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Analysis of the Behavioral Relationships of Railroad Track Maintenance Spending

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21 Cabot Rd.
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Final Report

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16. Abstract

This report summarizes the activities and results of the research effort on Class I railroads operating in 1978 and between 1962 and 1977.

Five tasks have been presented as follows: (1) industry interviews, (2) hypothesis development, (3) data acquisition, (4) model development, and (5) forecast and assessment of results through the year 1990.

Application of the model to the 1978-90 forecast for the Class I industry as a whole demonstrated the utility of the model as a means of assisting Federal policy evaluation and analysis.

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Track Maintenance Expenditures, Track Safety Standards, Track-related Accidents, Train Speeds, Class I Railroads

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PREFACE

DYNATREND wishes to acknowledge and express our appreciation for the guidance and assistance of Mr. Mark Hollyer, the TSC Contracting Officer Technical Representative, and Dr. Robert A. Smith of the TSC technical staff.

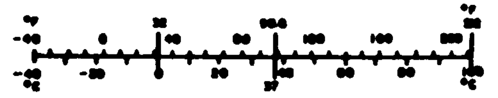
METRIC CONVERSION FACTORS

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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EXECUTIVE SUMMARY

The primary objective of this research effort was to develop a set of predictive equations comprising a model explaining track maintenance spending, average train speed, and track-caused accidents, and their interactions. Ancillary objectives included (1) assessment of structural change in the predictive equations which could be attributable to federal policy actions, including but not limited to imposition of track safety standards, and (2) development of forecasts of maintenance spending, speed and accidents for the Class I railroads as a group through the year 1990.

The research contract was comprised of five tasks, which are identified below:

1) Industry Interviews
2) Hypothesis Development
3) Data Acquisition
4) Model Development
5) 1978-90 Forecast and Assessment of Results

This report summarizes the results achieved for each of the tasks listed above.

Formal interviews were conducted with key executives in five railroads. The railroads visited were selected to be representative of the industry as a whole in terms of size, traffic density, profitability, geography, and train operations. The results of the interview were combined with the results of prior studies conducted by DYNATREND and other researchers to develop testable hypotheses to guide development of the predictive model. In general, the postulated hypotheses were confirmed by the subsequent statistical analyses used in the model development efforts.

The model was developed using publicly available data for 25 large (greater than 1000 track miles) railroads, which as a group account for more than 90 percent of the track, traffic, and accidents associated with all Class I roads. The study period was 1967-77, using the data listed below:

Financial - ICC R-1 Reports, 1962-77
Train Operation Details - ICC R-1 Reports, 1962-77
Total Traffic, Track Miles, and Rail/Tie Installations,
- ICC R-1 Reports, 1934-77
Track Related Accidents - FRA RAIRS Data Base, 1967-77.

The data were adjusted to account for mergers and consolidations, inflation, and reporting thresholds (for accidents).

The statistical methodology employed was the Generalized Least Squares (GLS) procedure described by Kmenta. This procedure corrects for both first order autocorrelation and heteroskedasticity (non-homogenous variance) of the residuals (errors between actual and predicted values).

On the whole, the predictive power of the equations for track maintenance (maintenance of way, or MOW) spending and speed was reasonably good, while the explanatory power of the equations for accident prediction was less satisfactory. The accompanying table summarizes the composition of the model in terms of the statistically significant variables included and the coefficient of determination (explanatory power) for each equation.

Assessment of structural change was accomplished by applying the Chow statistical test for equality of variance between the regression equations covering the entire period (1968-77) and similar equations developed for each sub-period (1968-72, 1973-77). Structural change was detected for all equations comprising the model, with less than five percent chance that the structural change is due only to chance. The existence of structural change implies that federal policy actions have had effect on railroad operations and maintenance decisions. However, it is not clear that these changes can be attributed solely to the imposition of track safety standards because the effects of other federal actions such as the 3R and 4R Acts and ICC determinations are not separately identifiable.

The impact of federal track inspection and sanctions (fine claims) was also investigated. Although the results were not statistically significant, there were indications that the intensity of federal track inspection and fines claimed resulted in slightly increased maintenance spending.

Finally, the forecast of MOW spending, average speed and accidents was developed based on two alternative scenarios. The first assumed continuation of the conditions extant in 1977 unchanged through 1990. This scenario indicated that MOW spending would continue to climb slowly, speed would gradually decline, and accidents would increase until the late 1980's, when all would level off and change direction.

The second forecast scenario assumed continuation of the trends evident in the 1967-77 time frame, except for very moderate acceleration in traffic growth and the rate of track abandonment which would be made possible through deregulation of the industry. This scenario resulted in a much higher rate of growth in MOW spending over the entire period, and a gradual increase in speed and reduction in accidents commencing in the early 1980's, with the improved performance slightly accelerating over the rest of the decade.

TABLE ES-1. SIGNIFICANT VARIABLES EXPLAINING TRACK MOW SPENDING, SYSTEM AVERAGE SPEED, AND ACCIDENTS

Explanatory Variable	MOW Spending	Average Speed	Accidents
Traffic Density	o		
Funds*	o		
Relative Prices**	o		
30 Year Sum Deferred Rail***	o	o	o
Loaded Car Weight	o		o
Average Haul		o	
Tons Pulled/Locomotive		o	
No. Tracks/Route		o	
5-Yr Prior MOW Spending			o

*Gross Margin before MOW spending, per gross ton-mile.

**Ratio of MOW unit costs to Transportation unit costs.

***Surrogate for Track Quality.

In addition to the two major alternative scenarios, variations in the trends of "gross margin"/ton mile, excluding MOW spending and other fixed costs, were examined. The first alternative assumed a continuation of the profit squeeze trend evident in the 1967-77 data, while the second assumed an immediate reversal (in 1978) in direction but only a gradual improvement over time, such that the level observed in 1967 would be reached in 1990. These two variations in gross operating margin were applied to both base scenarios. The base scenario results were only moderately influenced by variations in the "gross margin" variable, with about the same relative effect in both scenarios. The absolute effect was considerably greater in the 1967-77 Continued Trends Scenario, of course.

Application of the model to the 1978-90 forecast for the Class I industry as a whole demonstrated the utility of the model as a means of assisting federal policy evaluation and analysis.

SECTION 1
INTRODUCTION AND SUMMARY

1.1 BACKGROUND

Since its inception in 1967 as part of the formation of the U.S. Department of Transportation, the Federal Railroad Administration (FRA) has required railroads to report accidents and other safety-related incidents which have consequences exceeding certain threshold criteria. Since that reporting process commenced, the number of accidents reported has generally increased over time. The number of accidents reported to be caused by defects in track structure, however, have increased at a faster rate that those attributed to the other two principal categories, equipment defects, and human factors. The disproportionately rapid increase in the number of accidents attributed to track causes has been particularly apparent since about 1973.

