect of coupled cars, i.e., entrainment, is critical. Code 115 occurs on track of higher track class than most track-related accidents and at higher speeds.

4.1.2.3 Superelevation, Improper (117) - The unusual feature of this cause code is that the trailing tonnage of trains affected is less than for the typical track-related accidents, but train length is typical. This suggests that trains with a larger than normal number of light or empty cars may contribute to this cause code. The position of empty cars may also be important. For example, a train with many empties towards the front and loaded cars at the rear could be affected more adversely by superelevation defects.

4.1.2.4 Cross Level of Track, Irregular (119 at Joints and 120 Not at Joints) - The primary occurrence of these cause codes on main track, the effect of high temperatures and the first car involved being toward the rear of the train indicate similar relationships, as discussed above under the track alignment codes 114 and 115. Cause code 119 also tends to occur on track of higher track class and with longer trains. As with code 115, this tends to suggest that track-train dynamics are critical in contributing to this cause.

4.1.3 Rail and Joint-Bar Group

4.1.3.1 Bolt-Hole Crack or Break (130) - This cause code occurs on track of somewhat better quality than for other track-related accidents, at higher train speeds and at lower temperatures. All these factors provide an indication that this code may be caused by the excessive impact of trains at the joint, especially at low temperatures, when the metal may be more prone to brittle fractures.

4.1.3.2 Broken Base of Rail (131) - This code occurs on track of low class, with trains of low trailing tonnage and at low temperatures.

4.1.3.3 Head and Web Separation, Outside Joint-Bar Limits (136) - This code occurs on track of low traffic density but with trains that are high in trailing tonnage and length.

4.1.3.4 Transverse/Compound Fissure (141) - The train length associated with this cause code, in yards, is quite long and indicates that the effect of trains, in contrast to single cars or short trains, contributes to its occurrence. Low tempreatures are also associated with the occurrence of this code.

4.1.3.5 Vertical Split Head (142) - The association of train trailing tons and temperature with the occurrence of this cause code is the same as train length and temperature with transverse/ compound fissures described above.

4.1.3.6 Joint-Bar, Broken, Noninsulated (147) - The only significant factor associated with this cause code is that the track traffic density tends to be low. This suggests that the rail may be of poor quality and consist of older rail joints.

4.1.4 Frog, Switches and Appliance Group

4.1.4.1 Switch Point, Worn or Broken (165) - This cause code occurs primarily in yards, with low train trailing tonnage and low speeds. This evidence simply reflects the fact that the greatest number of switches are found in yards. It further indicates that train characteristics of length and speed do not contribute to this cause code if it is assumed that smaller and slower trains are typical in yards.

4.2 ANALYSIS OF CAUSE CODE AVERAGE DAMAGES

An analysis of the average damages resulting from accidents caused by the leading cause codes was performed. The major objective of this analysis was to determine whether the factors investigated in the previous section had an effect on the average damages of specific codes that was different from that for all track-related accidents. If any differences did occur, then additional information could be inferred as to how specific factors contribute to track-related accident damages.

Results of the analysis did not provide significant additional information. In general, the average damages of the leading track-related cause codes varied with respect to the factors investigated in a manner similar to all track-related accidents as described in Section 2.3 and Appendix D. For example, the average damages for each cause code increased with train speed, similar to all track-related accidents. Where differences did occur, they were usually the result of the influence of a small number of extreme cases, since the number of accidents reported for a specific cause code and level of a factor was often very few. Reliable results could not be inferred from these statistics. The only consistent trend observed was that code 165, Switch Points Worn or Broken, was typically the lowest in average damage for all levels of the factors investigated.

4.3 ANALYSIS OF CONTRIBUTING CAUSE CODES

An improvement made to the 1975 accident reporting system was the incorporation of a contributing cause code in addition to the primary cause code. The contributing cause codes are the same as the primary codes listed in Appendix A. Taken together, the two cause codes could provide additional knowledge as to the causes of, and factors contributing to, track-related accidents. An analysis of the contributing cause codes was therefore performed.

It was quickly established that the contributing cause codes were rarely used in 1975, and thus their usefulness diminished. There were seven contributing cause codes which were used with some frequency, however. These contributing codes were categorized into track-related and non-track-related codes and listed in Tables 4-2 and 4-3, respectively, along with the primary codes which they contributed to. Table 4-2 demonstrates a strong relationship between roadbed - (101), elignment - (114), crosslevel - (119 & 120) and gauge-width (110) defects. These cause codes are primary and contributing causes with one another. This finding is not particularly unusual since track with one of these defects would tend to have the others; i.e., they all stem from general poor quality track.

The non-track-related cause codes are more informative, as shown in Table 4-3. A significant relationship that can be seen is between track-geometry primary causes and train-related contributing causes. Excessive buffing or slack action, train speed and side-bearing clearance combine with geometry defects to cause accidents. Another significant train-track interaction is the effect of worn wheel flanges in contributing to switch point-caused accidents.

TABLE 4-2. PRIMARY TRACK-RELATED CAUSES WITH TRACK-RELATED CONTRIBUTING CAUSES

TRACK-RELATED PRIMARY CAUSE CODE	TRACK-RELATED CONTRIBUTING CAUSE CODE	PERCENT OF PRIMARY CAUSE ATTRIBUTED TO CONTRIBUTING CAUSE BY TYPE OF TRACK	
		MAIN TRACK	YARD TRACK
(101) Roadbed, Settled or Soft	(120) Cross level of track irregular, not at joint	6.4	3.2
	(110) Wide gauge, ties	6.4	6.5
(110) Wide Gauge, Ties	(101) Roadbed, settled or soft	2.7	1.5
(114) Track Alignment, Irregular	(119) Cross level of track, irregular, at joints	3.6	5.3
(119) Cross Level of Track, Irregular, at Joints	(110) Roadbed, settled or soft	4.1	2.1
	(117) Superelevation, improper	2.0	0
(120) Cross Level of Track, Irregular, Not at Joints	(101) Roadbed, settled or soft	7.2	6.8

TABLE 4-3. PRIMARY TRACK-RELATED CAUSES WITH TRACK-RELATED CONTRIBUTING CAUSES

TRACK-RELATED PRIMARY CAUSE	NON-TRACK-RELATED CONTRIBUTING CAUSE	PERCENT OF PRIMARY CAUSE ATTRIBUTABLE TO CONTRIBUTING CAUSE BY TYPE OF TRACK	
		MAIN	YARD
(114) Track Alignment, Irregular	(570) Buffing or Slack Action, Excessive	4.8	0
	(559) Other Speed-Related Causes	2.4	5.3
(117) Superelevation, Improper	(570) Buffing or Slack Action, Excessive	6.8	0
	(559) Other Speed-Related Causes	6.8	0
(119) Cross Level of Track, Irregular, at Joints	(570) Buffing or Slack Action, Excessive	2.0	0
	(440) Side-Bearing Clearance, Improper	0.7	2.1
(120) Cross Level of Track, Irregular, at Joints	(440) Side-Bearing Clearance, Improper	2.6	0
(165) Switch Point, Worn or Broken	(464) Worn Flange	7.0	5.3

5. ANALYSIS OF CAUSE CODES RELATIVE TO THE TRACK SAFETY STANDARDS

5.1 GENERAL

A major improvement in the new accident reporting system is that the track-related cause codes have been made generally consistent with the Track Safety Standards. As a result, many of the standards are covered by specific cause codes. This is useful since it permits ranking of the standards by the accident damages for which they are accountable. Used together with results described earlier in the report, where factors related or contributing to accidents have been identified, this ranking of standards should be useful in determining more effective means of applying the standards to improve railroad safety.

5.2 RANKING OF TRACK STANDARDS

The Track Safety Standards were compared with the cause codes to determine the damages by accidents covered by each standard. The results of this analysis are shown in Table 5-1, where each standard is matched with applicable cause codes and rated according to the total damages for which it is accountable. Many of the standards pertain to administrative aspects of rail safety that could not be reportable as accident causes, and thus were not included in Table 5-1. The results show that as few as five critical sections of standards account for over 74 percent of track-related accident damages, as summarized in Table 5-2. Defective rails (Section 213.113) was found to be the most critical standard, accounting for 31 percent of track-related damages. The damages for defective rails occur predominantly on class 3 track and less, as summarized for mainline track below:

	1	2	3	4	5	6
PERCENT OF DEFECTIVE RAIL-CAUSED ACCIDENT DAMAGES BY CLASS	3.1	26.0	45.2	25.2	0.5	0.0

TABLE 5-1. TRACK SAFETY STANDARDS VERSUS TRACK-RELATED CAUSE CODES (1 of 4)

TRACK STANDARDS SECTION	TRACK STANDARDS TITLE	CAUSE CODES NO.	CAUSE CODES TITLE	PERCENT OF TRACK-RELATED DAMAGES, 1975
SUBPART B - ROADBED		101	Roadbed Settled or Soft	2.9
		109	Roadbed, "Cause Code Not Listed"	1.1
213.33	Drainage	102	Washout/Rain/Etc. Damage to Track	5.1
213.37	Vegetation	200	Fixed Signal, Improperly Displayed (Due to Vegetation)	0.0
		209	Signal and Communication Failures, "Cause Code Not Listed" (Due to Vegetation)	0.1
SUBPART C - TRACK GEOMETRY		129	Track Geometry Defect, "Cause Code Not Listed"	3.3
213.53	Gauge	(Sum of 110-113 below)		(11.9)
		110	Wide Gauge (Defective or Missing Crossties)	10.1
		111	Wide Gauge (Defective or Missing Spikes or Fasteners)	1.0
		112	Wide Gauge (Loose, Broken or Defective Gauge Rod)	0.1
		113	Wide Gauge (Worn Rail)	0.7
213.55	Alignment	114-115	Track Alignment	7.2
213.57	Curves; Elevation and Speed	117	Superelevation	2.5
213.59	Elevation of Curved Track; Runoff	118	Superelevation	0.2
213.63	Track Surface	116-	Track Profile	0.8
		119-120	Cross Level of Track	17.1

TABLE 5-1. TRACK SAFETY STANDARDS VERSUS TRACK-RELATED CAUSE CODES (2 of 4)

TRACK STANDARDS SECTION	TRACK STANDARDS TITLE	CAUSE CODES NO.	CAUSE CODES TITLE	PERCENT OF TRACK RELATED DAMAGES, 1975
SUBPART D - TRACK STRUCTURE		149	Rail and Joint Bar Defect, "Cause Code Not Listed"	3.2
		180	Bridge Misalignment or Failure	0.0
		189	Other Way and Structure, "Cause Code Not Listed"	1.2
213.103	Ballast; General	101	Roadbed, Settled or Soft	See Subpart B, Roadbed above
		102	Washout/Rain/Etc.Damage to Track	See Drainage above
		116	Track Profile	See Track Surface above
		119-120	Cross Level of Track	See Track Surface above
213.109	Crossties	110	Wide Gauge (Defective or Missing Crossties)	See Gauge above
213.113	Defective Rails	(Sum of 130-143 below)		(31.1)
		140	Rail Defect with Joint Bar Repair	0.1
		143	Worn Rail	1.4
	Transverse Fissure and Compound Fissure	141	Transverse/Compound Fissure	7.2
	Detail Fracture	134	Detail Fracture	0.7
	Engine-Burn Fracture	135	Engine-Burn Fracture	0.1
	Defective Weld	132-133	Broken Weld	1.7
	Horizontal Split Head	138	Horizontal Split Head	1.3
	Vertical Split Head	142	Vertical Split Head	3.3
	Split Web	149	Rail Defect, "Cause Code Not Listed"	See Subpart D, Track Structure above
	Piped Rail	139	Piped Rail	0.6
	Head-Web Separation	136-137	Head-Web Separation	7.6
	Bolt-Hole Crack	130	Bolt-Hole Crack or Break	2.8
	Broken Base	131	Broken Base of Rail	4.3
	Ordinary Break	149	Rail Defect, "Cause Code Not Listed"	See Subpart D, Track Structure above
	Damaged Rail	149	Rail Defect, "Cause Code Not Listed"	See Subpart D, Truck Structure above

TABLE 5-1. TRACK SAFETY STANDARDS VERSUS TRACK-RELATED CAUSE CODES (3 of 4)

TRACK STANDARDS SECTION	TRACK STANDARDS TITLE	CAUSE CODES NO.	CAUSE CODES TITLE	PERCENT OF TRACK RELATED DAMAGES, 1975
213.115 and 213.117	Rail-End Mismatch Rail-End Batter	144	Mismatched Rail-Head Contour	0.1
213.121	Rail Joints	145-148	Joint Bar and Bolts	4.8
213.123	Tie Plates	111	Wide Gauge	See Gauge above
213.125	Rail Anchoring	115	Track Alignment	See Alignment above
213.127	Track Spikes	111	Wide Gauge	See Gauge above
213.129	Track Shims	111	Wide Gauge	See Gauge above
213.131	Planks used in Shimming	111	Wide Gauge	See Gauge above
213.133	Turnouts and Track Crossings	181	Flangeway Clogged	0.2
213.135	Switches	161-166, 174	Switches, Stock Rails and Spring	4.5
213.137	Frogs	167	Frog, Rigid	0.3
213.139	Spring-Rail Frogs	168	Frog, Spring	0.1
213.141	Self-Guarded Frogs	169	Frog, Self-Guarded	0.1
213-143	Frog-Guard Rails & Faces; Gauge	160	Guard Rails	0.1

TABLE 5-1. TRACK SAFETY STANDARDS VERSUS TRACK-RELATED CAUSE CODES (4 of 4)

TRACK STANDARDS		CAUSE CODES		PERCENT OF TRACK RELATED DAMAGES, 1975
SECTION	TITLE	NO.	TITLE	
SUBPART E -	TRACK APPLICANCE AND TRACK-RELATED DEVICES	172	Expansion Joint, Failed	0.0
		173	Retarder, Worn, Broken	0.3
		179	Frogs, Switches and Track Applicances, "Cause Code Not Listed"	1.7
213.205	Derails	171	Derail	0.1
213.207	Switch Heater	161	Switch, Damaged or out of Adjustment	See Switches above
		179	Frogs, Switches and Track Appliances, "Cause Code Not Listed"	See Subpart E, Track Applicances above
			TOTAL	100.0

TABLE 5-2. LEADING SECTIONS OF THE TRACK SAFETY STANDARDS, 1975

Rank by Total Damage	Section of Track Safety Standards	Percent of Total Track-Related Accident Damages
1	213.113 Defective Rail	31.1
2	216.63 Track Surface	17.9
3	213.109 Crossties	10.1
4	213.103 Ballast/213.33 Drainage*	8.0
5	213.55 Alignment	7.2
		74.3

* The same cause codes, 101 & 102 apply to both Standard Sections.

5.3 INCONSISTENCIES BETWEEN TRACK SAFETY STANDARDS AND CAUSE CODES

As evidenced by the results in Table 5-1, most of the Track Safety Standards can be matched exclusively with specific cause codes. Several standard sections, shown in Table 5-3, while having related cause codes can't be matched exclusively, however. Thus, accident damages covered by these standard sections cannot be assigned accurately. Future refinements to either the cause codes or the standards should involve consideration of means to eliminate these ambiguities.

TABLE 5-3. TRACK STANDARDS NOT HAVING EXCLUSIVE CAUSE CODES

SECTION NUMBER	TITLE
213.33	Drainage
213.37	Vegetation
213.103	Ballast
213.123	Tie Plates
213.125	Rail Anchoring
213.129	Track Shims
213.131	Planks Used for Shimming
213.133	Turnouts and Track Crossings
213.207	Switch Heater

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12. National Transportation Safety Board, Special Study of Train Accidents Attributed to the Negligence of Employees, Bureau of Surface Transportation Safety, Washington DC, May 24, 1972.

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APPENDIX A
DESCRIPTION OF FRA ACCIDENT-INCIDENT REPORTING SYSTEM

The following is a brief description of the new FRA Railroad Accident/Incident Reporting System which served as the basic data source for this study. Because the system was completely revised in 1975, the description below is prepared in terms of discussing the major changes incorporated into it in relation to the old reporting system.

Accident Types - The old system classified all railroad accidents into three types:

1. Train: accidents, with or without casualties, arising in connection with the operation or movement of trains, locomotives, or cars that result in more than $750 of damage.
2. Train-Service: accidents arising in connection with the operation or movement of trains, locomotives or cars that result in reportable casualties to persons, but not in damage to railroad equipment, track or roadbed of more than $750.
3. Non-Train: accidents not caused directly by the operation or movement of trains, locomotives, or cars that result in reportable casualties.

The new reporting system classified all railroad accidents into three different types:

1. Rail-Highway Grade Crossing: all rail-highway grade-crossing accidents regardless of the extent of damages or casualties. These accidents were formerly a subset of Train-Service Accidents.
2. Rail Equipment: every rail equipment accident exceeding a monetary threshold specified every two years ($1,750 in 1975). This type of accident is equivalent to train accidents in the old system.

3. Death, Injury and Occupational Illness: any death, injury or occupational illness arising from the operation of a railroad. This type of accident covers all accidents in the former Train-Service and Non-Train categories in addition to occupational illnesses.

For the Rail-Highway Grade-Crossing and Rail-Equipment accident types of the new system it is possible to establish trends in relationship to earlier years. The Death, Injury and Occupational-Illness type accidents are not consistent within the two reporting systems, however. This study has concentrated exclusively on Rail-Equipment type accidents since all track-related accidents are included within this category. A sample of the new form used by railroads to report Rail-Equipment Accidents is contained in Appendix B.

Accident Causes - For the category of rail-equipment type accidents, there are four major groups of reportable accident causes that are consistent within the old and new reporting systems:

1. Track, Roadbed and Structures;
2. Mechanical and Electrical Failures;
3. Train Operation-Human Factors; and
4. Miscellaneous Causes Not Otherwise Listed.

This study has investigated Track, Roadbed and Structures causes of Rail-Equipment Accidents since these are of most relevance to the Track Structures Improvement Program. Within the Track, Roadbed and Structures causes there are six subgroups of accident causes that are generally equivalent within the old and new reporting systems:

1. Track Geometry;
2. Rail and Joint-Bar Defects;
3. Roadbed Defects;
4. Frogs, Switches and Track Appliances;

5. Other Way and Structures; and

6. Signal and Communications.

Within the six cause subgroups listed above, there is a total of 57 individual cause codes in the new reporting system. The cause codes in the new system differ substantially from those of the old system, as can be seen by a comparison of the two sets of cause codes in Tables A-1 and A-2. A significant improvement that was made to the cause code structure, in the new system, was to make it compatible with the Track Safety Standards.

Contributing Cause Codes/Factors - The new reporting system contains added information in the form of contributing cause codes and factors related to railroad accidents. This information was not available in the old system and represents a significant improvement in the ability to determine causes of, and conditions contributing to, track-related accidents. The contributing cause codes used in the reporting system are the same as the primary cause codes listed in Table A-1. Contributing factors provided on the accident report include the following:

1. Track Factors
    a. Type of track: main, yard, siding, industry;
    b. FRA track class;
    c. Annual traffic density.
2. Train Factors
    a. Type of equipment consist: 8 types;
    b. Trailing tons;
    c. Number of cars, loaded status, number derailed;
    d. Principal car/unit involved: initial and number, position, number derailed, loaded status;
    e. Locomotives: number, position, number derailed;
    f. Crew: number, type, hours on duty.

TABLE A-1. 1975 TRACK-RELATED CAUSE CODES: TRACK, ROADBED AND STRUCTURES

ROADBED DEFECTS

101 Roadbed, settled or soft.
102 Washout/rain/slide/flood/snow/ice damage to track.
109 Cause code not listed; enter code 109 in Item 37 and explain in Item 50.

TRACK-GEOMETRY DEFECTS

110 Wide gauge (defective or missing crossties).
111 Wide gauge (defective or missing spikes or other rail fasteners).
112 Wide gauge (loose, broken or defective gauge rods).
113 Wide gauge (worn rail).
114 Track alignment, irregular.
115 Track alignment, irregular (buckled).
116 Track profile, improper.
117 Superelevation, improper, excessive or insufficient.
118 Superelevation runoff, improper.
119 Cross level of track, irregular (at joints).
120 Cross level of track, irregular (not at joints).
129 Cause code not listed; enter code 129 in Item 37 and explain in Item 50.

RAIL AND JOINT-BAR 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 or head check.
135 Engine-burn fracture.
136 Head and web separation (outside joint-bar limits).
137 Head and web separation (within joint-bar limits
138 Horizontal split head.
139 Piped rail.
140 Rail defect with joint-bar repair.
141 Transverse/compound fissure.
142 Vertical split head.
143 Worn rail.
144 Mismatched rail-head contour.
145 Joint bar, broken, compromise.
146 Joint bar, broken, insulated.
147 Joint bar, broken, noninsulated.
148 Joint bolts, broken or missing.
149 Cause code not listed; enter code 149 in Item 37 and explain in Item 50.

FROGS, SWITCHES AND TRACK APPLIANCES

160 Guard rail, loose/broken, or mislocated.
161 Switch, hand-operated, damaged or out of adjustment.
162 Switch, hand-operated, stand mechanism broken, loose or worn.
163 Switch connecting or operating rod, broken or defective.
164 Stock rail, worn, broken or disconnected.
165 Switch point, worn or broken.
166 Switch rod, worn, bent, broken or disconnected.
167 Frog, rigid, worn or broken.
168 Frog, spring, worn or broken.
169 Frog, self-guarded, worn or broken.
171 Derail, defective.
172 Expansion joint, failed or malfunctioned.
173 Retarder, worn, broken or malfunctioning.
174 Spring/power switch malfunction.
179 Cause code not listed; enter code 179 in Item 37 and explain in Item 50.

OTHER WAY AND STRUCTURE

180 Bridge misalignment or failure.
181 Flangeway, clogged.
189 Cause code not listed; enter code 189 in Item 37 and explain in Item 50.

SIGNAL & COMMUNICATION FAILURES

200 Fixed signal, improperly displayed (defective).
201 Radio communication equipment failure.
202 Other communication equipment failure.
209 Cause code not listed; enter code 209 in Item 37 and explain in Item 50.

TABLE A-2. 1974 TRACK-RELATED CODES; DEFECTS IN, OR IMPROPER MAINTENANCE OF, WAY AND STRUCTURES

BRIDGES, TRESTLES, CULVERTS, AND TUNNELS

3001	Structural defect or failure.
3004	Improper or insufficient maintenance.
3088	Other defects in or failures.

TIES AND TIE PLATES

3102	Ties, decayed, worn or splintered.
3103	Ties, broken, soft or poor quality of timber or other defects.
3104	Ties, insufficient number or size.
3105	Tie plates, broken or otherwise defective.
3106	Steel, concrete or other nonwood tie defective.

RAILS AND JOINTS

3201	Broken rail end, with bolted joints.
3202	Broken rail end, with welded joints.
3203	Flow of metal.
3204	Crushed head.
3205	Split head.
3206	Split web.
3207	Broken base.
3208	Other forms of rail failures not due to wear.
3209	Rails, spreading because improperly spiked or braced.
3210	Rails, spreading because joints loosely or improperly bolted.
3211	Rails, spreading, other causes.
3212	Rails, giving way because of worn condition.
3213	Rail joints, angle bars or bolts broken or otherwise defective.
3214	Rail joints, failure at, due to insulation.
3215	Rail joints, improperly maintained.
3216	Compromise joints, defect, or improper maintenance.
3288	Other defects in, or failures of, rail joints.

FROGS AND SWITCHES

3301	Frogs, broken or missing bolts.
3302	Frogs, guard rail or fastenings defective or missing.
3303	Frogs, guard rail improperly placed or secured.
3304	Frogs, springs or spring bolts loose or defective.
3305	Frogs, wing rails broken.
3306	Frogs, point broken or worn.
3307	Other defects in frogs.
3308	Switch-detector bar or connecting rods broken or defective.
3309	Switch, lost motion or out of adjustment.
3310	Switch lug, broken.
3311	Switch point, bent or sprung.
3312	Switch point, broken.
3313	Switch point, worn.
3314	Switch stand or head block, loose, broken, or defective.
3315	Switch rod, broken or disconnected.
3316	Switch heater, broken or otherwise defective.
3317	Switch rod, bent or sprung.
3318	Switch indicator, missing or defective.
3319	Spring switch, defective.
3320	Keeper or latch, broken, defective, or missing.
3321	Electric or interlocking parts or appurtenances, failure or defect.
3322	Switch spiked, working loose.
3388	Other defects in, or improper maintenance of, switches.

INTERLOCKING AND BLOCK SIGNAL SYSTEM

3401	Signal displaying false indication.
3402	Improper location of signal.
3403	Sand, rust or other deposits on rails.
3488	Other defects in, or improper maintenance of, signal system.

OTHER WAY AND STRUCTURE ITEMS

3501	Guard rail, improperly placed or secured.
3502	Improper superelevation of track.
3503	Improper alignment of track.
3504	Improper surface of track.
3505	Improper gauge of track.
3506	Improper curvature for traffic conditions and equipment used.
3507	Dirty ballast or other poor drainage.
3508	Soft track, not otherwise provided for.
3509	Insufficient side clearance.
3510	Insufficient overhead clearance.
3511	Insufficient clearance between adjacent tracks.
3512	Car retarder, worn, out of adjustment or otherwise defective.
3513	Skates and skate-placing mechanism worn, out of adjustment or otherwise defective.
3514	Mules, car-dumping equipment and car-shakeout devices worn, out of adjustment, or otherwise defective.
3515	Float bridges.
3516	Fueling facilities.
3517	Sanding facilities.
3518	Water columns and other water supply facilities for servicing equipment.
3519	Turntables and transfer tables.
3520	Catenary, third rail, or other wayside current distribution apparatus.
3588	Other defects in way and structures.

3. Operations Factors

   a. Train speed: estimated, recorded;

   b. Method of train operation: 13 methods.

4. Environmental factors

   a. Location;

   b. Temperature;

   c. Visibility;

   d. Weather;

   e. Date, time.

Monetary Reporting Thresholds - Prior to 1975, Rail-Equipment Accidents were not reported unless the damage exceeded $750. Over the years, inflation has caused more accidents to be reported and has created difficulties in establishing unbiased trends. The new system has a flexible reporting threshold which is to be updated every two years to compensate for inflation. In 1975 the reporting threshold was $1,750, and in 1977 it was $2,300.

Assignment of Cause Codes - The assignment of accident cause codes was performed by FRA on the basis of brief, written accident descriptions provided by the reporting railroad in the old system. The reporting railroad assigns the cause code directly in the new reporting system, which should eliminate errors in the translation of reports.

APPENDIX B

DEPARTMENT OF TRANSPORTATION
FEDERAL RAILROAD ADMINISTRATION

RAIL EQUIPMENT INCIDENT REPORT

FORM APPROVED
OMB NO. 04R4008

1. NAME OF REPORTING RAILROAD — Amtrak ☐ Autotrain ☐ | 1a. Alphabetic Code | 1b. Railroad Incident No.

2. NAME OF OTHER RAILROAD INVOLVED IN TRAIN INCIDENT | 2a. Alphabetic Code | 2b. Railroad Incident No.

3. NAME OF RAILROAD RESPONSIBLE FOR TRACK MAINTENANCE *(single entry)* | 3a. Alphabetic Code | 3b. Railroad Incident No.

4. U. S. DOT-AAR GRADE CROSSING IDENTIFICATION NUMBER | 5. DATE OF INCIDENT (month | day | year) | 6. TIME OF INCIDENT (am ☐ pm ☐)

7. TYPE OF INCIDENT *(enter number in code box, single entry)* — CODE
1. Derailment 2. Head on collision 3. Rear end collision 4. Side collision 5. Raking collision 6. Broken train collision 7. Hwy grade crossing 8. RR grade crossing 9. Obstruction 10. Explosion-Detonation 11. Fire or violent rupture 12. Other *(specify)*

HAZARDOUS MATERIALS *(number of)*

8. CARS CARRYING | 9. CARS DAMAGED OR DERAILED | 10. CARS WHICH RELEASED HAZ. MAT. | 11. PEOPLE EVACUATED *(est.)*

LOCATION

12. DIVISION | 13. NEAREST STATION | 14. MILEPOST *(to nearest tenth)* | 15. STATE *(two letter code)* — CODE

ENVIRONMENTAL CONDITIONS

16. TEMPERATURE *(specify if minus)* °F | 17. VISIBILITY *(single entry)* — CODE: 1. Dawn 2. Day 3. Dusk 4. Dark | 18. WEATHER *(single entry)* — CODE: 1. Clear 2. Cloudy 3. Rain 4. Fog 5. Sleet 6. Snow

OPERATIONAL DATA

19. METHOD *(place X in appropriate box(es))*
1 ☐ Manual block 2 ☐ Interlocking 3 ☐ Cab signal 4 ☐ Automatic block 5 ☐ Traffic control 6 ☐ Auto. train stop 7 ☐ Yard rules 8 ☐ Time table 9 ☐ Radio 10 ☐ Auto. train control 11 ☐ Verbal permission 12 ☐ Train orders 13 ☐ Other *(specify)*

20. SPEED *(recorded speed, if available)* MPH — Est. / Recorded | 21. TRAIN NUMBER | 22. TIME TABLE DIRECTION — CODE: 1. North 2. South 3. East 4. West

EQUIPMENT

23. TRAILING TONS *(gross tonnage, excluding power units)* | 24. TYPE OF EQUIPMENT CONSIST *(single entry)* — CODE: 1. Freight train 2. Passenger train 3. Mixed train 4. Work train 5. Single car 6. Cut of cars 7. Yard/switching 8. Light loco(s) | 25. WAS THE EQUIPMENT IDENTIFIED IN ITEM 24 UNATTENDED? — CODE: 1. Yes 2. No

26. TRACK NUMBER OR NAME | 27. FRA TRACK CLASSIFICATION | 28. ANNUAL TRACK DENSITY *(gross tons in millions)* | 29. TYPE OF TRACK — CODE: 1. Main 2. Yard 3. Siding 4. Industry

30. PRINCIPLE CAR/UNIT	30a. Initial and Number	30b. Position in Train	30c. Loaded *(yes or no)*
(1) First Involved *(derailed, struck, striking, etc.)*			
(2) Causing *(mechanical failures)*			

31. LOCOMOTIVE UNITS *(no. of)*	a. Head End	Mid Train b. Manual	Mid Train c. Remote	Rear End d. Manual	Rear End e. Remote
(1) Total in Train					
(2) Total Derailed					

32. CARS *(no. of)*	Loaded a. Freight	Loaded b. Pass.	Empty c. Freight	Empty d. Pass.	e. Caboose
(1) Total in Equipment Consist					
(2) Total Derailed					

PROPERTY DAMAGE *(estimated cost, including labor, to repair or replace)*

33. EQUIPMENT DAMAGE *(to be reported for this equipment consist only)* $ | 34. TRACK, SIGNAL, WAY AND STRUCTURES DAMAGE *(to be reported by railroad in item 3 only)* $

INCIDENT CAUSE CODE

35. PRIMARY CAUSE — CODE | 36. CONTRIBUTING CAUSE — CODE | 37. If no code available, explain cause.

CASUALTIES

38. NUMBER OF PERSONS INJURED | 39. ESTIMATED TOTAL DAYS DISABILITY | 40. NUMBER OF FATALITIES

CREW *(no. of)*

41. ENGINEERS | 42. FIREMEN | 43. CONDUCTORS | 44. BRAKEMEN

HOURS ON DUTY

45. ENGINEER Hrs: Mins: | 46. CONDUCTOR Hrs: Mins:

47. TYPED NAME AND TITLE | 48. SIGNATURE | 49. DATE

50. NARRATIVE DESCRIPTION — *Describe the cause, nature and circumstances of incident.*

FORM FRA F 6180-54 (6-74) REPLACES FORM FRA F 6180-15 (11-72) WHICH IS OBSOLETE

APPENDIX C- SUMMARY STATISTICS OF TRACK-RELATED ACCIDENT CAUSES (2 of 3)

CAUSE	# OF ACCIDENTS	# OF REPORTS	DAMAGES (000)	MEAN DAMAGES	MEDIAN DAMAGES	SEVERITY INDX(000)	INJURIES	FATALITIES
134	9	11	517.781	47071	8725	78.525	0	0
135	6	6	43.505	7250	3725	22.350	0	0
136	94	100	3994.118	39941	7540	708.760	8	0
137	36	37	1280.128	34598	9400	338.400	3	0
138	20	23	889.541	38675	4033	80.660	1	0
139	5	5	426.092	85218	3486	17.430	0	0
140	10	13	62.341	4795	2700	27.000	0	0
141	157	170	5001.737	29421	7200	1130.400	6	0
142	109	120	2273.849	18948	5335	581.515	5	0
143	54	59	954.892	16184	5830	314.820	4	0
144	12	15	57.598	3839	2610	31.320	0	0
145	11	11	545.694	49608	7390	81.290	1	0
146	8	9	344.764	38307	12700	101.600	5	0
147	50	53	2162.550	40802	8950	447.500	4	0
148	21	23	256.717	11161	4175	87.675	2	0
149	76	81	2198.136	27137	5340	405.840	3	0
160	11	12	52.378	4364	3198	35.178	0	0
161	57	66	376.337	5702	2614	148.998	0	0

APPENDIX C- SUMMARY STATISTICS OF TRACK-RELATED ACCIDENT CAUSES (3 of 3)

CAUSE	# OF ACCIDENTS	# OF REPORTS	DAMAGES (000)	MEAN DAMAGES	MEDIAN DAMAGES	SEVERITY INDX(000)	INJURIES	FATALITIES
163	20	22	685.571	31162	3987	79.740	0	0
164	9	10	54.656	5465	2705	24.345	0	0
165	307	360	1878.801	5218	3225	990.075'	2	0
166	9	10	81.956	8195	4714	42.426	0	0
167	18	20	239.433	11971	3614	65.052	0	0
168	4	5	74.446	14889	4400	17.600	0	0
169	7	8	89.299	11162	2622	18.354	0	0
171	3	4	10.603	2650	2327	6.981	0	0
173	42	61	204.450	3351	2575	108.150	0	0
174	8	10	51.652	5165	4700	37.600	0	0
179	61	75	1154.501	15393	3375	205.875	2	0
181	9	9	106.701	11855	3710	33.390	0	0
189	9	13	844.756	64981	3832	34.488	0	0
201	5	8	35.674	4459	1440	7.200	3	0
209	6	7	94.911	13558	6250	37.500	1	0
	3185	3529	69554.710	19709			157	0