Because an accident was not reportable by the railroads unless the estimated damage to track and equipment exceeded a threshold value of $750, which remained fixed from 1967 to 1974, a study[1] was conducted to determine the effects of inflation on the number of accidents reported. As a consequence of this study and other investigations, the FRA adopted a policy of changing the level of dollar damages reporting threshold every two years to minimize the effects of inflation on the apparent reported safety performance of the railroads. The first such increase in the reporting threshold was operable for the year 1975, at which time the whole reporting system was substantially revised. The reporting threshold was increased again in 1977 and in 1979.

In the early 1970's, concern regarding the increasing number of accidents attributed to track conditions resulted in the promulgation of federal track safety standards by the FRA, with participation of the railroad industry. The standards basically define speed limits for passenger and freight trains based upon compliance with a set of track geometry and track components physical condition requirements, and track inspection requirements which depend principally on allowed speeds and whether the track regularly carries passenger traffic. These standards were imposed in stages in 1972 and 1973, with full compliance by the railroads required in October of the latter year.

After promulgation of the federal track safety standards, the FRA also initiated a program of federal inspection, supplemented by inspection activities conducted by a few states. The FRA inspection program consisted of six inspection vehicles, operated by contractors for the FRA, and a number of inspectors (about 45 in 1977) who were empowered to physically inspect railroad track and related records and to recommend enforcement actions to the FRA. As a consequence of these federal inspection activities, the FRA instituted an enforcement program of fines and other sanctions imposed on railroads failing to comply with the track safety standards, as allowed by the legislation authorizing their promulgation. The aggregate dollar magnitude of the fines was quite low in the early years, but increased substantially in the late seventies.

In the mid-seventies, continuing concern regarding the deterioration of the track structure and, indeed, the poor financial condition of the railroad industry in general, prompted action by the federal government to increase the funds available to upgrade track. The U.S. Congress passed the Railroad Revitalization and Regulatory Reform (4R) Act in early 1976, which authorized the U.S. Department of Transportation to establish and administer a funding program - comprised of preference share financing, loan guarantees, and other mechanisms - to assist the railroads in rehabilitating track. The 4R Act also directed the Interstate Commerce Commision (ICC) to reduce economic and operating regulation of the railroads where adequate competition existed, and to reduce the time period involved in resolving applications for mergers and line abandonments.

During the latter 1970's, the ICC also instituted a rate proceeding which was designed to increased the dollars available for track rehabilitation. The ICC also required the railroads to report periodically on the extent of deferred track maintenance and slow-ordered mileage. Subsequent reports by the railroads indicate that deferred maintenance and slow ordered mileage have been declining; unfortunately, uniform standards were not established by the ICC for reporting of deferred maintenance and slow-orders, and thus physical interpretation of the reported values is difficult if not impossible.

Despite the federal regulatory and economic assistance actions summarized above, the number of track-caused accidents reported has continued to increase, nearly doubling from 1972 to 1977, even after correcting for inflation and changes in the reporting threshold. The FRA established, in the mid-seventies, a modestly funded track structures research and development program oriented toward improving track safety and durability. This program is comprised of a number of research projects whose purpose is to better understand the physical and economic factors which affect track structure, its maintenance and inspection, and their relation to track safety and the long-term financial health of the railroad industry. The overall objective is to provide better information, analytic and management tools, and maintenance and inspection techniques leading to more effective, less costly track maintenance, inspection and safety regulation. The research effort described in this report is a small part of that overall program.

1.2 CONTRACT OBJECTIVES

The specific objectives of this research were to identify the principal factors affecting track maintenance of way (MOW) spending, average train speeds, and track-caused accidents, and the interactions of the first (MOW spending) with the others (speed and accidents). In particular, the end objective was to develop a mathematical model, based on econometric and statistical techniques, of these factors and relationships which can be used to support further policy analysis and forecasting studies, and to demonstrate the use of that model in forecasting MOW spending, average speed, and accidents through the year 1990. A key subsidiary objective was to determine whether promulgation of the federal track safety standards and other related federal actions had any significant effect on railroad track maintenance spending, speed, and track-related accidents.

The overall research contract was subdivided into five tasks, as follows:

- Task 1 - Industry Interviews
- Task 2 - Hypothesis Development
- Task 3 - Data Base Development
- Task 4 - Model Development
- Task 5 - Model Application and Critique

The above task breakdown also provides a convenient outline for the presentation and discussion of results in the remainder of this summary.

1.3 TASK 1 - INDUSTRY INTERVIEWS

The objectives of the industry interviews were three-fold:

(1) To confirm or modify the preliminary model hypotheses developed by the research team.

(2) To identify additional factors which should be considerd in the analysis.

(3) To obtain additional background information regarding railroad practices and management attitudes in response to federal safety regulation and its implementation.

Originally, it was proposed that interviews would be conducted with a broad sample of the Class I railroads comprising the industry. However, after conducting interviews with senior executives at five railroads, the remainder were eliminated since it was believed that sufficient consensus had been developed such that continuation of the interviews would not be cost-effective. The five railroads which participated in the interview process are characterized by Table 1-1. As examination of the table indicates, the five railroads interviewed constitute a reasonable cross-section of the industry, except for the small Class I railroads, with broad coverage in terms of geography, size, traffic density, speeds, average haul (operations), track MOW spending, and track-caused accidents. In addition, the level of the individuals interviewed assures that railroad policy and decision-makers were involved.

The methodology employed during the interview process is summarized below:

- Select railroads to be interviewed, in conjunction with TSC.

TABLE 1-1. CHARACTERISTICS OF RAILROADS INTERVIEWED

RR	Region	Track Miles (K) Running	Track Miles (K) Total	Traffic Density	Avg. Haul	Avg. Speed	MOW Spending*	Accidents/BGTM Running	Accidents/BGTM Total
A	Northeast	24.0	34.7	9.5	352	16	2.7-6.9K	1.083	2.093
B	Northeast	1.0	1.3	5	195	14	2.2-2.7K	1.401	3.064
C	Western	15.2	19.6	11	670	29	3.0-3.6K	0.230	0.382
D	Midwest/South	10.5	13.4	6.5	328	17	1.6-3.2K	1.517	3.027
E	Northwest	10.8	13.3	5	301	17	1.4-2.2K	3.214	5.426

*Low-High during period 1973-77, in dollars/equated track mile.

RR	Person(s) Interviewed
A	Staff Assistant to Chief Engineer Director, MOW Rehabilitation
B	Vice-President-Engineering
C	Chief Engineer
D	Chief Operations Planning Officer
E	Director of Maintenance Planning

- Identify key individuals and arrange interview, forward agenda in confirmation letter.
- Conduct background research
- Conduct interview
- Document notes
- Conduct comparative analysis
- Prepare informal report, submit to TSC.