APPENDIX D

ANALYSIS RESULTS OF FACTORS CONTRIBUTING TO TRACK-RELATED ACCIDENTS

ALL DATA PERTAINS TO 1975

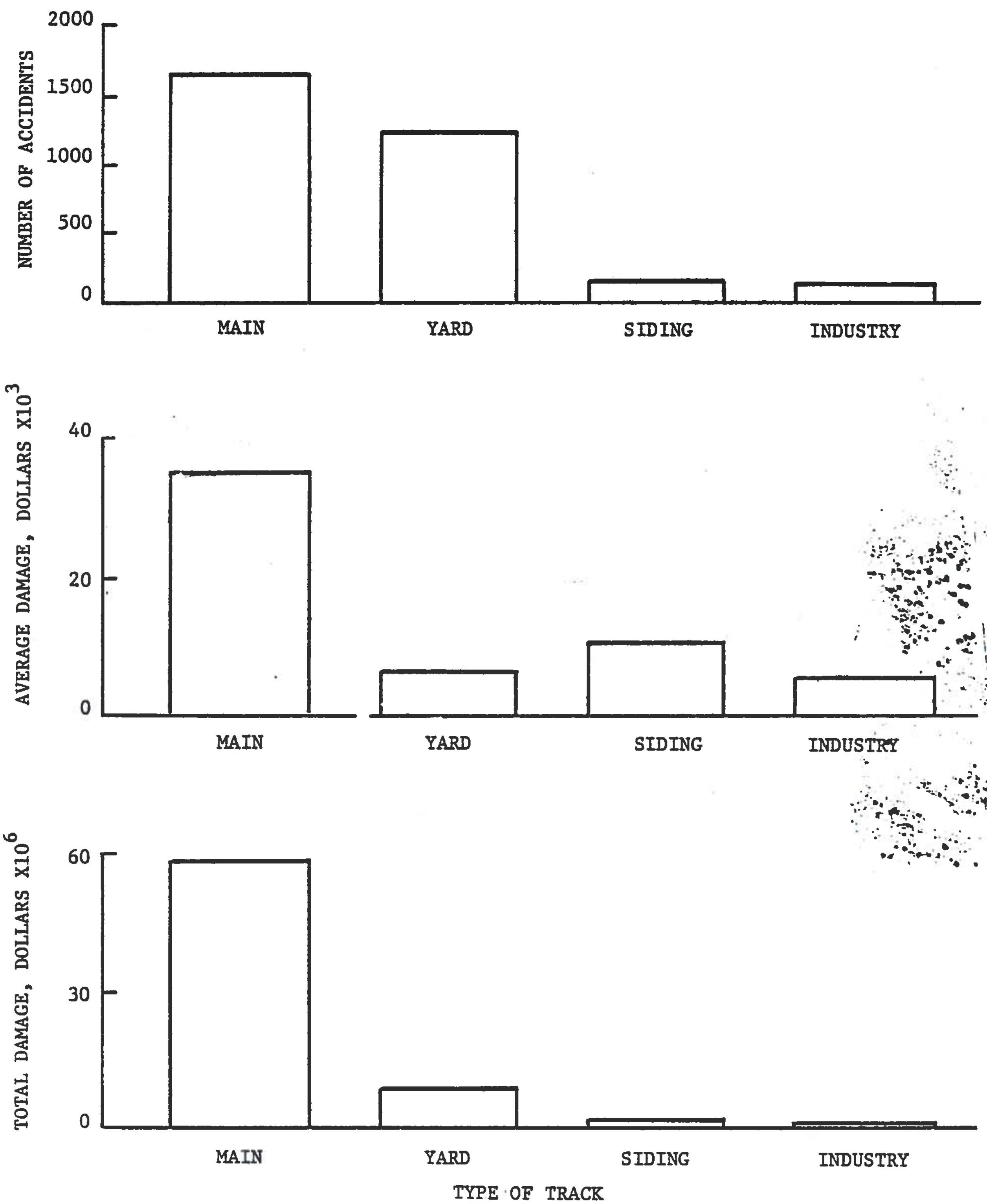

FIGURE D-1. NUMBER, AVERAGE DAMAGE AND TOTAL DAMAGE OF TRACK-RELATED ACCIDENTS BY TYPE OF TRACK

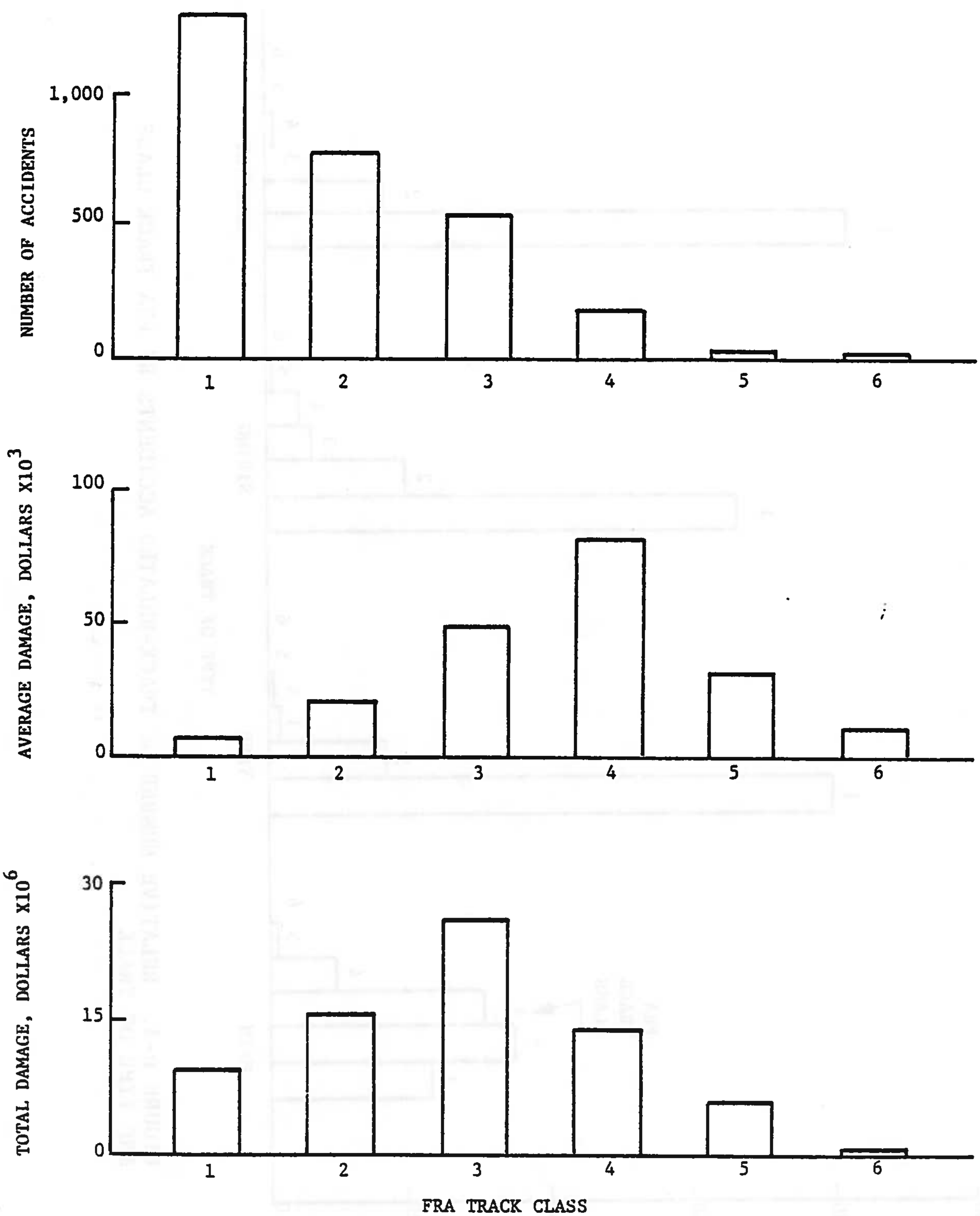

FIGURE D-2. NUMBER, AVERAGE DAMAGE AND TOTAL DAMAGE OF TRACK-RELATED ACCIDENTS BY FRA TRACK CLASS

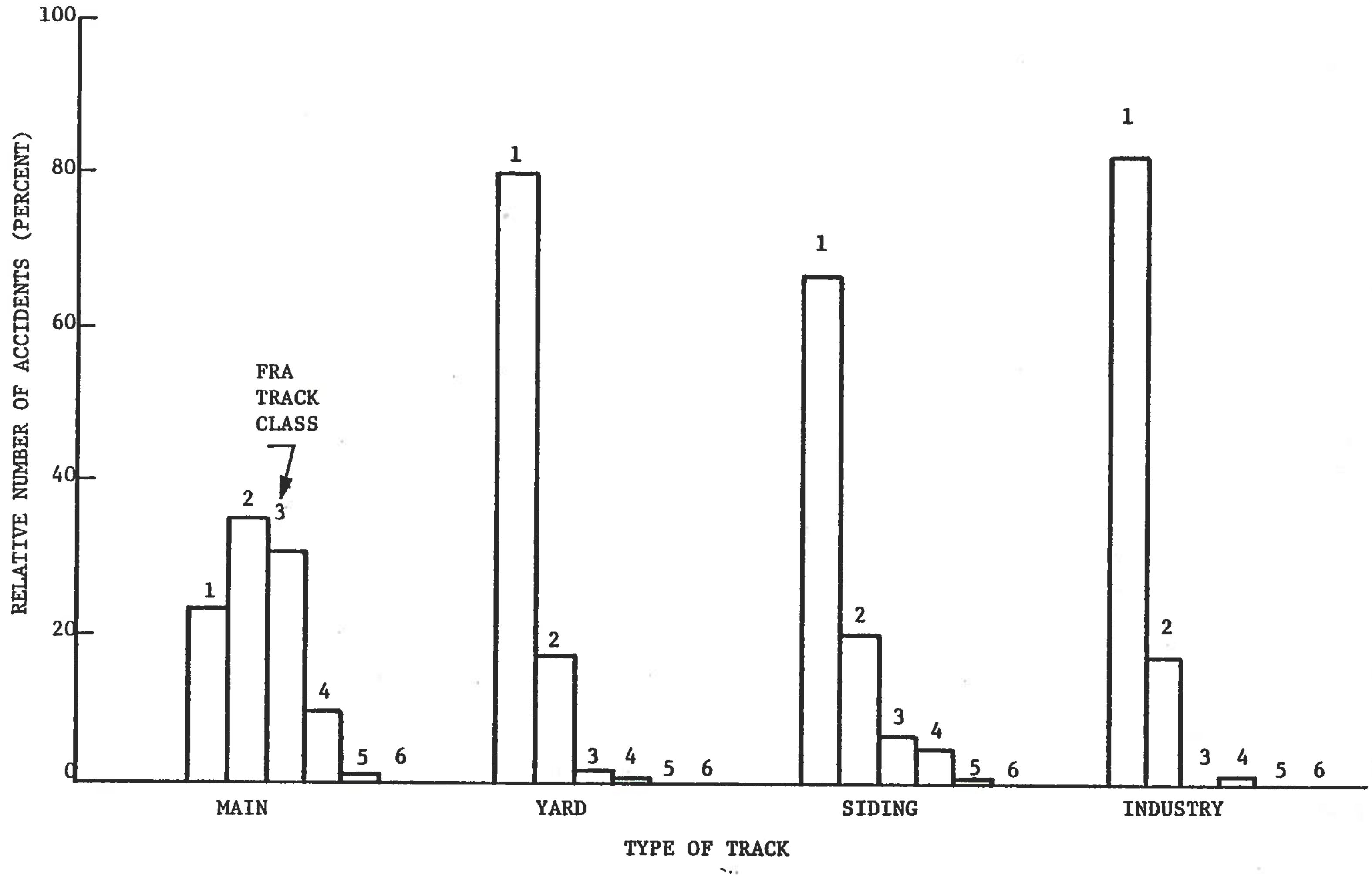

FIGURE D-3. RELATIVE NUMBER OF TRACK-RELATED ACCIDENTS BY FRA TRACK CLASS AND TYPE OF TRACK

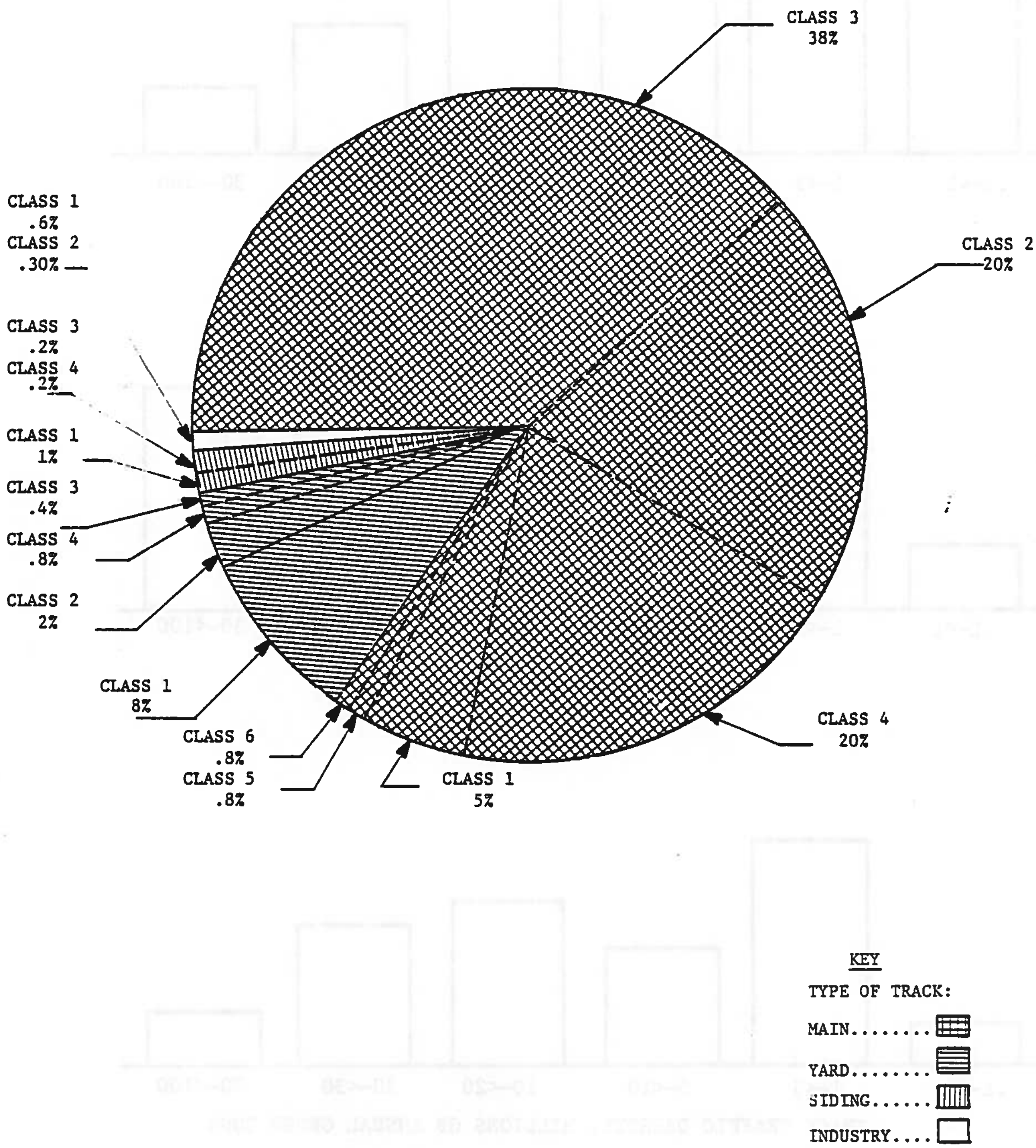

FIGURE D-4. PERCENT OF TOTAL TRACK-RELATED ACCIDENT DAMAGES BY FRA TRACK CLASS AND TYPE OF TRACK

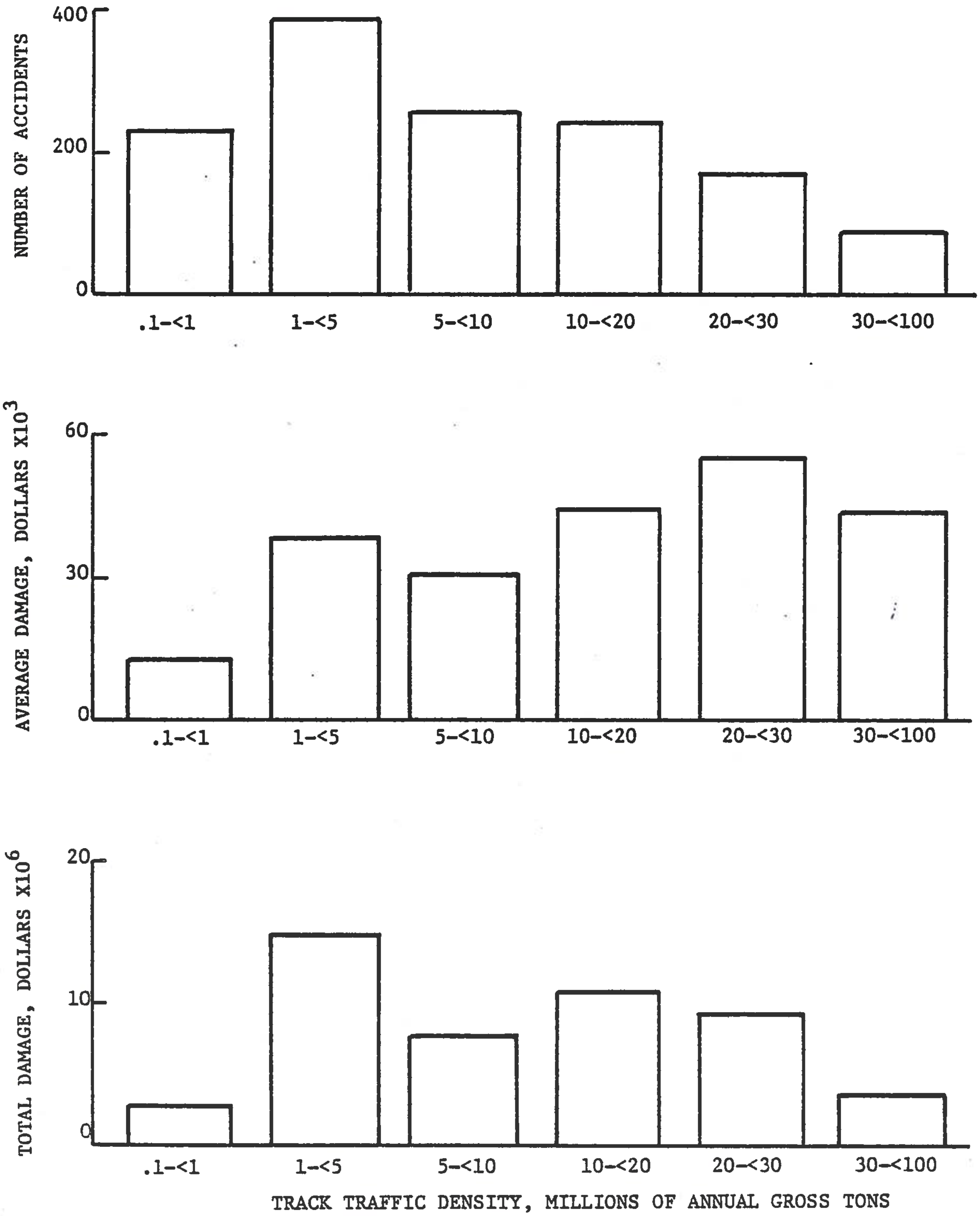

FIGURE D-5. NUMBER, AVERAGE DAMAGE AND TOTAL DAMAGE OF TRACK-RELATED ACCIDENTS BY TRACK TRAFFIC DENSITY, MAIN TRACK ONLY

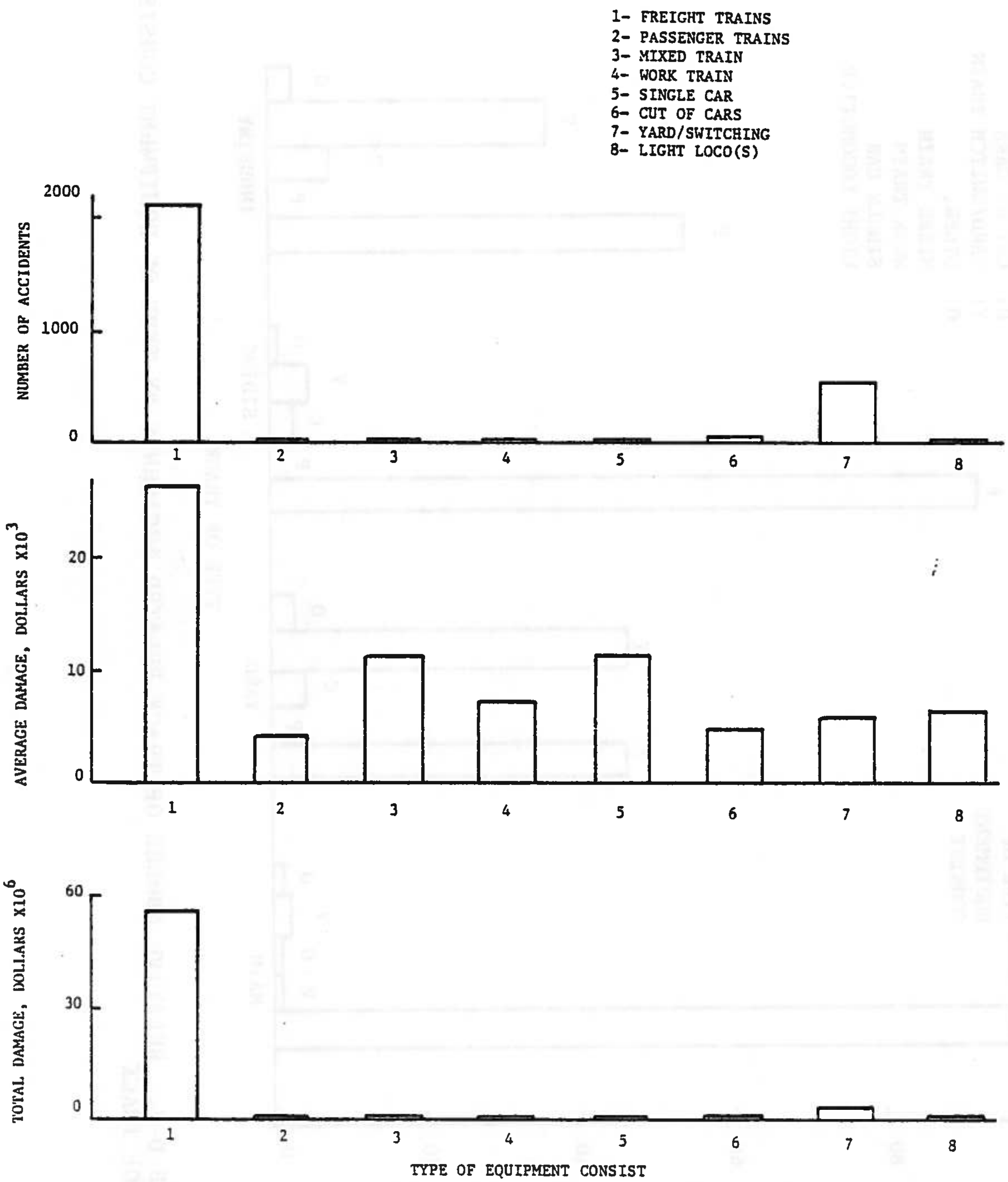

FIGURE D-6. NUMBER, AVERAGE DAMAGE AND TOTAL DAMAGE OF TRACK-RELATED ACCIDENTS BY TYPE OF EQUIPMENT CONSIST

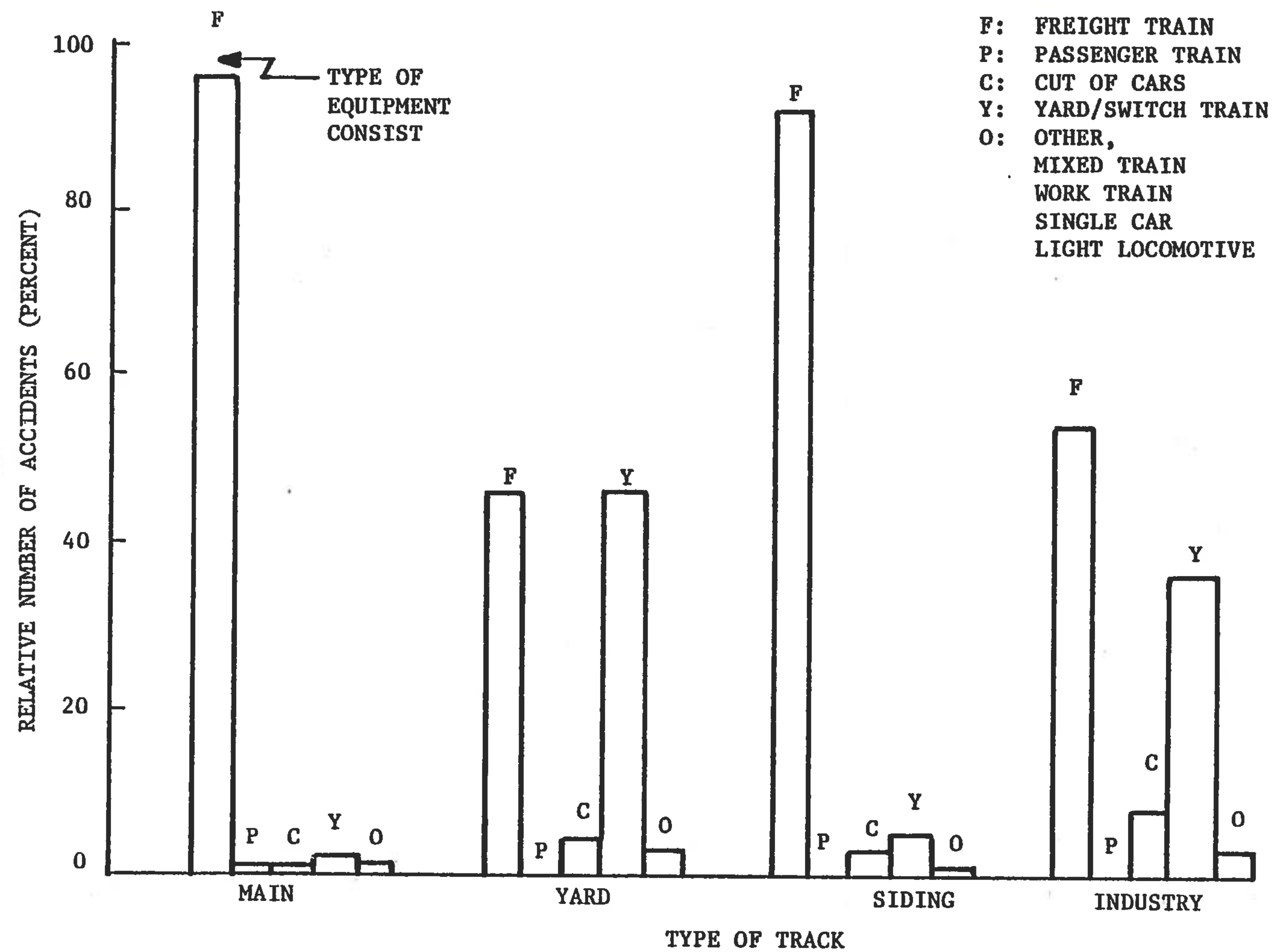

FIGURE D-7. RELATIVE NUMBER OF TRACK-RELATED ACCIDENTS BY TYPE OF EQUIPMENT CONSIST AND TYPE OF TRACK

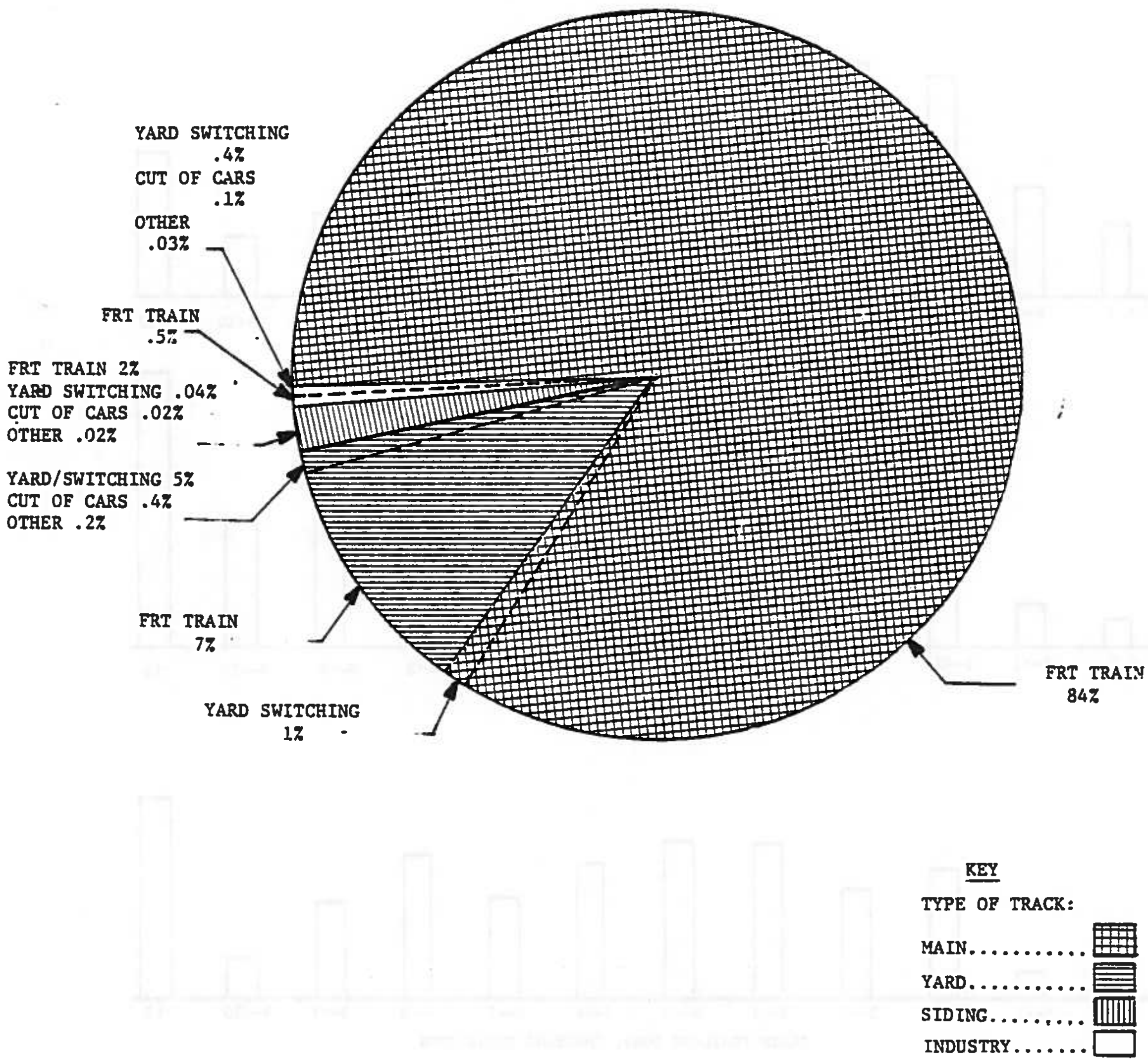

FIGURE D-8. PERCENT OF TOTAL TRACK-RELATED ACCIDENT DAMAGES BY TYPE OF EQUIPMENT CONSIST AND TYPE OF TRACK

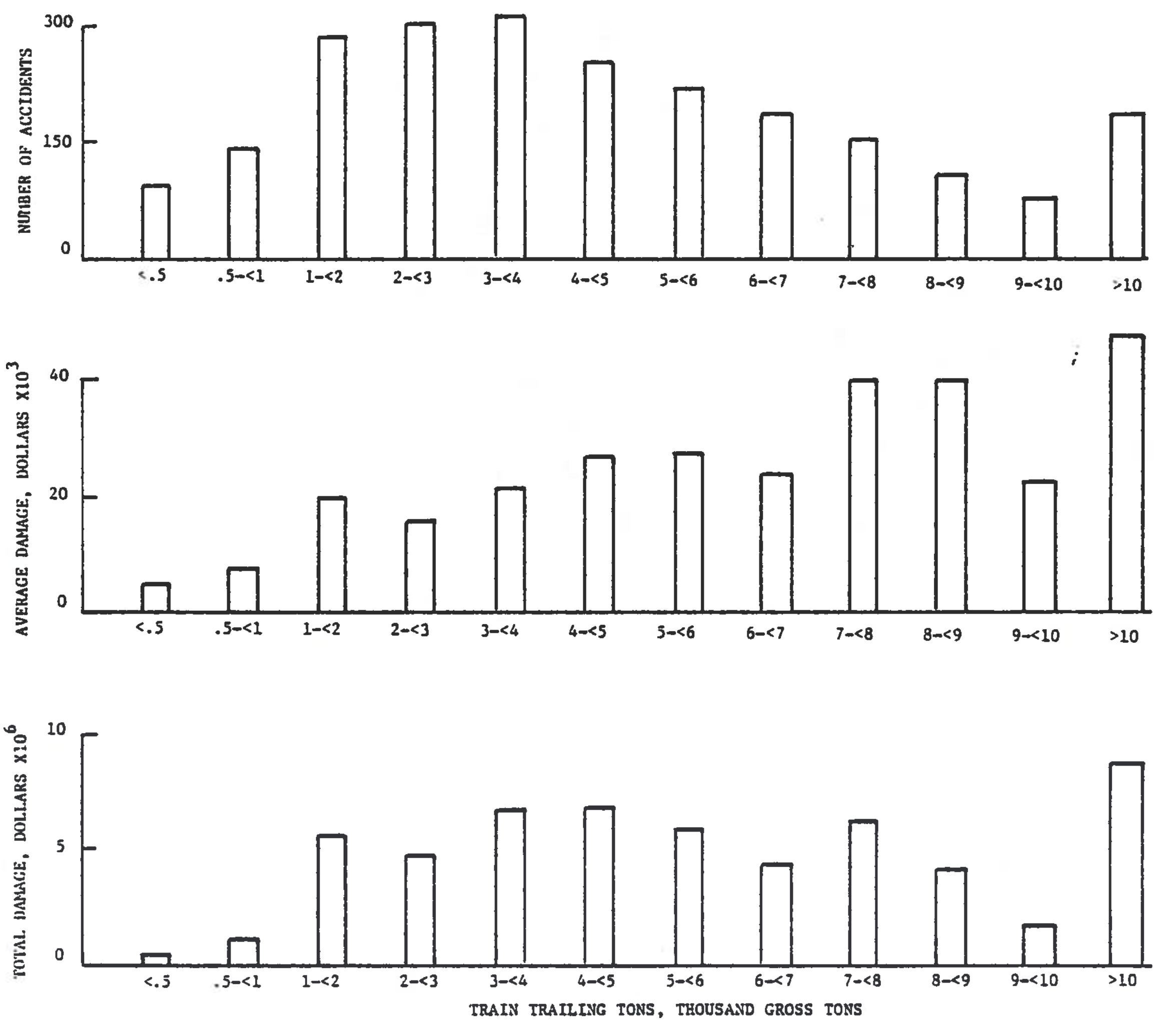