This following discussion summarizes those decision factors which were articulated by the interviewers as having (or not having) an influence on the MOW resource allocation process. It is emphasized that the discussion represents a "piecing together" of the information and perspectives provided by the interviewers and does not represent an in-depth management study of the decision process. Nevertheless, the basic philosophies and approaches which presented are useful for the purpose of applying the appropriate caveats to the use and interpetation of the MOW predictive model presented later.

Table 1-2 provides an overview of the principal MOW resource allocation influencing factors which were common to the five railroads interviewed, as well as attitudes expressed relative to FRA's track safety standards and track inspection program. Brief discussions concerning each follow:

1.3.1 Tonnage and Axle Loads

Tonnage and axle loads were two primary factors expressed as influencing MOW resource allocation decisions. Once current and projected annual tonnage for a line is determined, attention is

TABLE 1-2. MOW RESOURCE ALLOCATION FACTORS

	Railroad				
Item	A	B	C	D	E
Tonnage (Density)	Emphasized	Key Consideration	Emphasized	Key Consideration	Emphasized
Axle Loads	Key Consideration	Key Consideration	Emphasized	Key Consideration	Emphasized
Commodity (Including hazardous materials)	Key Consideration	Key Consideration	Key Consideration	Key Consideration	Key Consideration
Speed	Emphasized	Key Consideration	Key Consideration	Emphasized	Not A Key Consideration
Line Revenue Production/ Potential	Key Consideration	Emphasized	Emphasized	Emphasized	Key Consideration
FRA Track Safety Standards	Not A Factor	Not A Factor	Not A Factor	Not A Factor	Not A Factor
FRA Track Inspection	Not A Factor	Not A Factor	Not A Factor	Not A Factor	Not A Factor
Remarks	Speed is a key concern but not a driving factor. Slow orders on main lines receive immediate attention in order to maintain maximum speeds.	Fines imposed by track inspectors do not impact budget development process. Slow orders are considered insignificant.	Slow order impacts are assessed regularly for corrective action at local/ site-specific level, but do not enter into MOW budget development process	Fines impact at the local/ site-specific level; do not impact MOW program development process.	Track structure which is maintained to handle appropriate tonnage and axle loads can support any reasonable speed.

directed to the car weight's/axle loads which are to carry the particular commodities. An assessment is then made of the condition of the rail, ties, ballast, sunfacing, and the required maintenance actions necessary to support operations over the line. Secondary considerations such as geography, climatic conditions, etc., are also introduced at this time.

1.3.2 Commodity and Line Revenue

As would be expected, line revenues are a principle factor in MOW resource allocation considerations. Those lines which are the prime revenue producers, or have the potential for significant revenue growth (e.g., increased commodity shipments anticipated as determined by market analysis) will receive maintenance priority.

While line revenue assessments are a function of the type and nature of the commodities carried, the latter are also key considerations for track maintenance determinations. That is, the commodity mix and projected traffic define the physical characteristics and types of cars to be used, etc. Additionally, if the commodity is a hazardous material, routing considerations are introduced, such as geographic areas through which the materials are transported; if they are transported through populated areas the railroad might ensure maintenance to a " higher level" than would normally be the case for the given tonnage, axle loads, and speed and track maintenance would exceed that called for by both FRA Safety Standards and the railroad's design specifications. (It is noted, however, that such hazardous material considerations were cited by only one of the five railroads interviewed).

1.3.3 Speed

Speed on main lines to maintain operating/shipping requrements was identified as a prime concern by four of the five railroads.

The one exception indicated that speed was not a driving factor in MOW decisions; in this case, the rationale expressed was that if the track structure is maintained to handle the annual tonnage and axle loadings, it can safely carry trains at any "reasonable" speed.

1.3.4 FRA Track Safety Standards and FRA Track Inspection Program

Those interviewed, without exception, indicated that the FRA track safety standards and track inspection program are not key influencing factors insofar as the MOW resource allocation decision process is concerned.

The standards are viewed as a minimally acceptable baseline relative to operational requirements. The latter, as far as interviewers were concerned, incorporate safety as an implicit requirement; therefore, they feel that if track is maintained to their track design specifications (for applicable speed classifications) and operational requirements, safety requirements are met. It was unequivocally stated that the railroads' engineering maintenance standards (track design specifications) exceed those called for in the FRA standards. It may be noted however, that such statements apply primarily to main lines, not branch lines. Branch line concerns have more to do with shipper requirements (i.e., type of commodity and delivery times) than with track standards. Economically, the railroads are better able to cope with shipper requirements than they are with FRA imposed standards. For example, a slow ordered branch line which does not impact shipper requirements is acceptable, while maintenance costs to bring that line up to full compliance with FRA standards is not financially feasible to the railroad.

While the railroads view the standards in a somewhat ambivalent manner, they view the FRA Track Inspection Program very negatively. The consensus was that the FRA inspectors focus on branch lines, causing financial and management resources to be diverted from those areas requiring attention, namely, the main lines which are their primary revenue producers.

1.4 TASK 2 - HYPOTHESIS DEVELOPMENT

In conjunction with the industry interviews and drawing on the results of prior studies and research, a set of hypothesis were developed to guide the model development effort. These hypotheses are summarized below:

1.4.1 Track MOW Spending (per mile)

The first, and principal, hypothesis was that MOW spending is a function of traffic density, for several reasons. First, increasing density provides greater revenue capability to fund track maintenance. Second, track degradation rates, particularly rail wear, are a strong positive function of traffic density, which requires higher track maintenance spending with increased density.

The second hypothesis was that higher loaded car weights would result in higher spending, traffic density held constant. This is a consequence of the increased loads and stresses induced by heavy cars and the associated more rapid deterioration of track components, particularly rail. In addition, higher average loaded car weights (>90 tons or so) generally indicate a high fraction of unit train operations, which result in more rapid wear, but whose operating efficiency also provide a better ability to finance track maintenance. Finally, higher or rapidly growing loaded car weights on marginal track provide a major impetus to increased rail weights, ballast depth, and perhaps reduced tie spacing, which are betterments under ICC accounting rules, leading to higher MOW spending.

The next hypothesis was that MOW spending is conversely related to track condition. That is, all other things equal, a railroad whose track was in generally poor condition would tend to spend more on track maintenance, for two reasons. First, the railroad would attempt to upgrade the track to better facilitate and support operations, and that such upgrading is generally more extensive and expensive than on-going maintenance performed in track in good condition. Second, those railroads with track in relatively poor condition are also likely to be financially marginal, resulting in a higher proportion of spot versus programmed maintenance, and a lower degree of automation of MOW production activities, both of which lead to higher costs.

The fourth hypothesis was that those railroads with greater gross margins, on a per ton-mile basis, would tend to have greater MOW spending. That is, those railroads whose operating costs, exclusive of track MOW, were lower or revenues were higher on a per ton-mile basis would spend more because more funds would be avilable, traffic density held constant. Thus those railroads with a traffic mix comprised of high rate commodities or those with strong operating efficiencies, or both, would tend to spend more.

Finally, it was postulated that the unit MOW costs (prices) relative to unit transportation costs (prices) would affect MOW spending, such that a more rapid increase in unit transportation costs (say, for fuel) would tend to drive down MOW spending.

1.4.2 Average Speed

There were six principal hypotheses postulated to affect system average speed. These encompass operating factors, track condition, and track-route structure.

First, average speed is hypothesized to be a function of the general condition of the track within the system. Those railroads with track in good condition would tend to have higher average speed, all else equal, than railroads with track in relatively poorer condition.

The next set of hypotheses involve facets of train operations. First, it was postulated that speed tends to increase as average haul increases. This hypothesis is based on the rationale that as average haul increases, there is a relative reduction in switching (both way and yard) and a greater distance between cities and hence fewer stops involving acceleration and braking. Average speed was also postulated to be directly affected by way and yard switching, average haul held constant, with greater switching activity (on a per car mile basis) resulting in lower system average speeds. Finally, it was expected that systems which operated with greater tons per locomotive would tend to have lower speeds. (It is recognized that this last hypothesis is a simplification of the complex interactions which occur between tractive effort and its relationship to horsepower and locomotive weight and number of axles, train length and its impact on train handling, and topographical features such as grades and curves. However, sufficient detailed data were not expected to be available to support an analysis in that depth, and it was believed that the postulated hypothesis captured the essence of the variation expected in speed as a consequence of train consist arrangement.)

The next hypothesis involved the expectation that railroads with a large number of small accidents or a fewer number of bigger accidents, from any cause, would have lower speeds that a comparable railroad with better safety performance. This hypothesis is based on the rationale that accidents cause enroute delays or diversions of trains over less preferred routes, with poorer track quality or greater curves and grades, either of which would result in reduced speeds. Thus, total accident costs (property damage, excluding lading, and wreck clearing costs) per gross ton-mile were expected to affect adversely system speeds.

Finally, the influence of track-route structure and its potential effect of influencing traffic congestion and hence speed was considered. It was hypothesized that those railroads having higher number of tracks (including second and other main and passing sidings) per route mile would tend to have higher speeds, due to the operational flexibility they provide.

1.4.3 Accidents

A number of hypotheses were developed regarding the factors contributing to accidents.

The first, and most obvious, was that accident rates (number/gross ton-mile) are directly related to track condition, with higher accident rates associated with track in relatively poorer condition. Track condition, in turn, was postulated to be affected by both long-term and short-term considerations.

The long term factor acknowledges the long useful life (measured in decades) of many components of the total track structure. Ties, rail, other track material (OTM), and ballast frequently have useful lives of twenty to forty years or more, depending on traffic density and its nature (unit trains, speed, curvature and grades, and the underlying condition of the subroadbed). It was therefore postulated that the cumulative effects of both track maintenance, particularly in terms of tie and/or rail renewal, and traffic would be important in defining the overall track condition. Thirty years was selected as the time span for defining long-term maintenance, principally because three decades were believed to be a reasonable average useful life but also for practical considerations regarding data availability.

On the other hand, it was necessary to include consideration of the potential effects of short-term maintenance, say averaged over the prior five years. This approach attempts to recognize the influence of track maintenance with shorter useful lives, including such items as drainage and vegetation control and lining and surfacing activities, which last a few months to a few years depending on local circumstances. In addition, the short-term factor recognizes the possibility of a small extra contribution of recent tie and rail renewal compared with longer term effects.

The next hypothesis concerning track condition is the overall design "beefiness" of the track structure. It was postulated that heavier rail and closer tie spacing, or both, would tend to provide a generally stronger overall track structure, all else held equal. (It is recognized, however, that within limits a possible tradeoff between rail weight and tie spacing exists, particularly when traffic loads and the relative economics of track maintenance depending on local environment and productivity are considered.)

It was also hypothesized that the (implied) condition of running track would also be indicative of the condition of switching track. That is, railroads with running track in relatively poor condition would have switching track in similar or worse condition. This hypothesis is based on the premise, confirmed in the industry interviews as well as generally accepted practices within the industry, that railroads place greater emphasis and priority on running track maintenance, particularly on mainlines, than on switching track, both in terms of spending per mile, in first position of new rail, and in the relative beefiness and condition of the underlying ballast and substructure.

From a train operations point of view, it was hypothesized that average loaded car weights would be a contributing factor to accident rates. All else equal, it was expected that railroads with higher loaded car weights would have higher accident rates, due to the greater loads on the track.

Another factor considered was average speed, or a combination (product) of speed and loaded car weight (momentum), reflecting the hypothesis, which many believe, that accident rates increase with speed due to dynamic loads on the track structure. Since average speed is also affected by track condition, in that trains are held to lower speed limits on poorer track, as well as by other influencing factors as previously discussed, the contribution of speed to running track accident rates was not expected to be unequivocal.

The above discussion presents the principal hypotheses considered in the analyses leading to the development of the predictive model.

1.5 DATA BASE

Since the fundamental approach which was to be used in development of the predictive model and assessment of the impact of federal actions in the seventies rested on the use of statistical analyses, an important consideration was the data available for conduct of the modeling activities.

The basic data sources used for this study are identified below:

(1) Railroad Financial and Operations Data - ICC R-1 Tapes for the years 1962-77.

(2) Accident Data - FRA Rail Accident Incident Reporting System (RAIRS) Tapes for the years 1967-77.

(3) Rail and Tie Installations, Gross Track Mile and Traffic Data (extracted from R-1 reports) Tapes for the years 1934-77.

All of the data tapes identified above were provided by the Transportation Systems Center (TSC). It is emphasized that all data employed in the study is available to the general public.

The data bases, as furnished to Dynatrend, contained certain errors and omissions, in most cases limited to specific railroads in specific years. In the case of data believed to be needed, but not contained in the data bases provided by TSC, Dynatrend obtained the data from the original source (the hard-copy R-1 reports submitted to the ICC or as published in their annual Transportation Statistics). In the situation where data for specific railroad/year combinations was missing, it was either obtained from another source or estimated based on the values for prior and succeeding years (i.e., interpolated). In some cases, the order of magnitude (factors of 10) included on the data base were in error; these defects in the data base were also corrected.