FIGURE D-9. NUMBER, AVERAGE DAMAGE AND TOTAL DAMAGE OF TRACK-RELATED ACCIDENTS BY TRAIN TRAILING TONS

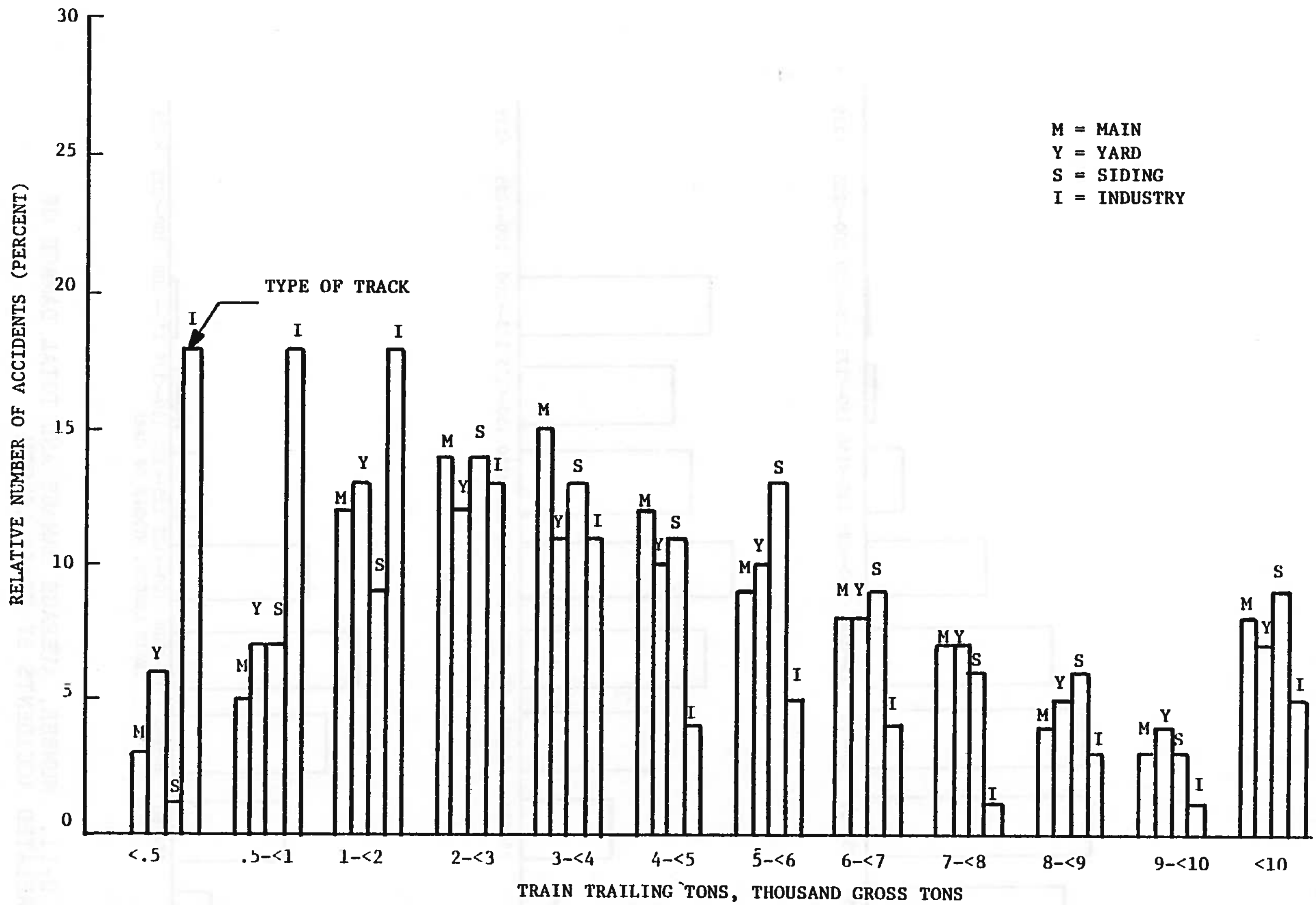

FIGURE D-10. RELATIVE NUMBER OF TRACK-RELATED ACCIDENTS BY TRAIN TRAILING TONS AND TYPE OF TRACK

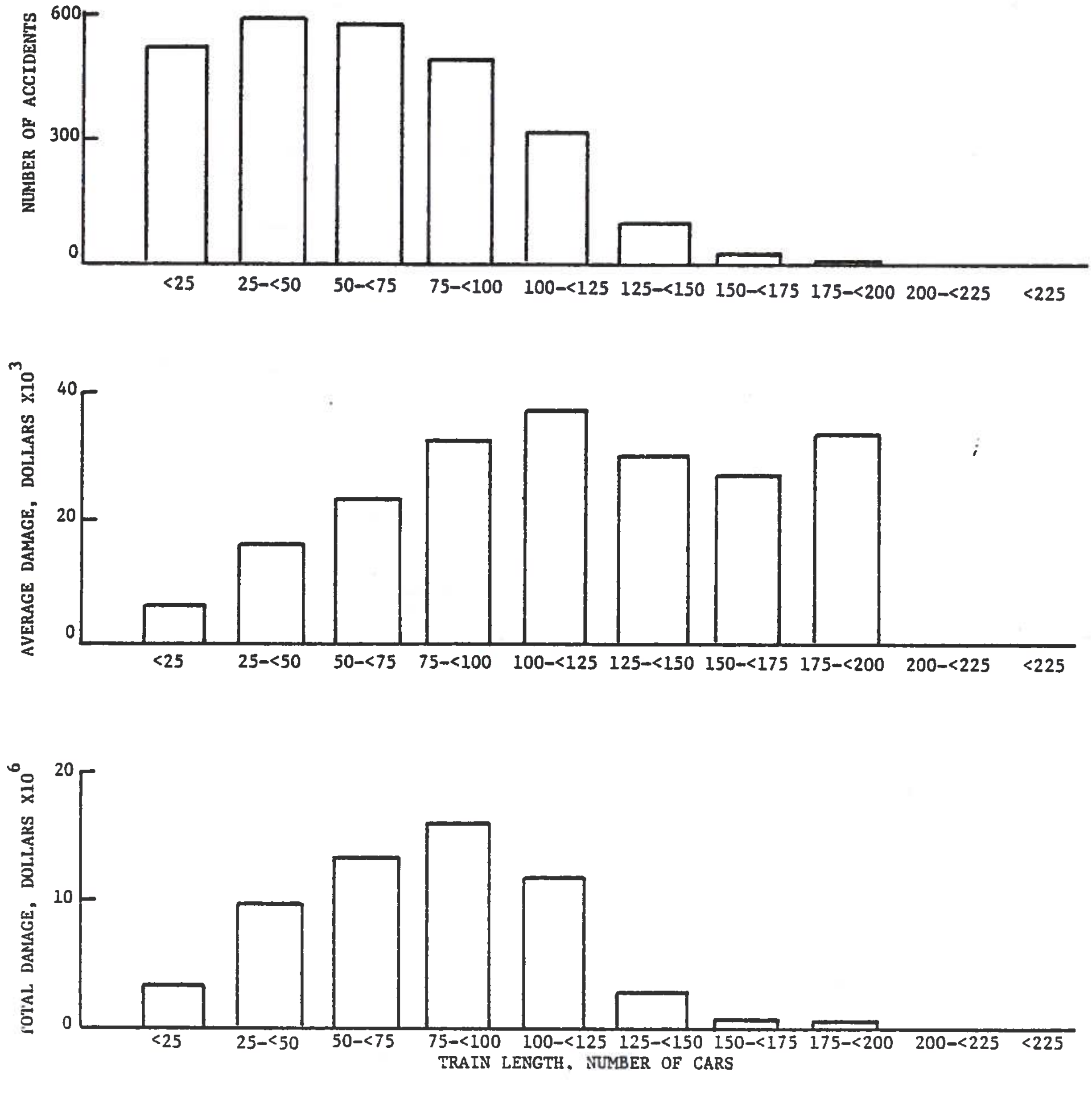

FIGURE D-11. NUMBER, AVERAGE DAMAGE AND TOTAL DAMAGE OF TRACK-RELATED ACCIDENTS BY TRAIN LENGTH

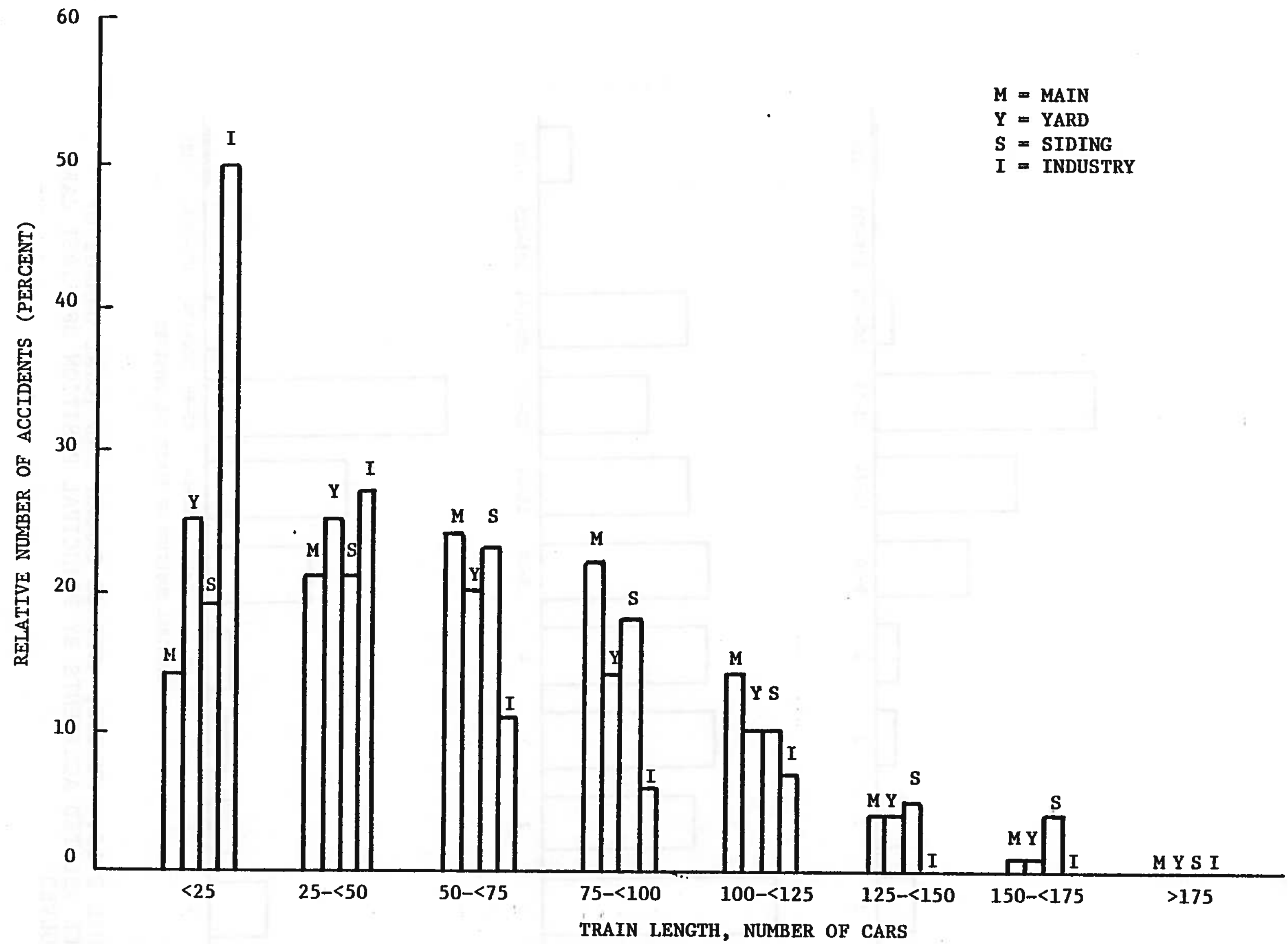

FIGURE D-12. RELATIVE NUMBER OF TRACK-RELATED ACCIDENTS BY TRAIN LENGTH AND TYPE OF TRACK

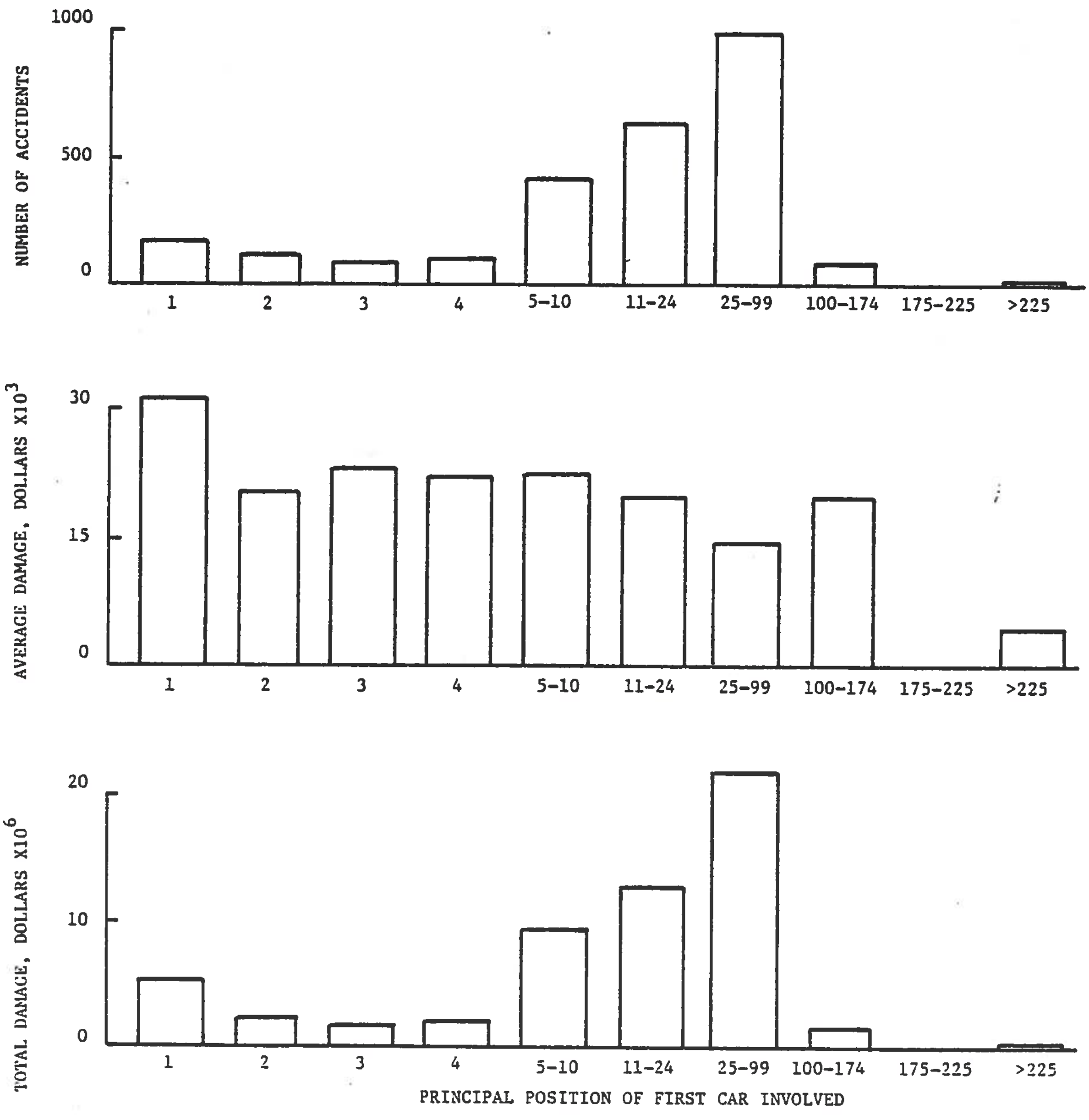

FIGURE D-13. NUMBER, AVERAGE DAMAGE AND TOTAL DAMAGE OF TRACK-RELATED ACCIDENTS BY PRINCIPAL POSITION OF FIRST CAR INVOLVED