In order to obtain a consistent data base to conduct the analyses supporting the modeling activities, it was necessary to process the raw data tapes provided by TSC. The first consideration was to remove the effects of price inflation from all data provided, using AAR inflation indices. The year 1967 was selected as the base year, and all current dollar values were inflated/deflated to equivalent real values.

The original accident data, as previously discussed, was inconsistent from year to year due to inflation and reporting threshold changes, affecting both the number of accidents and their damage values. In addition, the reporting requirements were changed in 1975, such that the format and contents of the data bases from 1967-74 and from 1975-77 were considerably different. Finally, the RAIRS data base, as provided to Dynatrend, contained numerous redundant records associated with changes to original accident reports or more than one report submitted for a given accident (as may occur when a train operated by Railroad A has an accident on track owned or maintained by Railroad B). Therefore, the RAIRS tapes were processed to eliminate the effects of inflation, threshold changes, and redundant records, thus providing a consistent accident history for each railroad over the 1967-77 period. In processing the RAIRS data base, the 1977 reporting threshold, deflated to its equivalent 1967 value, was used as the lower cut-off for inclusion of each individual accident in the data base supporting this study. Finally, the data base was processed to provide a variety of summary statistics for each of the Class I roads. (Although not used in the final analyses, these aggregate statistics included breakdown by three major track-related cause groups (geometry, rail, other), using a cross-mapping of the different cause codes used in the two periods 1967-74 versus 1975-77.)

Finally, all of the data (financial, operating, physical and accident) were processed to eliminate the effects of mergers and consolidations which had occurred over the years, with particular emphasis on the 1962-67 period when a number of major mergers occurred and CONRAIL was formed (in 1976).

In all of the above data base efforts, particular emphasis was placed on assuring consistent data for the twenty-five Class I railroads with over 1000 miles of track, since the data for these roads would form the basis for the subsequent statistical analyses. It was decided, by the research team, to use this group of large railroads for two related reasons. First, they represented, in the aggregate, greater than 90 percent of all track, traffic and accidents and therefore comprised the overwhelming majority of the industry. Second, their size tends to include a variety of environmental and operating (track and traffic) conditions within each road, such that the group is somewhat homogenous. Inclusion of smaller roads, which tend to be more specialized in either traffic or locale, would have added other complications which seemed unwarranted. Furthermore, the small railroads have an almost dichotomous situation with respect to accident rates; since they may have only one or two (or none) accidents in a given year, their accident rates are subject to wide fluctuation over time. Inclusion of the smaller roads would therefore have lead to greater statistical variance, clouding the meaning of the overall analysis.

An implicit assumption, both in the data preparation and in the subsequent analyses, was that railroads, under the same circumstances, will behave the same way. That is not to say that all railroads will have similar results; they won't, because the situation each faces is unique, different in some way from each of the others. Rather, the implicit assumption is tht there are underlying rules or patterns which govern the behavior of all railroads, as systems of a similar kind. Therefore, the combining of data to eliminate the effects of mergers and consolidations relies on this commonality of systemic behavior, ignoring other effects of operation as separate entities.

There are two major, and one less important, variables for which direct data were not available to support this study. The first of these was the skills, attitudes and operating philosophies of the management team for each railroad. This may be the most significant aspet of mergers and consolidations not accounted for in this study. More importantly, however, the general inability to define the quality of management, not only for railroads but for any organization, leads to dependence on the sometimes poor assumption that all managements are about the same. That is, under identical situations, identical (or nearly so) results will obtain. Since this research was also unable to characterize management quality, the usual assumption of similarity was implicitly operable.

The next major variable for which explicit data were not available is track condition (quality). Therefore, the research team was forced to develop an index of track quality which depends on presumed degradation behavior of rail and/or tie installations over time. A number of such indices were constructed and tested in the analyses, with varying results. It was finally decided to use a measure defined as "deferred rail" as the principal surrogate for track quality. The specific measure employed is based on the method used in the FRA capital needs study conducted by T. K. Dyer Associates. It was selected because it can be objectively calculated, and incorporates consideration of many of the factors believed to affect degradation rates; that is, rail weight, traffic density, curvature, and per cent continuous welded rail (CWR). The basic premise of the Dyer approach is based on calculation of the amount of new rail, given traffic density, rail weight and the fraction of CWR, which must be installed to maintain useful remaining life at the fifty percent level. Installation of less than that amount (in tons/mile) results in a deficit or rail deferral for that year, and when summed over time - in this case, 30 years - provides a means of capturing the long term maintenance effects on track condition, after accounting at least in part for traffic and design considerations.

The use of the Dyer method of computing deferred rail does not include, unfortunately, consideration of loaded car weights, speed, tie installation or numerous other factors, particular lining and surfacing actions, on track quality. Some of these factors, particularly loaded car weights, could be incorporated separately. Tie installations tend to correlate strongly with rail installations, such that inclusion of only one would tend to capture the total effect, anyway. It is emphasized that the use of the Dyer deferred rail approach used herein is meant only as a surrogate for overall track quality and does not imply that rail is the principal or only factor in determining track quality. There may well be other surrogates which have greater explanatory power, but their development was well beyond the scope of this effort, although a limited investigation was conducted as part of this effort.

The minor factor which could have some effect on the results of this study is that of maintenance productivity, both over time for a given railroad, and amongst railroads. One would expect that different track maintenance productivities would influence the results in either of or a combination of two ways. First, higher productivity could lead to greater installation of new track material, total budger held constant. Second, keeping installations and other conditions constant, total spending would decrease if productivity increased. In the aggregate, there is a clear trend of the industry toward improved track maintenance productivity, due to a shift from section-oriented to system-oriented maintenance. This shift involves a tendency toward increased programmed as opposed to spot maintenance, larger and more specialized gangs, and a greater degree of mechanization supported by continuing improvement in production machinery. Unfortunately, data were not readily available to account for variation in track maintenance productivity in this study.

Finally, it is emphasized that all of the analyses and results of this study are based on the use of system aggregates, that is, for railroads as a whole. The study does not address single line segments in any way, and therefore does not, for example, consider the allocation of MOW spending to lines of different traffic density, car weights, speeds or track condition within a given railroad. As will be shown in the next section, this limitation is not serious for modeling aggregate MOW spending or average system speeds, but likely accounts (in part) for the relatively poorer explanatory power of the predictive equations for accidents.

1.6 MODEL DEVELOPMENT

The basic approach used in the development of the predictive equations comprising the overall model relating MOW spending, speed, and accidents to each other and to exogenous explanatory variables rests on the application of reasonably sophisticated multi-variate regression techniques. Tests for structural change were conducted using the Chow (F-test) procedure.