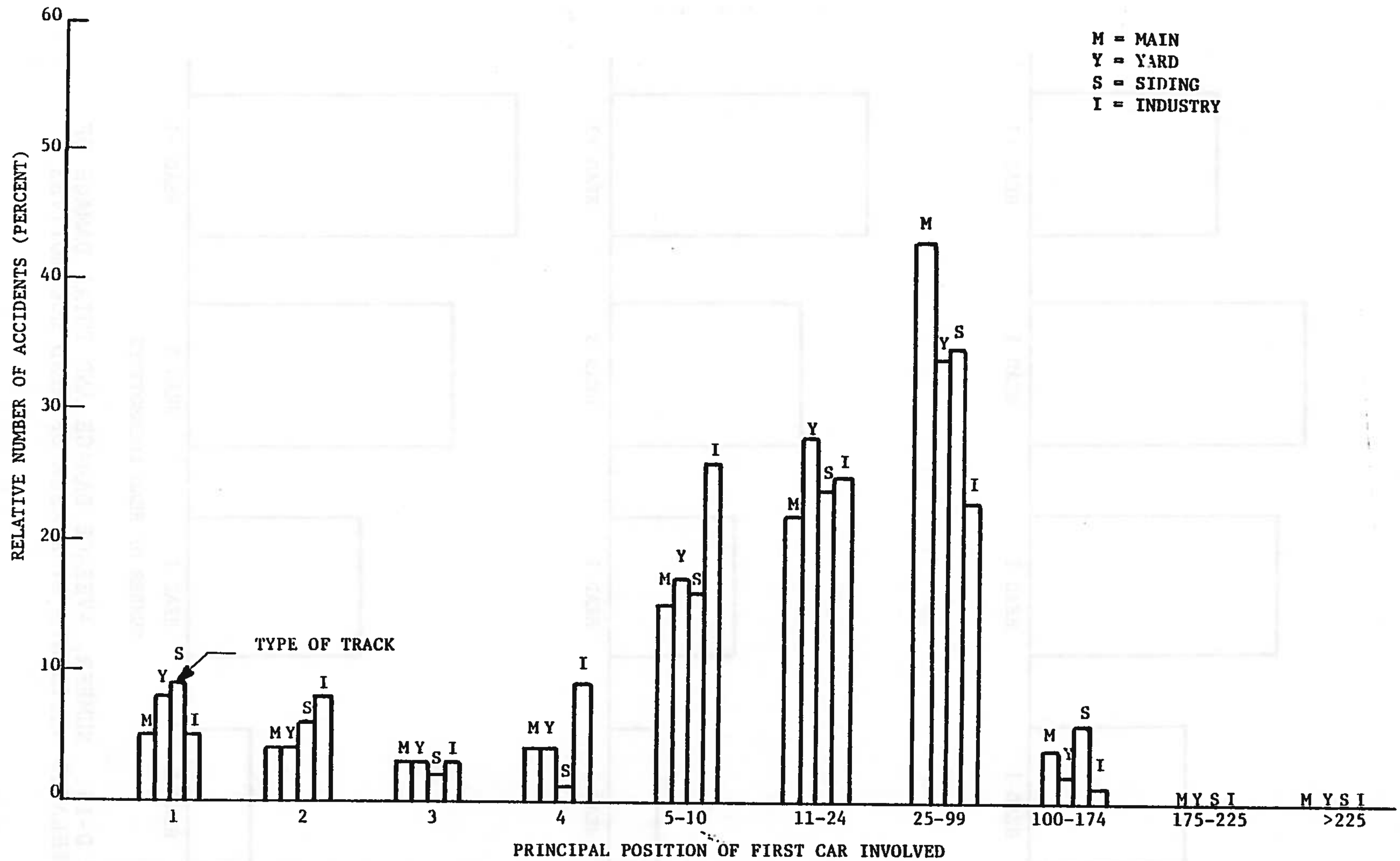

FIGURE D-14. RELATIVE NUMBER OF TRACK-RELATED ACCIDENTS BY PRINCIPAL POSITION OF FIRST CAR INVOLVED AND TYPE OF TRACK

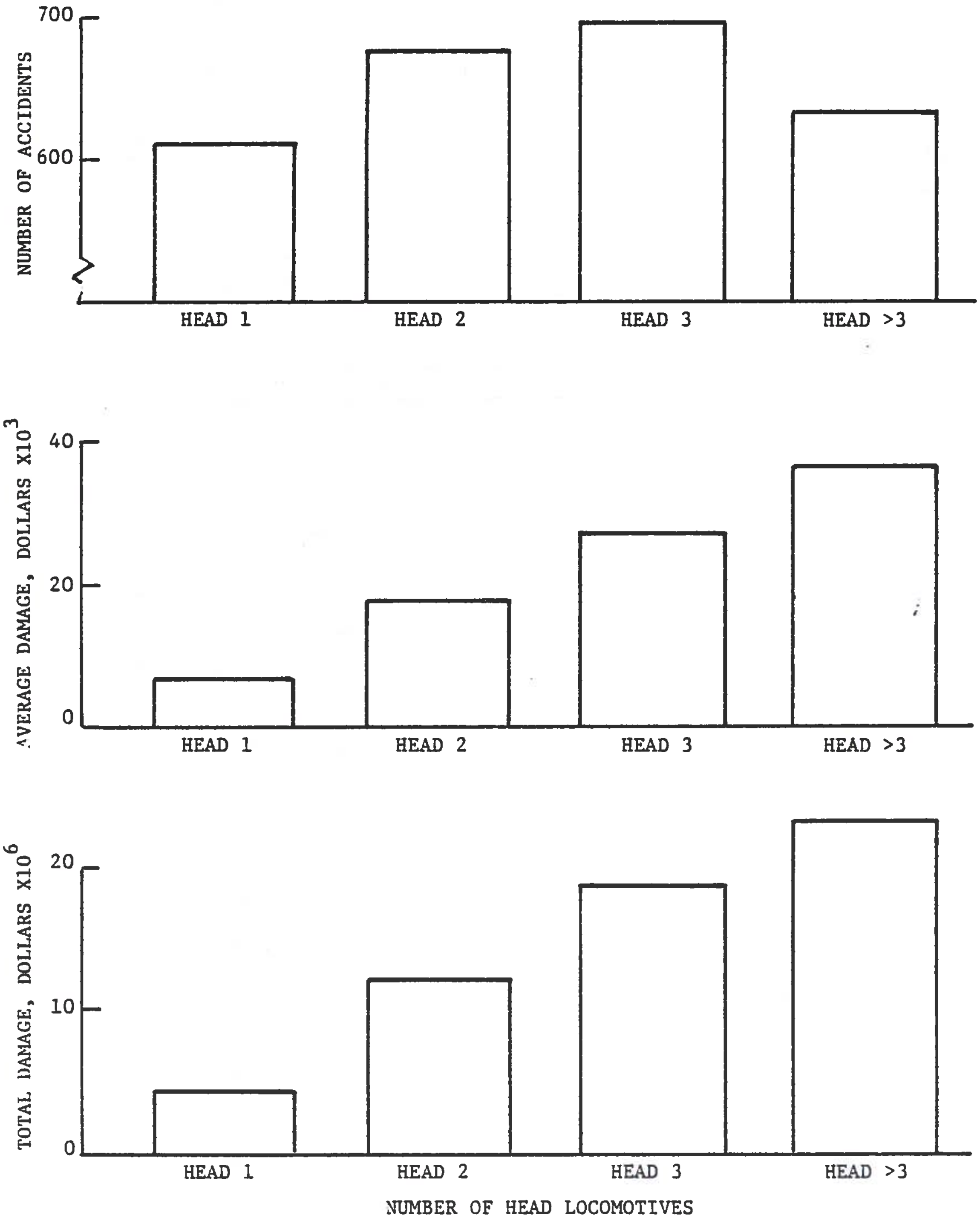

FIGURE D-15. NUMBER, AVERAGE DAMAGE AND TOTAL DAMAGE OF TRACK-RELATED ACCIDENTS BY NUMBER OF HEAD LOCOMOTIVES

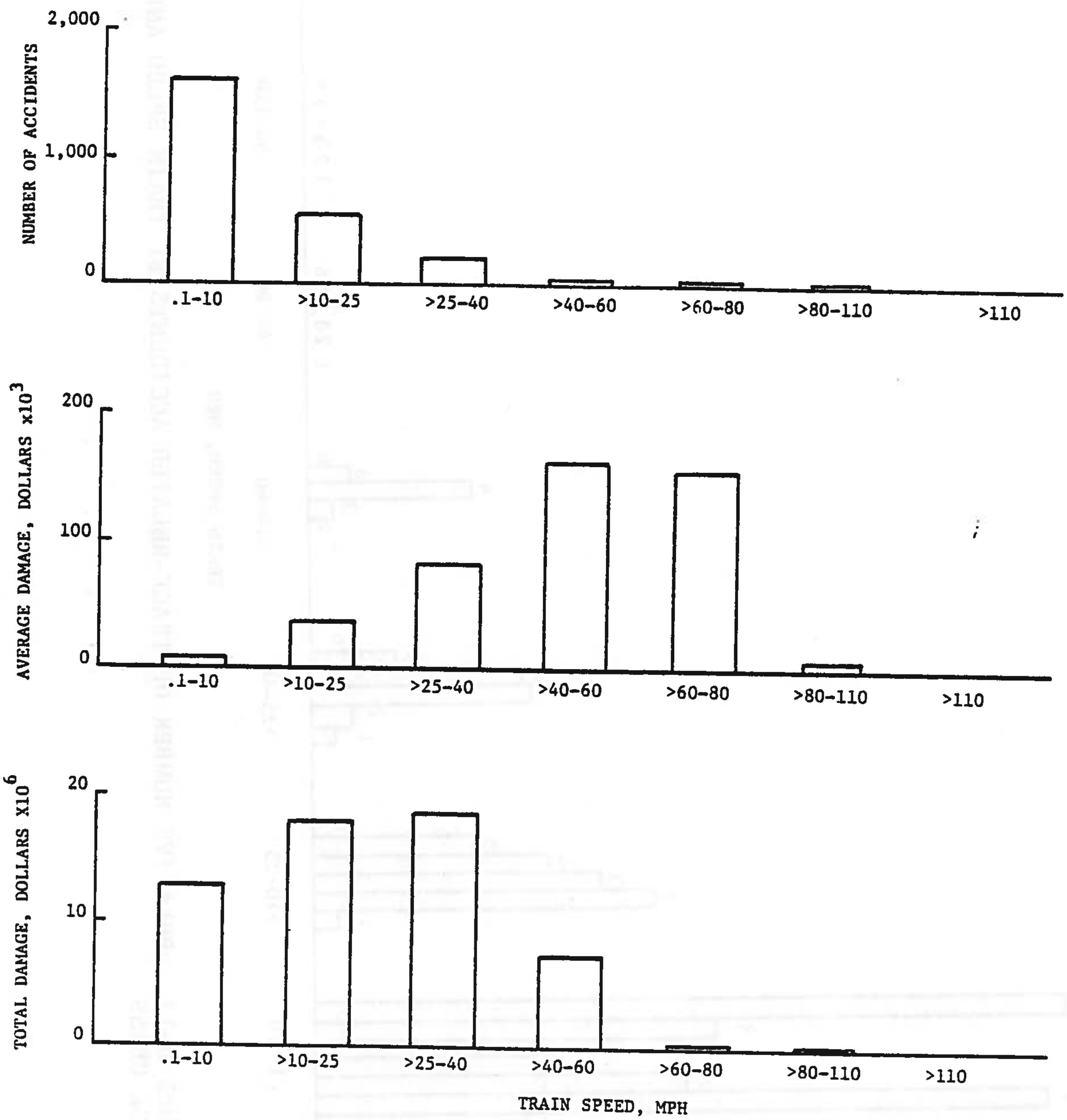

FIGURE D-16. NUMBER, AVERAGE DAMAGE AND TOTAL DAMAGE OF TRACK-RELATED ACCIDENTS BY TRAIN SPEED

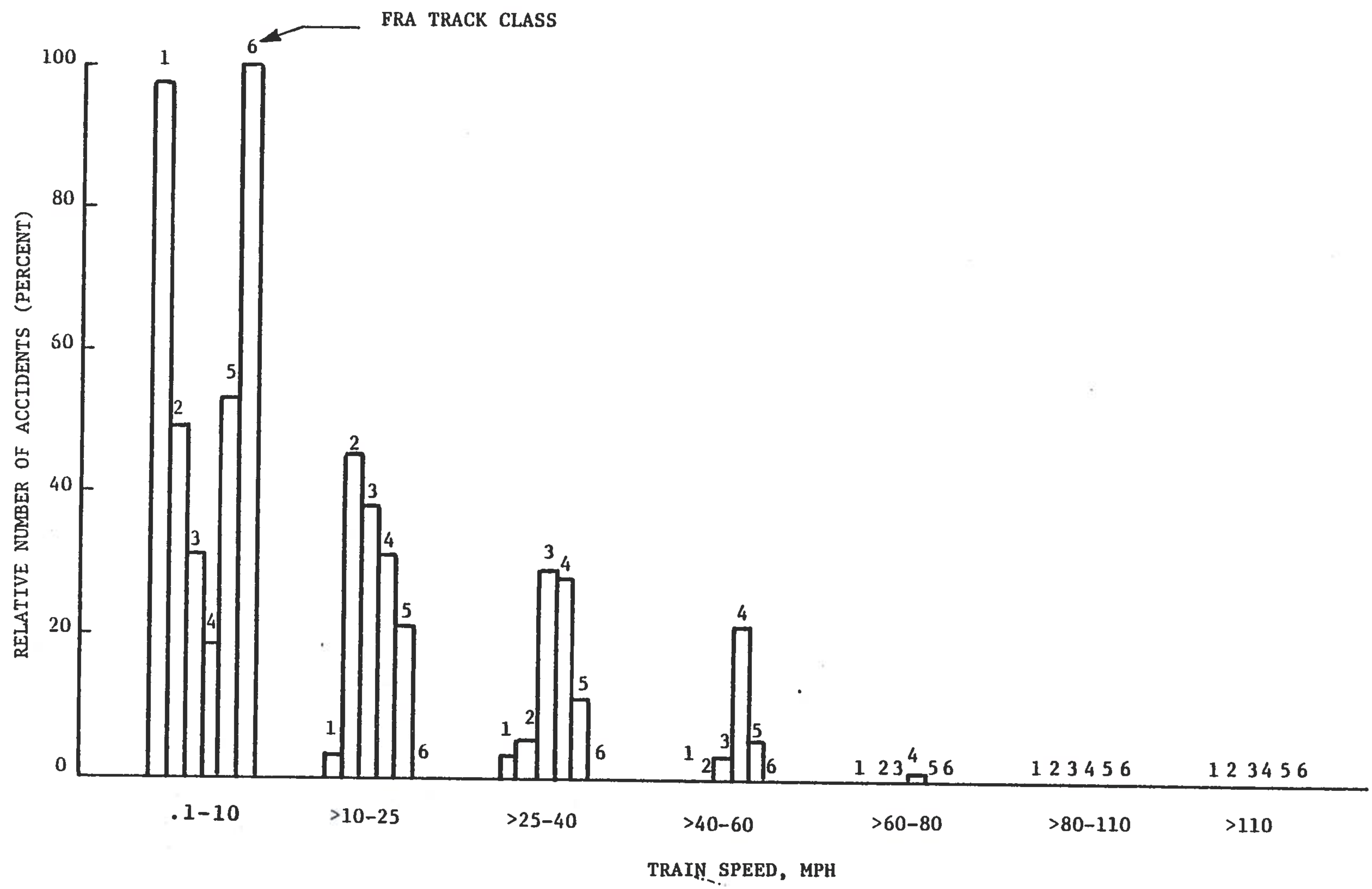

FIGURE D-17. RELATIVE NUMBER OF TRACK-RELATED ACCIDENTS BY TRAIN SPEED AND FRA TRACK CLASS

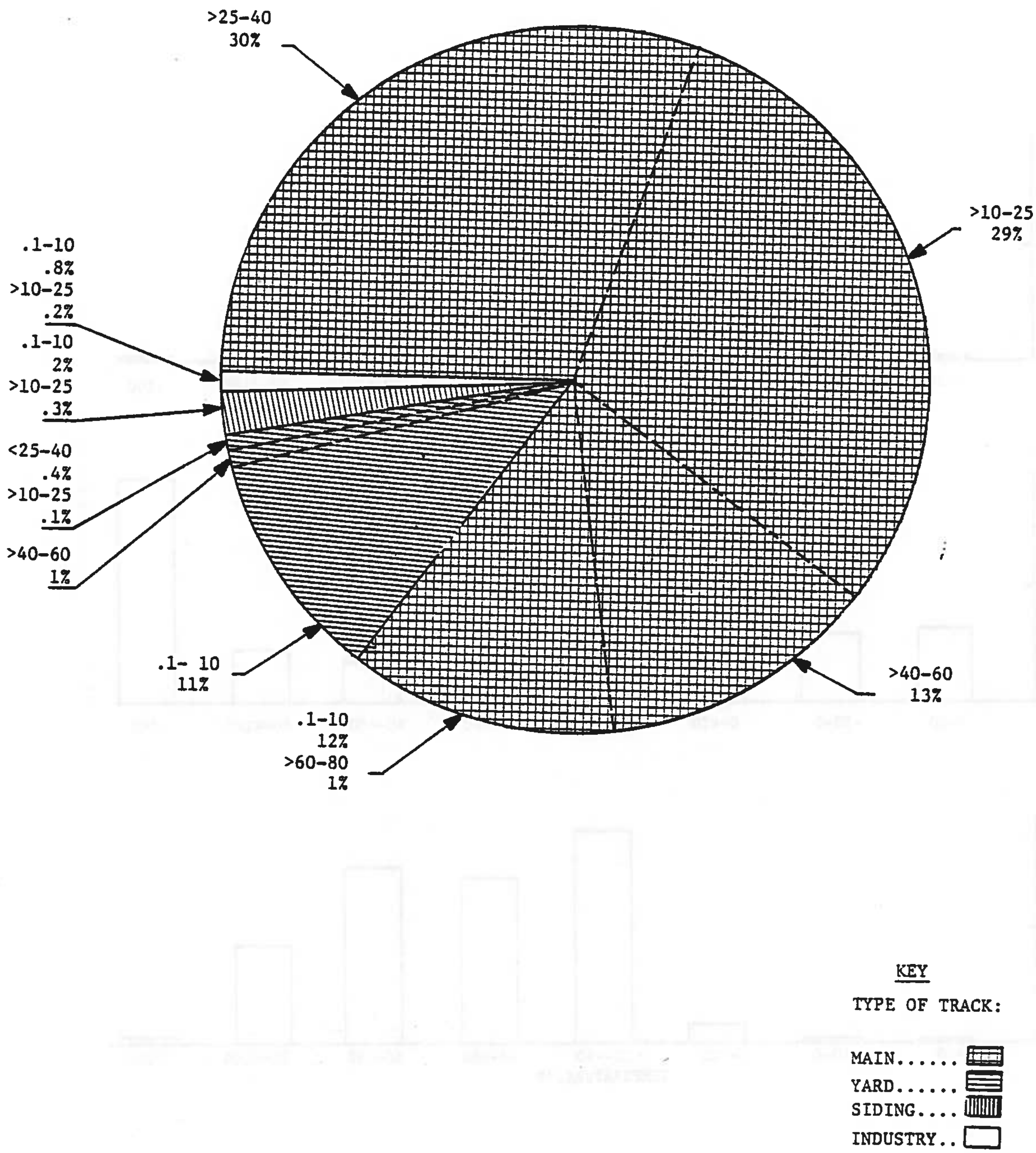

FIGURE D-18. PERCENT OF TOTAL TRACK-RELATED ACCIDENT DAMAGES BY TRAIN SPEED AND TYPE OF TRACK.

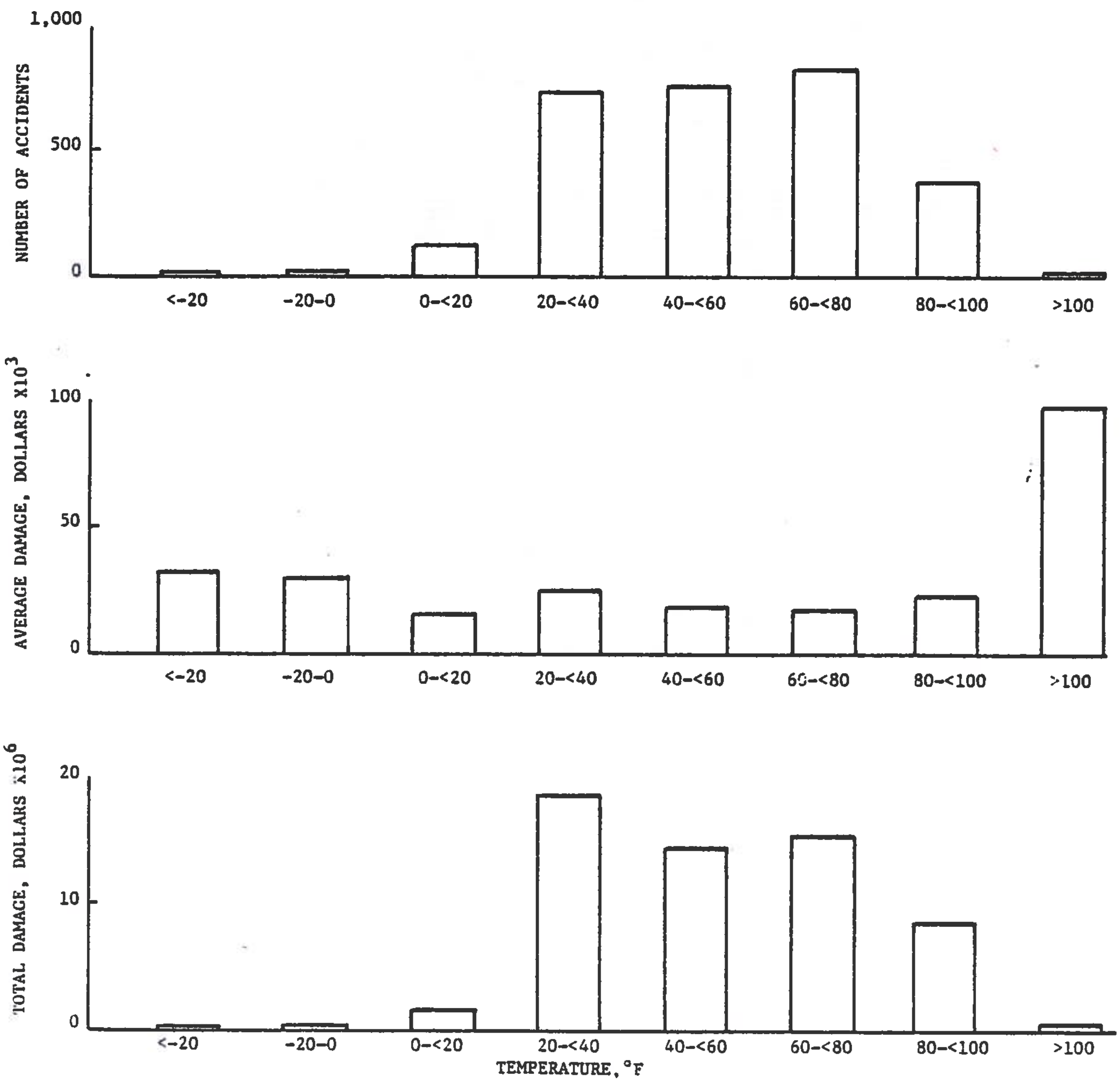

FIGURE D-19. NUMBER, AVERAGE DAMAGE AND TOTAL DAMAGE OF TRACK-RELATED ACCIDENTS BY TEMPERATURE

APPENDIX E

CALCULATION OF RELATIVE TRACK-RELATED ACCIDENT RATE ON TRACK OF LESS THAN AND GREATER THAN 20 MGT

1. Accident Rate, R, accidents per gross ton per mile of track

   $R = A/T \times M$

   where: A = Number of track-related Accidents

   T = Traffic density, gross tons (ton-miles per mile of track)

   M = Track-miles

2. Relative accident rate on track of less than and greater than 20 MGT:

   $$R_{1/g} = \frac{A_1/T_1 x M_1}{A_g/T_g x M_g}$$

   where: subscripts 1 and g mean less than and greater than 20 MGT

3. Data:

	Greater than 20 MGT Track	Less than 20 MGT Track
A (Percent of total accidents)	21%	79%
T (Average MGT)	20 MGT	5 MGT
M (Percent of total track-miles)*	35%	65%

4. Substituting data into 2:

   $$R_{1/g} = \frac{.79A/5 \times .65M}{.21A/20 \times .35M} = 8$$

---

*Assumes 75% of route-miles greater than 20 MGT and 25% of route-miles less than 20 MGT is double track.

APPENDIX F
SAMPLE OUTPUT: CAUSE CODES STATISTICS BY TYPE OF TRACK

The following is a sample output of track-related cause code statistics by levels of a factor investigated, in this case, type of track. The data presented in each cell of the matrix, with the exception of the right-hand total column, is arranged as follows:

Number of accidents by that cause code	Total dollar damage by that cause code
Percent distribution of accidents by that cause code	Percent distribution of dollar damages by that cause code
	Average dollar damage per accident by that cause code

The data in each cell of the right-hand total column is arranged as follows:

Number of accidents by that cause code	Total dollar damages by that cause code
Mean value of the factor investigated for that cause code	Average dollar damage per accident by that cause code

CODE	BLANK		MAIN		YARD		SIDING		INDUSTRY		TOTAL	
101	4	240962	40	1472491	31	233760	6	33289	4	23845	93	2004351
	.04	.12	.52	.73	.33	.12	.06	.02	.04	.01		
		60240		30676		7540		5548		5962	1.6	21552
102	0	0	47	3448724	13	80417	4	18663	1	2500	65	3550324
	.00	.00	.72	.97	.20	.02	.06	.01	.02	.00		
		0		73377		6185		4670		2500	1.4	54620
109	0	0	13	721192	6	38308	1	2641	2	7867	22	770008
	.00	.00	.59	.94	.27	.05	.05	.00	.09	.01		
		0		55476		6384		2641		3933	1.6	35000
110	3	60337	183	5611556	196	1053316	34	156874	29	114630	445	6996713
	.01	.01	.41	.80	.44	.15	.08	.02	.07	.02		
		20112		30664		5374		4613		3952	1.8	15722
111	0	0	21	434492	34	244911	3	38984	0	0	58	718387
	.00	.00	.36	.60	.59	.34	.05	.05	.00	.00		
		0		20690		7203		12994		0	1.7	12385
112	0	0	2	55075	3	21754	1	15345	1	8000	7	100174
	.00	.00	.29	.55	.43	.22	.14	.15	.14	.08		
		0		27537		7251		15345		8000	2.1	14310
113	0	0	15	353706	20	94536	1	2500	3	11450	39	462192
	.00	.00	.38	.77	.51	.20	.03	.01	.08	.02		
		0		23580		4726		2500		3816	1.8	11851
114	0	0	83	2042068	19	122983	2	39237	5	27588	109	2231876
	.00	.00	.76	.91	.17	.06	.02	.02	.05	.01		
		0		24603		6472		19618		5517	1.3	20475
115	1	31050	72	2612584	10	120430	2	38144	2	5505	87	2807713
	.01	.01	.83	.93	.11	.04	.02	.01	.02	.00		
		31050		36285		12043		19072		2752	1.2	32272
116	0	0	16	523818	2	10420	0	0	0	0	18	534238
	.00	.00	.89	.98	.11	.02	.00	.00	.00	.00		
		0		32738		5210		0		0	1.1	29679
117	1	52800	59	1703391	1	12780	0	0	1	3343	62	1772314
	.02	.03	.95	.96	.02	.01	.00	.00	.02	.00		
		52800		28871		12780		0		3343	1.1	28585
118	0	0	5	157014	1	3625	0	0	0	0	6	160639
	.00	.00	.83	.98	.17	.02	.00	.00	.00	.00		
		0		31402		3625		0		0	1.2	26773
119	1	0	293	7109134	96	695164	15	165236	6	45271	411	8014805
	.00	.00	.71	.89	.23	.09	.04	.02	.01	.01		
		0		24263		7241		11015		7545	1.4	19500
120	3	32268	152	3229399	44	334118	12	203437	3	77331	214	3876553
	.01	.01	.71	.83	.21	.09	.06	.05	.01	.02		
		10756		21246		7593		16953		25777	1.4	18114

CODE	BLANK		MAIN		YARD		SITING		INDUSTRY		TOTAL	
129	0	0	35	2156114	19	80233	3	64187	3	6810	60	2309344
	.00	.0C	.50	.93	.32	.03	.05	.03	.05	.0C		
		0		61603		4222		21395		2936	1.6	38489
130	0	C	44	1849776	18	76368	C	0	4	47650	66	1973794
	.00	.0C	.67	.94	.27	.04	.00	.00	.06	.02		
		0		42040		4242		0		11912	1.5	29905
131	1	36773	72	2443910	57	299486	6	236790	3	6332	139	3025291
	.01	.01	.52	.81	.41	.10	.04	.08	.02	.0C		
		36773		33943		5254		39465		2777	1.6	21764
132	0	0	5	197375	1	1850	0	0	0	0	6	199225
	.00	.0C	.83	.99	.17	.01	.00	.00	.00	.0C		
		0		39475		1850		0		0	1.2	33204
133	0	0	3	950303	0	0	0	0	0	C	3	950303
	.00	.00	1.00	1.00	.00	.C0	.CC	.00	.00	.0C		
		0		316767		0		0		C	1.0	316767
134	0	C	5	480712	4	37C69	C	0	0	C	9	517781
	.00	.00	.56	.93	.44	.07	.00	.00	.00	.0C		
		0		96142		9267		0		0	1.4	57531
135	0	0	4	38345	1	2160	C	0	1	3C0C	6	43505
	.00	.00	.67	.88	.17	.05	.00	.C0	.17	.07		
		C		9586		2160		0		3000	1.7	7250
136	1	8019	51	3644608	36	312051	4	21715	2	7725	94	3994118
	.01	.00	.54	.91	.38	.08	.04	.01	.02	.00		
		8019		71462		8668		5428		3862	1.5	42490
137	0	0	19	1184682	17	95446	0	0	0	0	36	1280128
	.00	.00	.53	.93	.47	.07	.00	.C0	.00	.0C		
		0		62351		5614		0		0	1.5	35559
138	0	0	9	839336	11	50205	0	0	0	0	20	889541
	.00	.00	.45	.94	.55	.06	.0C	.C0	.00	.0C		
		0		93259		4564		0		C	1.5	44477
139	0	0	2	416590	2	6016	C	0	1	3486	5	426092
	.00	.00	.40	.98	.40	.01	.00	.00	.20	.01		
		0		208295		3008		0		3486	2.0	85218
140	0	0	3	33185	7	29156	0	0	0	C	10	62341
	.00	.0C	.30	.53	.70	.47	.00	.00	.00	.0C		
		0		11061		4165		0		C	1.7	6234
141	0	C	80	4327143	52	444409	16	153533	9	76652	157	5001737
	.00	.00	.51	.87	.33	.09	.10	.03	.06	.02		
		0		54089		8546		9595		8516	1.7	31858
142	1	7636	59	1861327	40	310763	7	88173	2	595C	109	2273849
	.01	.00	.54	.82	.37	.14	.06	.C4	.02	.0C		
		7636		31547		7769		12596		2975	1.6	20861

CODE	BLANK		MAIN		YARD		SIDING		INDUSTRY		TOTAL	
143	0	C	31	830886	21	110191	2	13815	0	C	54	954692
	.00	.0C	.53	.87	.39	.12	.04	.C1	.00	.0C		
		0		26802		5247		6907		C	1.5	17683
144	0	0	3	7510	5	29538	1	49C0	3	1565C	12	57598
	.00	.00	.25	.13	.42	.51	.08	.C9	.25	.27		
		0		2503		5907		4900		5216	2.3	4799
145	0	C	8	320401	3	225293	0	0	0	C	11	545694
	.00	.00	.73	.59	.27	.41	.00	.C0	.00	.00		
		0		40050		75097		0		C	1.3	49608
146	0	0	7	339075	1	5689	C	0	0	C	8	344764
	.00	.00	.88	.98	.13	.02	.00	.00	.00	.0C		
		0		48439		5689		0		C	1.1	43C95
147	0	0	35	2105373	13	52177	1	2950	1	205C	50	2162550
	.00	.0C	.70	.97	.26	.02	.02	.00	.02	.0C		
		0		60153		4013		2950		205C	1.4	43251
148	0	0	5	160913	14	86107	1	7800	1	1897	21	256717
	.00	.00	.24	.63	.67	.34	.05	.03	.05	.01		
		0		32182		6150		7800		1897	1.9	12224
149	0	C	39	1929341	32	214744	5	54051	0	C	76	2198136
	.00	.0C	.51	.88	.42	.10	.07	.C2	.00	.00		
		0		49470		6710		10810		C	1.6	28922
160	0	0	5	31789	6	20589	C	0	0	C	11	52378
	.00	.00	.45	.61	.55	.39	.00	.00	.00	.0C		
		0		6357		3431		0		C	1.5	4761
161	0	C	8	123182	36	174290	5	34050	8	44815	57	376337
	.00	.0C	.14	.33	.63	.46	.09	.09	.14	.12		
		0		15397		4841		6810		5601	2.2	6602
162	0	0	0	0	12	50900	0	0	0	C	12	50900
	.00	.0C	.00	.00	1.00	1.C0	.00	.00	.00	.0C		
		0		0		4241		0		C	2.0	4241
163	0	0	6	610001	13	69265	C	0	1	6305	20	685571
	.00	.00	.30	.89	.65	.10	.00	.00	.05	.01		
		0		1C1666		5328		0		6305	1.8	34278
164	0	C	1	2540	6	46756	1	2700	1	266C	9	54456
	.00	.00	.11	.05	.67	.86	.11	.05	.11	.05		
		C		2540		7792		2700		2660	2.2	6672
165	7	251513	59	389445	208	951109	14	175294	19	11144C	307	1878801
	.02	.13	.19	.21	.68	.51	.05	.09	.06	.06		
		35930		6600		4572		12521		5865	2.0	6119
166	0	C	4	52938	5	29018	0	0	0	C	9	81956
	.00	.00	.44	.65	.56	.35	.00	.C0	.00	.00		
		0		13234		5803		0		0	1.6	9106

CODE	BLANK		MAIN		YARD		SIDING		INDUSTRY		TOTAL	
167	0	0	4	164550	12	59983	2	14900	0	0	18	239433
	.00	.00	.22	.69	.67	.25	.11	.06	.00	.00		
		0		41137		4998		7450		0	1.9	13301
168	0	0	4	74446	0	0	0	0	0	0	4	74446
	.00	.00	1.00	1.00	.00	.00	.00	.00	.00	.00		
		0		18611		0		0		0	1.0	18611
169	0	0	2	60500	5	28799	0	0	0	0	7	89299
	.00	.00	.29	.68	.71	.32	.00	.00	.00	.00		
		0		30250		5759		0		0	1.7	12757
171	0	0	0	0	3	10603	0	0	0	0	3	10603
	.00	.00	.00	.00	1.00	1.00	.00	.00	.00	.00		
		0		0		3534		0		0	2.0	3534
172	0	0	0	0	0	0	0	0	0	0	0	0
	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00		
		0		0		0		0		0	0.0	0
173	0	0	0	0	42	204450	0	0	0	0	42	204450
	.00	.00	.00	.00	1.00	1.00	.00	.00	.00	.00		
		0		0		4867		0		0	2.0	4867
174	0	0	1	12842	7	38810	0	0	0	0	8	51652
	.00	.00	.13	.25	.88	.75	.00	.00	.00	.00		
		0		12842		5544		0		0	1.9	6456
179	0	0	19	467517	35	652687	4	24735	3	9562	61	1154501
	.00	.00	.31	.40	.57	.57	.07	.02	.05	.01		
		0		24606		18648		6183		3187	1.9	18926
180	0	0	0	0	0	0	0	0	0	0	0	0
	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00		
		0		0		0		0		0	0.0	0
181	0	0	6	97056	2	7725	0	0	1	1920	9	106701
	.00	.00	.67	.91	.22	.07	.00	.00	.11	.02		
		0		16176		3862		0		1920	1.6	11855
189	0	0	7	839936	1	2180	1	2640	0	0	9	844756
	.00	.00	.78	.99	.11	.00	.11	.00	.00	.00		
		0		119990		2180		2640		0	1.3	93861
200	0	0	0	0	0	0	0	0	0	0	0	0
	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00		
		0		0		0		0		0	0.0	0
201	0	0	0	0	5	35674	0	0	0	0	5	35674
	.00	.00	.00	.00	1.00	1.00	.00	.00	.00	.00		
		0		0		7134		0		0	2.0	7134
202	0	0	0	0	0	0	0	0	0	0	0	0
	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00		
		0		0		0		0		0	0.0	0

CODE	BLANK		MAIN		YARD		SIDING		INDUSTRY		TOTAL	
209	0	0	4	80732	2	12164	0	2015	0	C	6	94911
	.00	.0C	.67	.85	.33	.13	.00	.02	.00	.0C		
		0		20183		6082		0		C	1.3	15818
TOT	23	721358	1658	58599023	1230	7930475	154	1618618	120	685238	3185	69554712
	.01	.01	.52	.84	.39	.11	.05	.02	.04	.01		
		31363		35343		6447		10510		5710	1.6	21638

3529 RECORDS PROCESSED.
3185 ACCIDENTS.
344 JOINT ACCIDENTS.

APPENDIX G

ANALYSIS RESULTS OF FACTORS CONTRIBUTING TO CAUSE CODE OCCURRENCE

ALL RESULTS PERTAIN TO 1975

TABLE G-1. MEAN TRACK TYPE FOR THE 17 LEADING TRACK-RELATED CAUSE CODES

CAUSE CODE	(CODE NO.)	MEAN TRACK TYPE (1 = Main, 2 = Yard, 3 = Siding, 4 = Industry)
ROADBED GROUP		
Roadbed, settled or soft	(101)	1.6
Washout/Rain/etc. Damage	(102)	1.4
TRACK-GEOMETRY GROUP		
Wide gauge, defective ties	(110)	1.8(+)
Track alignment	(114)	1.3(-)
Track alignment, buckled	(115)	1.2(-)
Superelevation	(117)	1.1(-)
Cross level, at joints	(119)	1.4(-)
Cross level, not at joints	(120)	1.4(-)
Other	(129)	1.6
RAIL AND JOINT-BAR GROUP		
Bolt hole crack/break	(130)	1.5
Broken base of rail	(131)	1.6
Head & web separation	(136)	1.5
Transverse/compound fissure	(141)	1.7
Vertical split head	(142)	1.6
Joint bar	(147)	1.4
Other	(149)	1.6
TRACK APPLIANCE GROUP		
Switch point	(165)	2.0(+)
All track-related cause codes		1.6 STD DEV = 1.0

TABLE G-2. MEAN FRA TRACK CLASS FOR THE 17 LEADING TRACK-RELATED CAUSE CODES BY TRACK TYPE

CAUSE CODE	(CODE NO.)	MAIN TRACK	YARD TRACK	SIDING TRACK	INDUSTRY TRACK
ROADBED GROUP					
Roadbed, settled or soft	(101)	2,1	1.3	1.2	1.0
Washout/rain/etc. damage	(102)	2,5	1.8(+)	1.3	NA
TRACK-GEOMETRY GROUP					
Wide gauge, defective ties	(110)	1,9(-)	1.2	1.2	1.2
Track alignment	(114)	2,3	1.3	2.5	1.5
Track alignment, buckled	(115)	2.8(+)	1.9	2.5	1.5
Superelevation	(117)	2,5	NA	NA	NA
Cross level, at joints	(119)	2.4(+)	1.2	1.7	1.6(+)
Cross level, not at joints	(120)	2.3	1.2	1.2	1.3
Other	(129)	2,7(+)	1.3	3.0(+)	1.0
RAIL AND JOINT-BAR GROUP					
Bolt hole crack/break	(130)	2,7(+)	1.1	NA	1.3
Broken base of rail	(131)	2.1	1.2	1.2	1.0
Head & web separation	(136)	2.2	1.4	2.0	1.5
Transverse/compound fissure	(141)	2.3	1.2	1.4	1.3
Vertical split head	(142)	2.2	1.1	1.7	1.5
Joint bar	(147)	2.2	1.3	2.0	1.0
Other	(149)	2.3	1.3	1.4	NA
TRACK APPLIANCE GROUP					
Switch point	(165)	2.3	1.3	1.9(+)	1.1
All track-related cause codes		2.3 STD DEV = 1.0	1.3 STD DEV = .78	1.5 STD DEV = .90	1.2 STD DEV = .48

TABLE G-3. MEAN ANNUAL TRAFFIC DENSITY FOR THE 17 LEADING TRACK-RELATED CAUSE CODES

CAUSE CODE	(CODE NO.)	MEAN ANNUAL TRAFFIC DENSITY, MILLIONS OF GROSS TONS
ROADBED GROUP		
Roadbed, settled or soft	(101)	39
Washout/rain/etc. damage	(102)	10
TRACK-GEOMETRY GROUP		
Wide gauge, defective ties	(110)	10
Track alignment	(114)	22
Track alignment, buckled	(115)	22
Superelevation	(117)	28
Cross level, at joints	(119)	17
Cross level, not at joints	(120)	30
Other	(129)	35
RAIL AND JOINT-BAR GROUP		
Bolt hole crack/break	(130)	12
Broken base of rail	(131)	16
Head & web separation	(136)	8
Transverse/compound fissure	(141)	20
Vertical split head	(142)	26
Joint bar	(147)	8
Other	(149)	51(+)
TRACK APPLIANCE GROUP		
Switch point	(165)	18
All track-related codes		21

TABLE G-4. MEAN TRAILING TONNAGE FOR THE 17 LEADING TRACK-RELATED CAUSE CODES BY TRACK TYPE

CAUSE CODE	(CODE NO.)	MAIN	YARD	SIDING	INDUSTRY
ROADBED GROUP					
Roadbed, settled or soft	(101)	4(-)	5	4	2
Washout/rain/etc. damage	(102)	5	3	4	8
TRACK-GEOMETRY GROUP					
Wide gauge, defective ties	(110)	4(-)	4	5	3
Track alignment	(114)	5	7	8	1
Track alignment, buckled	(115)	5	10(+)	NA	3
Superelevation	(117)	4(-)	2	NA	1
Cross level, at joints	(119)	5	4	5	3
Cross level, not at joints	(120)	5	4	5	4
Other	(129)	5	4	8	1
RAIL AND JOINT-BAR GROUP					
Bolt hole crack/break	(130)	5	7	NA	5
Broken base of rail	(131)	4(-)	5	6	1
Head & web separation	(136)	6(+)	6	8	7
Transverse/compound fissure	(141)	5	5	5	5
Vertical split head	(142)	5	7(+)	7	4
Joint bar	(147)	5	3	NA	NA
Other	(149)	4	5	5	NA
TRACK APPLIANCE GROUP					
Switch point	(165)	4(-)	4(-)	4	2
All track-related cause codes		5 STD DEV = 3.9	5 STD DEV = 4.7	5 STD DEV = 4.2	3 STD DEV = 4.0

TABLE G-5. MEAN TRAIN LENGTH FOR THE 17 LEADING TRACK-RELATED CAUSE CODES BY TRACK TYPE

CAUSE CODE	(CODE NO.)	MAIN	YARD	SIDING	INDUSTRY
ROADBED GROUP					
Roadbed, settled or soft	(101)	57	54	59	19
Washout/rain/etc. damage	(102)	78(+)	40	43	7
TRACK-GEOMETRY GROUP					
Wide gauge, defective ties	(110)	54(-)	50(-)	52(-)	31
Track alignment	(114)	70	44	101	14
Track alignment, buckled	(115)	66	90(+)	NA	67
Superelevation	(117)	66	43	NA	12
Cross level, at joints	(119)	73(+)	55	69	39
Cross level, not at joints	(120)	67	53	58	44
Other	(129)	80(+)	57	109(+)	13
RAIL AND JOINT-BAR GROUP					
Bolt hole crack/break	(130)	70	55	NA	51
Broken base of rail	(131)	60	63	108(+)	61
Head & web separation	(136)	67	70(+)	91	61
Transverse/compound fissure	(141)	64	70(+)	70	47
Vertical split head	(142)	62	62	86	30
Joint bar	(147)	69	61	NA	2
Other	(149)	50(-)	57	55	NA
TRACK APPLIANCE GROUP					
Switch point	(165)	63	55	55	31
All track-related cause codes		66 STD DEV = 36	56 STD DEV = 39	65 STD DEV = 41	34 STD DEV = 30