1.6.1 Statistical Methodology

The first step in the modeling activities was the selection of the modeling approach to be used. It was decided that a recursive modeling approach would be used. In the recursive model, lag relationships in which prior year(s) values for some of the independent variables affect current years values for the dependent variable are used to explain behavior. This approach was selected because it was believed that simultaneous mutual interactions between variables was, on the whole, rather weak, and use of a recursive model would eliminate the additional complications and uncertainties associated with use of multistage least squares techniques without sacrificing the utility of the final results.

The next step in the analysis was the translation of the hypotheses, previously discussed, into specific mathematical models (specifications). Generally, the models were cast in linear form; however, use of log-linear and polynomial forms was also investigated, but did not yield significant improvement in explanatory power of the predictive equations.

After specification of the form of the model, the generalized least squares (GLS) regression technique described by Kmenta was applied to the pooled time series/cross-section data for the 25 large railroads. This procedure involves execution of the following sequence of procedures:

(1) Conduct ordinary least squares (OLS) regression on the specified model, using the data for all (25) railroads in the sample.

(2) Using the OLS results, compute the difference between the actual and predicted value of the dependent variable (called the residual or error), for each railroad for each year.

(3) Compute the first order correlation between the value for a given year and the value of the residual for the preceding year (first order correlation) for each railroad separately.

(4) Using the computed correlation of residuals for each railroad, transform each variable into a new variable using the following:

$$X^*_{it} = X_{it} - (RHO_i)(X_{i,t-1})$$

where:
X = Each variable (both dependent and independent)
i = Railroad in the equation
RHO = Correlation between residuals
t = Current period
t - 1 = Preceding period

(5) Using the transformed variables of procedure (4), run the OLS regression separately for each railroad and record the standard error of the estimate (SEE).

(6) Re-transform each of the variables by dividing X* by SEE to obtain X**.

(7) Run OLS regression on the re-transformed variables (X**) using all railroads, for

    (1) the total period of interest

    (2) the subperiods of interest.

(8) Correct the intercept coefficient of the GLS equation to eliminate bias.

Data for the years 1967-77 were used for procedures (1) and (2), and 1968-77 for the remainder; the subperiods in procedure (8b) were 1968-72 and 1973-77.

In conducting the above technique, the SPSS (Statistical Package for the Social Sciencies) computer program was used. Forward stepwise regression procedures were employed in procedures (1) and (7) above, with all variables entered simultaneously in procedures (2) to (6).

The above procedure was used to reduce or eliminate the effects of two statistical problems, autocorrelation and heteroskedasticity. The first, autocorrelation, occurs because for a given entity (a railroad) one year's results are typically very similar to the results for the previous year, leading to underestimation of the variance and inclusion of explanatory variables which are not statistically significant. The second, heteroskedasticity, violates the underlying basis of regression procedures - uniform variance, and usually occurs because the size of the error is related to the size of one or more explanatory variables; heteroskedasticity generally leads to OLS variances which are overestimated.

In specifying the original OLS model, normalized data were generally used to correct for size; depending on the nature of the variable, the normalization factor was either track miles or gross ton-miles. Hence, for example, the dependent variables in the MOW spending equation was expressed as $/equated track mile. Use of normalized variables frequently reduces heteroskedasticity substantially, with the remainder further reduced by the procedures (5) and (6) in the technique summarized above.

In conducting the initial OLS regressions, the results were examined to identify likely problems of severe multicollinearity or mis-specification. However, generally, variables which were not statistically significant in the initial OLS regression were nevertheless retained and carried through to the final GLS regression procedure. At this point, the Student's t-statistic for each coefficient was exmained for significance, with at worst a 10 percent level of significance applied. The final predictive equations contain only variables which are statistically significant (i.e., unlikely to have occurred strictly by chance) and of the right algebraic sign. It is noted that non-significant variables were not simply dropped from the full set of predictors. Rather, the coefficients developed in a previous step were used, or the regression was re-run with the non-significant variable(s) omitted. This process is required because the coefficients generally change as new variables are added to the regrssion equation, due to small effects of multi-collinearity.

Procedure (8) in the sequence noted above is required because the GLS procedure operates on transformed data. When the original variables are substituted for the transformed variables, bias occurs becaue the intercept coefficient has not been corrected (adjusted) for the effects of autocorrelation. Bias in the GLS intercept term is indicated when application of the GLS equation to the original results in a sum of the errors which is not equal to zero. Correction of the bias involves adjustment of the intercept via either use of average values for each variable and the calculation of the correct value of the intercept coefficient, or the adjustment of the intercept value by the sum of the errors divided by the sample size (N). After the bias in the intercept term was eliminated, the squared errors were recomputed using the original data, in order to identify the explanatory power (R^2) of the final equations using the original data.

Step (7) of the procedure provides the results needed for analysis of the presence of structural change. For this purpose, it is necessary to have the identical set of variables in both the full period and each of the sub-periods, irrespective of their statistical significance (t-test) or algebraic sign. Also, the original, unadjusted GLS intercept term is used. The residual sum of squares (squared errors) is used for the whole period as compared with the sum for the sub-periods combined, together with their associated degrees of freedom to compute the Chow ratio, which is an F-statistic for which standard tables for statistical significance are readily available. A five percent level of significance was used.

1.6.2 Summary of Statistical Results

It is more convenient, for summary purposes, to first discuss the results of the tests for structural change, and then the specific details of the predictive equations for track MOW spending, average speed, and accidents.

As summarized above, the Chow test was used to determine whether there were statistically significant differences between the GLS equations developed for the entire 1968-77 period and the comparable GLS equations developed for the two sub-periods, 1968-72 and 1973-77. The sub-periods were chosen to reflect the fact that the federal track safety standards were phased in commencing in 1972, with full compliance required in late 1973; thus the transition period was about equally apportioned to the two sub-periods. In addition, the selection of the periods resulted in an equal division of the years between the two sub-periods, and thus eliminated consideration of any bias or spurious results which might be introduced by unequal sample sizes.

Application of the Chow test to the GLS equations containing the full set of explanatory variables indicated the existence of structural change for all of the predictive equations in the model, with less than a five percent probability of the structural change occurring strictly by chance. The high likelihood that structural change exists is a strong indicator, but not 'proof', that railroad behavior as defined by the mathematical (GLS regression) models was different in the two sub-periods and that use of a single explanatory equation covering the entire period (which assumes unchanging behavior) would be inappropriate. It is noted, however, that existence of structural change does not imply, necessarily, that a significant difference exists between the values of the dependent (predicted) variables in the two periods (although it is generally true), but rather that the relative strength of the coefficients for each of the independent variables has changed (is different) in the two sub-periods, i.e., that the relative strengths or contributions of the independent variables has changed (are different). (Strictly speaking, the existence of structural change indicates that the squared difference (error) between actual and predicted values of the dependent variable is significantly less (statistically) when using the two sub-period equations than the single equation covering the entire period, when the identical set of variables is used in all of the equations.) Discussion of the possible reasons for the structural change indicated by the statistical tests will be deferred until the discussion portion of this summary.

Not all variables in each equation carried through the GLS process were statistically significant and of the 'right' algebraic sign. In addition, the set of variables meeting the tests for significance and sign were not identical in both subperiods for all dependent variables (speed, MOW spending, etc.). Since it is generally preferable to use predictive equations which contain only statistically significant variables (determined by t-tests on their coefficients), only those final equations will be presented in this summary; full details are provided later in the report.

The final GLS predictive equations are presented in Table 1-3. The results essentially confirm the hypotheses discussed earlier. Table 1-3 also includes the coefficient of determination (R^2) for each predictive equation; this value indicates the fraction of variation in the dependent variable explained by the predictive equation. It is noted that the R^2 values included in Table 1-3 are based on use of the original, untransformed data, and are computed by using the predictive equations to calculate the sum of the squared errors used in the expression to determine $R^2 = (1-SSE/SST)$; adjustment for sample size is not included because the effect is quite small when the sample size is reasonably large (n = 125 for each equation).

The explanatory power (R^2) of the predictive equations for track MOW spending and speed are reasonably good. The equations for speed explain about 60-65 percent of the variation in actual speed for each of the twenty five railroads throughout the 1968-77 decade. The explanatory power of the MOW spending equations is somewhat better for the earlier period (1968-72) than for the later period (1973-77). The decline in R^2 from 0.677 to 0.54 may be due to a variety of factors, including but not limited to the effects of federal track safety regulation as well as federal assistance programs. For example, CONRAIL received substantial federal financial assistance after its formation in 1976 and

TABLE 1-3. FINAL PREDICTIVE EQUATIONS

MOW Spending ($K/Equated Track Mile)

1968-72 (R^2 = .677): MOW = -0.1546 + 0.2012 * DENSITY + 0.0049534 * DEFRAIL + 0.33675 * FUNDS

1973-77 (R^2 = .540): MOW = -0.041816 + 0.19151 * DENSITY + 0.0068203 * DEFRAIL + 0.5522 * FUNDS
+ 0.039628 * CARWT - 3.413 * RELPRICES

Average Speed (mph)

1968-71 (R^2 = .626): FRTSPD = -0.059168 + 0.034457 * AVEHAUL - 0.025013 * DEFRAIL + 8.8463 * MLPTRK

1973-77 (R^2 = .647): FRTSPD = -0.1004 + 0.028022 * AVEHAUL - 0.033104 * DEFRAIL + 14.211 * MLPTRK
-2.9243 * LOCPUL

Running Track Accident Rates (Accidents/BGTM)

1968-72 (R^2 = .282): ACRNGTM = 0.21318 + 0.0056081 * DEFRAIL + 0.0049173 * CARWT - 0.11486 * AVMOW

1973-77 (R^2 = .329): ACRNGTM = 0.41494 + 0.008624 * DEFRAIL + 0.0072376 * CARWT - 0.22265 * AVMOW

Number of Running Track Accidents

1968-72 (R^2 = .483): NACRUN = -7.3285 + 0.060042 * TDEFRAIL + 0.109018 * BGTM

1973-77 (R^2 = .566): NACRUN = 0.2907 + 0.090041 * TDEFRAIL + 0.266 * BGTM
+ 0.073297 * CARWT - 0.98898 * TAVMOW

Accident Rates, All Track (Accidents/BGTM)

1968-72 (R^2 = .185): ACTOTGTM = 0.24645 + 0.0038002 * DEFRAIL + 0.0164696 * CARWT - 0.26055 * AVMOW

1973-77 (R^2 = .243): ACTOTGTM = 0.78175 + 0.0066757 * DEFRAIL + 0.020893 * CARWT - 0.3837 * AVMOW

Number of Accidents, All Track

1968-72 (R^2 = .587): NACTOT = 3.19215 + 0.071686 * TDEFRAIL + 0.25091 * CARWT

1973-77 (R^2 = .515): NACTOT = 17.6927 + 0.11266 * TDEFRAIL + 0.28757 * CARWT
+ 0.39477 * BGTM - 1.27378 * TAVMOW

TABLE 1-3. FINAL PREDICTIVE EQUATIONS (CONTINUED)

* = Multiplication Operator

MOW = $K/Equated Track Mile

EQTRK = Equated Track Miles, in 1000's (= Running Track + 0.32 * Switching Track (including yards and wayswitching))

RUNTRK = Running Track Miles, in 1000's

DENSITY = Traffic Density in MGT (Millions of Gross-Tons (Tons-Miles/Mile))

DEFRAIL = 30 Year Sum Deferred Rail (using Dyer formulation) in Tons/Running Track Mile

FUNDS = (Operating Revenue - (Operating Expense - Total MOW Spending)), in $K/Equated Track Mile

CARWT = Average Loaded Car Weight, in Tons/Car

RELPRICES = Relative MOW: Transportation Unit Costs, dimensionless

AVSPD = Average System Speed (Train Miles/Train-Hours), in mph

AVEHAUL = Average Haul (Revenue Ton-Miles/Revenue Tons), in miles

MLPTRK = Average Number of Track/Route Miles (Total Running Track/First Main Track)

LOCPUL = Tons pulled (trailing) per Locomotive (Gross Trailing Ton-Miles/Locomotive Miles), in K-Tons/Locomotive

AVMOW = Preceding 5 Year Moving Average MOW, in $K/Equated Track Mile

BGTM = Billion Gross Ton-Miles

TABLE 1-3. FINAL PREDICTIVE EQUATIONS (CONTINUED)

ACRNGTM = Accident Rate for Running Track Only, in Accidents/BGTM

ACTOTGTM = Accident Rate for All Track (including Switching Track) in Accidents/BGTM

NACRUN = Number of Running Track Accidents/Year

NACTOT = Number of Accidents for All Track/Year.

TDEFRAIL = Total Running Track Deferred Rail (= DEFRAIL * RUNTRK), in K-Tons

TAVMOW = Total MOW Spending (= AVMOW * BQTRK), in $M.

other railroads have received preference share funding and loan guarantees under the provisions of the 4R Act. In addition, those railroads whose track was in relatively poor condition may have been affected to a greater degree by the federal track standards than those roads whose track was in better shape.

The explanatory power of the accident equations is less than that for speed and MOW spending. The R^2 for number of accidents is about twice as high as the explanatory power for accident rates (number of accidents/billion gross-ton-miles (BGTM)); the rate equations were based on normalized variables whereas the equations for number of accidents were not. Some of the relatively poor explanatory power of the accident equations can be attributed to the fact that accidents are stochastic in nature, occurring in part as a result of chance. In addition, however, accidents occur due to very local track conditions, which are not captured by system level aggregates such as the deferred rail surrogate for overall track condition used in this study. Finally, the surrogate for track quality, the 30 year sum of deferred rail, is probably not a very good measure of track condition generally within a system, but it was the best objective measure found.