TABLE G-6. MEAN POSITION OF FIRST CAR INVOLVED FOR THE 17 LEADING TRACK-RELATED CAUSE CODES BY TRACK TYPE

CAUSE CODE	(CODE NO.)	MAIN	YARD	SIDING	INDUSTRY
ROADBED GROUP					
Roadbed, settled or soft	(101)	26	19	40	6
Washout/rain/etc. damage	(102)	21(-)	20	10	13
TRACK-GEOMETRY GROUP					
Wide gauge, defective ties	(110)	23(-)	23	18	13
Track alignment	(114)	41(+)	20	37	6
Track alignment, buckled	(115)	42(+)	67(+)	NA	38
Superelevation	(117)	36	6	NA	8
Cross level, at joints	(119)	39(+)	31	28	27
Cross level, not at joints	(120)	36(+)	28	22	26
Other	(129)	39	19	48	1
RAIL AND JOINT-BAR GROUP					
Bolt hole crack/break	(130)	35	38	NA	30
Broken base of rail	(131)	25	26	29	49
Head & web separation	(136)	27	28	48	5
Transverse/compound fissure	(141)	27	34	35	25
Vertical split head	(142)	30	23	30	6
Joint bar	(147)	26	30	NA	2
Other	(149)	26	26	29	NA
TRACK APPLIANCE GROUP					
Switch point	(165)	24	25	18	19
All track-related cause codes		31 STD DEV = 29	26 STD DEV = 31	27 STD DEV = 29	17 STD DEV = 20

TABLE G-7. MEAN TRAIN SPEED FOR THE 17 LEADING TRACK-RELATED CAUSE CODES BY TRACK TYPE

CAUSE CODE	(CODE NO.)	TYPE OF TRACK (ALL FRA TRACK CLASSES) MAIN	YARD	SIDING	INDUSTRY
<u>ROADBED GROUP</u>					
Roadbed, settled or soft	(101)	14(-)	5	7	5
Washout/rain/etc. damage	(102)	44(+)	6	7	NA
<u>TRACK-GEOMETRY GROUP</u>					
Wide gauge, defective ties	(110)	12(-)	5	5	5
Track alignment	(114)	18	8(+)	15	13(+)
Track alignment, buckled	(115)	25(+)	9(+)	NA	4
Superelevation	(117)	19	NA	NA	NA
Cross level, at joints	(119)	18	6	11(+)	8(+)
Cross level, not at joints	(120)	16(-)	6	5	8(+)
Other	(129)	22(+)	6	5	5
<u>RAIL AND JOINT-BAR GROUP</u>					
Bolt hole crack/break	(130)	26(+)	5	NA	7
Broken base of rail	(131)	19	5	5	6
Head & web separation	(136)	18	5	6	7
Transverse/compound fissure	(141)	19	5	6	7(+)
Vertical split head	(142)	18	6	7	5
Joint bar	(147)	18	6	NA	4
Other	(149)	24(+)	5	6	NA
<u>TRACK APPLIANCE GROUP</u>					
Switch point	(165)	8(-)	5	6	4
All track-related cause codes		18 STD DEV = 11	5 STD DEV = 3	6 STD DEV = 4	5 STD DEV = 3

TABLE G-8. MEAN TEMPERATURE FOR THE 17 LEADING TRACK-RELATED CAUSE CODES BY TRACK TYPE

CAUSE CODE	(CODE NO.)	MAIN	YARD	SIDING	INDUSTRY
ROADBED GROUP					
Roadbed, settled or soft	(101)	49	57	51	62
Washout/rain/etc. damage	(102)	47	29(-)	43	62
TRACK-GEOMETRY GROUP					
Wide gauge, defective ties	(110)	51	54	56	57
Track alignment	(114)	58(+)	58	52	55
Track alignment, buckled	(115)	81(+)	73(+)	NA	80
Superelevation	(117)	54	35	NA	10(-)
Cross level, at joints	(119)	54	58(+)	55	68
Cross level, not at joints	(120)	56(+)	53	56	62
Other	(129)	54	44	77(+)	82(+)
RAIL AND JOINT-BAR GROUP					
Bolt hole crack/break	(130)	36(-)	44	NA	48
Broken base of rail	(131)	47(-)	51	58	59
Head & web separation	(136)	50	48	58	49
Transverse/compound fissure	(141)	42(-)	54	45(-)	54
Vertical split head	(142)	46(-)	46	47	77
Joint bar	(147)	54	48	NA	20
Other	(149)	51	41(-)	38	NA
TRACK APPLIANCE GROUP					
Switch point	(165)	51	54	54	59
All track-related cause codes		52 STD DEV = 22	52 STD DEV = 21	54 STD DEV = 20	57 STD DEV = 23

APPENDIX H

A REVIEW AND EVALUATION OF METHODS FOR RANKING TRACK-RELATED RAILROAD ACCIDENT CAUSES

H.1 INTRODUCTION

The new railroad accident/incident reporting system installed by the FRA in 1975 will be used to assist in prioritizing research to reduce railroad accidents. The information contained in the accident file can be applied at a general level to determine where overall research emphasis should be directed; e.g., reduction of grade-crossing accidents versus occupational illnesses, or at detailed levels to determine which specific kinds of accidents are to be addressed, based on severity ranking of accident causes. A variety of methods has been used to rank accident causes, using the data contained in accident files, to determine priorities for research. This paper will review these methods and provide recommendations for preferred methods to use in support of the track-related accident causes study of the Track Structures Research Program.

H.2 DISCUSSION OF METHODS

H.2.1 Ranking by Number of Accidents

The simplest method of ranking accident causes is by the number of accidents they produce. All of the data required to do this is contained in the accident files. The major deficiency of this approach is that it ignores the differences in severity of accidents in terms of resulting economic impacts and casualties. Ranking by number of accidents would be acceptable only in those cases where the accidents investigated all have equal impacts.

H.2.2 Ranking by Dollar Damage

This approach takes into consideration the economic impacts of accidents but ignores the casualties produced. The data provided by the accident files concerning dollar damages is incomplete. Railroads are required to report only the damages to train equipment and roadbed in excess of a certain threshold value which is increased every two years to account for inflation. In 1975 this value was $1,750. The costs, resulting from accidents, of clearing wrecks, losses and damage to lading, and delays and service disruptions are not recorded. Two FRA studies*[5,6], have shown that total costs (excluding casualties) of accidents are about 2.5 times the reported amount of damages. The dollar damage ranking concept can be applied in several different ways:

1. Catastrophic Accidents - The severity ranking of accidents could be established by the number of accidents exceeding a specified large dollar cost, i.e., the number of catastrophic accidents. This approach does not consider the total dollar impact of all accidents, however, and could produce erratic results from year to year since catastrophic accidents tend to occur infrequently.

2. Average Damage - Ranking by average dollar damage per accident is more indicative of the typical accident severity since the effect of catastrophic accidents is diluted. There is some question as to whether the mean or median dollar damage is the preferred statistic to use. Recent AAR studies[2,4] of FRA accident statistics have used the median because it is less affected by extreme values. The median value would, therefore, also be a more stable statistic from one year to the next. The primary concern, however, in evaluating the merits of the two methods is the degree to which each measures the expected damage due to specific accident causes, and thus the benefits to be derived from eliminating those causes. Using this criteria, we find the mean is the best statistic since it is the expected value of damages. In situations such as track-related accidents where the damage distributions are skewed to the right, the median statistic will underestimate the expected damages.

*Reference numbers refer to Section 6 of main report.

3. Total Damage - Ranking by total accident damage is the best indicator of accident severity (excluding casualties) since it combines both the average amount of damage and accident frequency. The considerations mentioned above should be used as a guide in selecting either the mean or median value as the average statistic.

H.2.3 Ranking by Casualties

This approach considers the impact of accidents in terms of human injuries and fatalities but ignores their economic impacts in terms of damage to equipment, lading and trackage. The advantage of this method is that there will be little disagreement as to where research should be applied if it can be demonstrated that a specific accident type produces a large number of casualties regardless of other impacts, e.g., grade-crossing accidents.

The ranking of accidents by casualties can be accomplished by simply adding together the number of injuries and fatalities to produce the total number of casualties. There are generally many more injuries than fatalities, however, so this approach tends to be biased toward injuries which typically have much less of a social impact than fatalities. A method of shifting the emphasis from injuries to fatalities is to normalize the number of injuries and fatalities on the same scale by determining their percent distribution among the various accident types. The sum of the percent injuries and fatalities will thus increase the emphasis on fatalities by the ratio of the number of injuries and fatalities for that category of accident. The weighting of injuries and fatalities can be further affected by multiplying the percent distributions of either category by a constant factor. An NTSB study,[12] for example, multiplied the percent distribution of fatalities by a factor of 2.0 to give it added weighting relative to the percent distribution of injuries.

Another method of reconciling the relative severity of injuries and fatalities is to use the number of days disabled. The accident reports permit computation of the days disabled from injuries for different accident types. An average number of productive days lost due to fatalities must be determined, however. The FRA Accident Bulletin [1] assumes 6,000 days per fatality. With days disabled assigned to injuries and fatalities, several indices of overall accident severity can be developed based on the number of casualties. One approach would be to sum the total days disabled from injuries and fatalities for each accident category. Another approach, used by the AAR, [4] is to determine the median days disabled due to injuries and fatalities and multiply this figure by the number of accidents. The advantage of this approach is that the median statistic is unaffected by the assumed value for the number of days disabled per fatality as long as it is sufficiently large. On the other hand, the median days disabled figure decreases greatly the actual influence of fatalities since injuries are generally much more numerous than fatalties. If an appropriate number of days disabled can be determined for fatalities, the mean number of days disabled from injuries and fatalities would be a more representative statistic for casualty severity than the median.

H.2.4 Ranking by Total Societal Impact

This procedure attempts to combine accident impacts of dollar damages and casualties to create a more comprehensive index of accident severity. Because it combines the economic and casualty losses of accidents, it is more representative of their true social impacts. The difficulty with this procedure is that two dissimilar measures, dollars and numbers of casualties, must be reconciled in common units, resulting in inaccuracies in the conversion. Several approaches can be used to combine damages and casualties:

1. Percent Distributions - The percent distributions of damages and casualties can be summed to create an index for ranking accident severity. Percent distributions of damages can be based

on either the number of accidents or the amount of dollar damage of accidents for each accident category. The total dollar damage of accidents, a better overall indicator than number, can be constructed from either the mean or median dollar damage. The percent distributions of casualties can be based on either the number of casualties or the number of days disabled produced by various accident categories. The days disabled would be preferred as this is a more representative index of casualty severity. Again, either the mean or median statistic can be used to determine average days disabled, depending upon the emphasis to be placed on fatalities and the degree of confidence in the days disabled determined for fatalities. A potential weakness of summing the percent distributions of damages and casualties is that it gives overall equal weight to damages and casualties. In reality, the total cost to society may be greater for one category than another. This shortcoming can be overcome, in part, by introducing a weighting factor to be applied to one of the categories to affect its overall impact; e.g., the percent distributions of casualties could be multiplied by 1.5 to give an added 50 percent weight to casualties over damages.

2. Dollar Impact - An alternative means of measuring, in common units, the impacts of damages and casualties is to determine their dollar costs to society. As discussed earlier, the cost of damages can be determined from reported equipment and track-damage data multiplied by a factor of 2 to 3 to account for lading damage, wreckage clearing and business impacts. Assigning societal costs to casualties is more difficult and controversial. The basic approach followed is to total all identifiable costs to society that result from an injury or fatality. Such costs include medical care, legal and court costs, investigation costs, insurance administration costs, and losses in individual productivity. However, these costs are not the value placed on a human life or the total cost to society of casualties and are thus only indicators of the relative severity of different accident types. On the other hand, these cost estimates are better indicators of the casualty impacts of accidents than only days disabled. Furthermore,

the costs of casualties can be added directly to the costs of damages so that their relative impacts are more nearly approximated than is the case when percent distributions are used. NHTSA has recently completed a study[13] to determine the societal costs of automobile accidents. The average costs of injuries and fatalities were determined by NHTSA to be $1,360 and $282,105 respectively. A preliminary investigation of the 1974 FRA accident statistics resulted in an estimate of the average injury and fatality costs for railroad accidents of $2,400 and $200,000, respectively.

H.3 APPLICATION OF RANKING METHODS TO FRA ACCIDENT DATA

Most of the ranking methods discussed in the previous section were applied to the 1975 FRA accident data to determine the rank of track-related accident causes. Both the number of accidents and the number of casualties were eliminated from consideration as neither was representative of accident severity. In the case of casualties, the reported data indicated no fatalities for all track-related accidents and no injuries for many specific cause codes. The ranking methods that were employed are listed below:

1. Total Dollar Damages;

1a. Mean damage x number of accidents;

1b. Median damage x number of accidents;

2. Total Societal Impact;

2a) Damages + casualties: dollar cost; and

2b) Damages + casualties: percent distributions.

The rankings of cause codes obtained by using the above methods are graphically displayed in Figure H-1, which shows plots of relative severity versus the 24 leading cause codes. The horizontal axis contains the cause codes listed by rank according to dollar damages (based on the mean); hence, the curve for that ranking method is continuously decreasing. The relative severity is the ratio of a code's severity, determined by any of the ranking methods, to the leading code's severity.

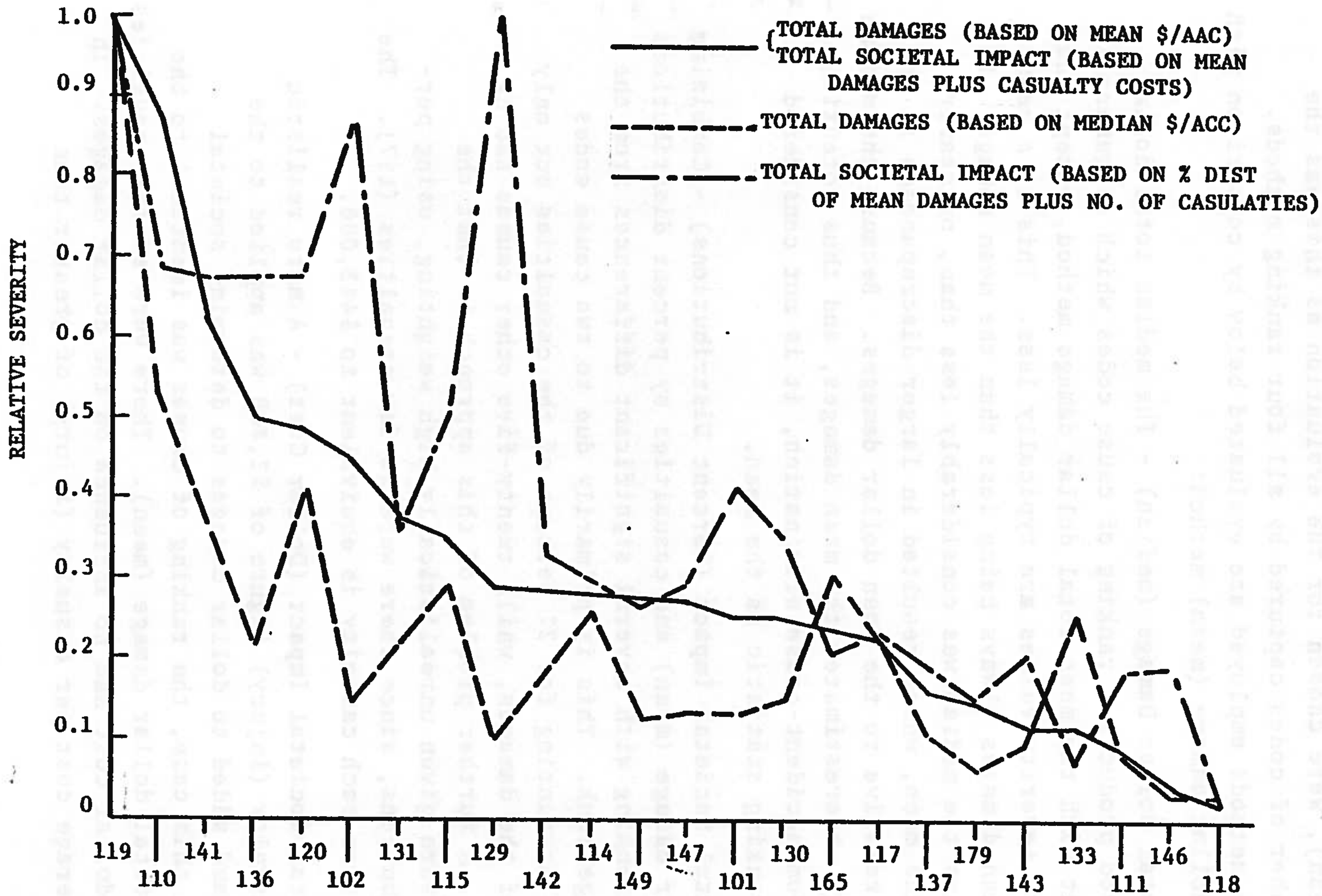

FIGURE H-1. RELATIVE SEVERITY OF TRACK-RELATED CAUSE CODES FOR DIFFERENT RANKING METHODS

The leading 24 cause codes, determined by total dollar damages (mean), were chosen for the evaluation as this was the minimum number of codes captured by all four ranking methods. The ranking methods employed are evaluated below by comparison with the total dollar damage (mean) method:

a. Total Dollar Damage (median) - The median total dollar damage method produces a ranking of cause codes which is generally in agreement with the mean total dollar damage method, except that the relative severity values are typically less. This is a result of the median damages always being less than the mean damage. In several cases the median was considerably less than, or nearly equal to, the mean, which resulted in larger discrepancies in the ranking of relative to the mean dollar damages. Because the median consistently underestimates the mean damages, and thus potential benefits from accident-cause elimination, it is not considered as good a ranking statistic as the mean.

b. Total Societal Impact (Percent Distributions) - Combining total dollar damage (mean) and casualties by percent distributions produces a ranking with several significant differences from the dollar damage rank. This is primarily due to two cause codes (102 & 129) accounting for 27 percent of the casualties but only 8 percent of the damages, while twenty-five other causes had no casualties. A further problem of this approach is that the casualties were given unrealistically high weighting, using percent distributions, since there were so few casualties (157). The weighting given each casualty is equivalent to $443,000.

c. Total Societal Impact (Dollar Cost) - A more realistic cost per casualty (injury) figure of $2,400 was applied to the casualties and added to dollar damages to determine societal impact. In this case, the ranking of causes was identical to the ranking by total dollar damage (mean). There were so few casualties that their dollar cost had no influence on the dollar damages. In fact, an average cost per casualty (injury) of greater than

$30,000 would be required to change the ranking of cause codes. Since this cost is so large, the ranking by total dollar damages (mean) alone appears best for this situation. In a situation involving more injuries and the inclusion of fatalities, the comboned dollar impact of damages and casualities would probably be a better measure.