The predictive equations in Table 1-3, in reality, are simplifications of the complex relationships of the many factors affecting track maintenance spending, accidents and speed for individual railroads. These other factors account for the unexplained ($1-R^2$) variation in the actual values of the dependent variables. The effects of some of these other factors may be important, but indirect. For example, a railroad with car utilization substantially better than average would have more money available for investment in track improvement and maintenance, all else held equal; to some degree, this effect would be included (with others) in the FUNDS variable, along with variations in average revenue rates, crew costs and a variety of other factors. Thus, some of these other factors are at least indirectly included in the mode. Others not included, such as the effects of grade, curvature, distance between cities and towns, route structure complexity and grade crossings per mile, were excluded due to lack of data or the inability to define a meaningful variable that captures the complexities of the factor involved.

The predictive equations were developed to predict the results for individual railroads, which have unique operating circumstances and factors under their control, and some beyond their control. In applying the equations, it should be recognized that some values of the independent variable are the result of very long term processes and trends, such that some of the "independent" variables are, in reality, not independent. For example, a railroad with a history of high density, long average haul operations is unlikely to have high values of deferred rail, because that railroad would have been consistently able to finance track maintenance. On the other hand, a low-density, short-haul railroad would be very likely to have higher values of deferred rail due to high switching costs and high fixed costs (per mile) of track maintenance which cannot be spread over a substantial traffic volume. Therefore, considerable caution should be exercised to assure compatibility of the values used for each of the independent variables in the model in an analysis.

Although recognizing that the specific value predicted for the dependent variables depends on the values of each of the independent variables in each equation, it is useful to examine the results provided by the model for an average railroad over the 1967-77 period. The results are presented incrementally for each variable in order to indicate the relative contribution of each to the total predicted result, as well as the difference in contribution due to structural change.

The trends of the weighted average values for each of the key independent variables is shown in Figure 1-1; the values are shown in indexed form, with the value for 1967 as the basis, in order to provide a uniform scale for comparison of trends over time. The overall trends are summarized below, in the order of their relative change during the period:

Deferred Rail (Track Quality): 35% Growth
5-Year Average MOW Spending/Mile: 34% Growth
Loaded Car Weight: 23% Growth
Tons Pulled/Locomotive: 17% Growth
Average Haul: 16+% Growth
Relative Prices: 5% Decline
Funds (Margin): 20% Decline

The values for gross ton-miles, total deferred rail and total average MOW spending for the 25 railroads as a group are provided in Figure 1-2; these variables are used only in the equations used to predict, directly, the number of accidents, and are representative of an "average" railroad, consistent with the weighted average values used for the other independent variables. It is noted that the trends for total deferred rail and total average MOW spending ($) in Figure 1-2 are not as steep as those for the per mile equivalents in Figure 1-1, due to the decline in track mileage over the eleven year period, as indicated by the greater upward trend of traffic density as compared with total traffic by itself. It is interesting to note that the growth of deferred rail (deterioration of long term track quality) does not level off until late in the period, despite continued increased in average MOW spending, coupled with the general upward trend in traffic density. This suggests that MOW spending in the future must be substantially higher for a reasonably long time to overcome accummulated deferred maintenance.

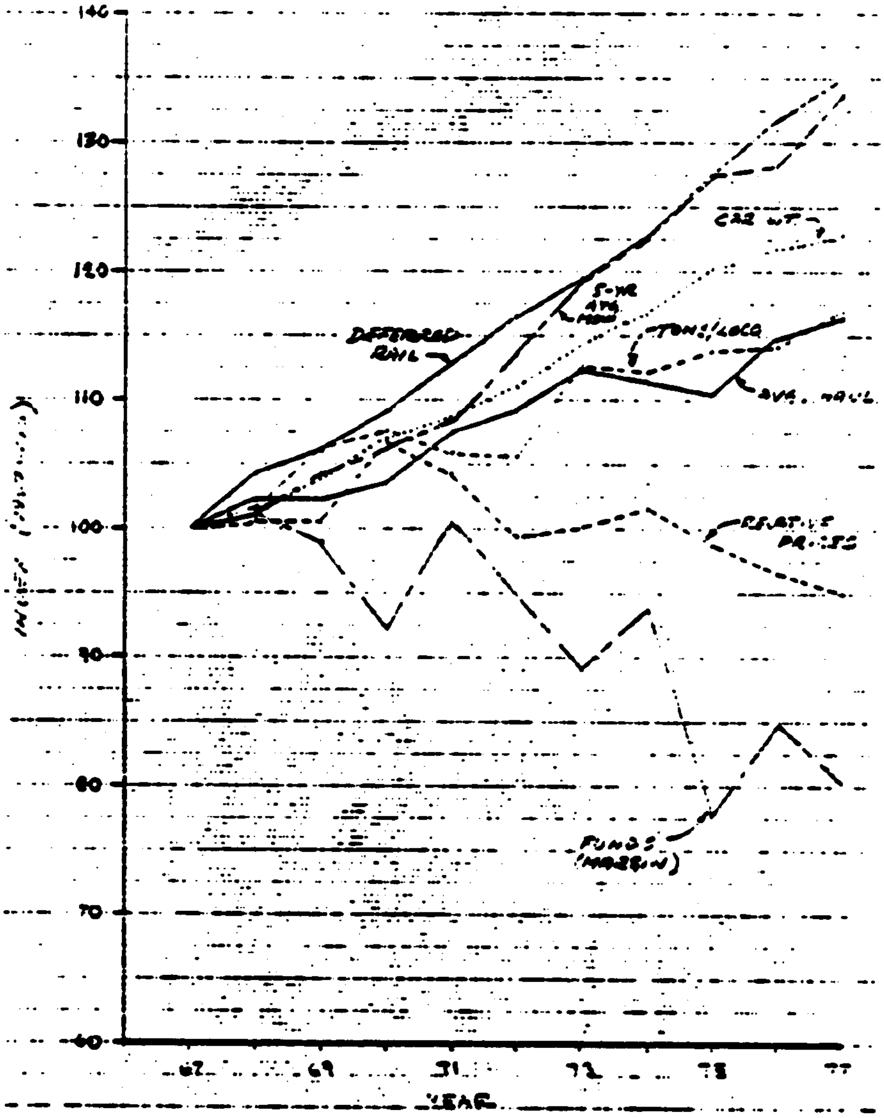

FIGURE 1-1. TRENDS OF THE INDEPENDENT VARIABLES, 1967-77

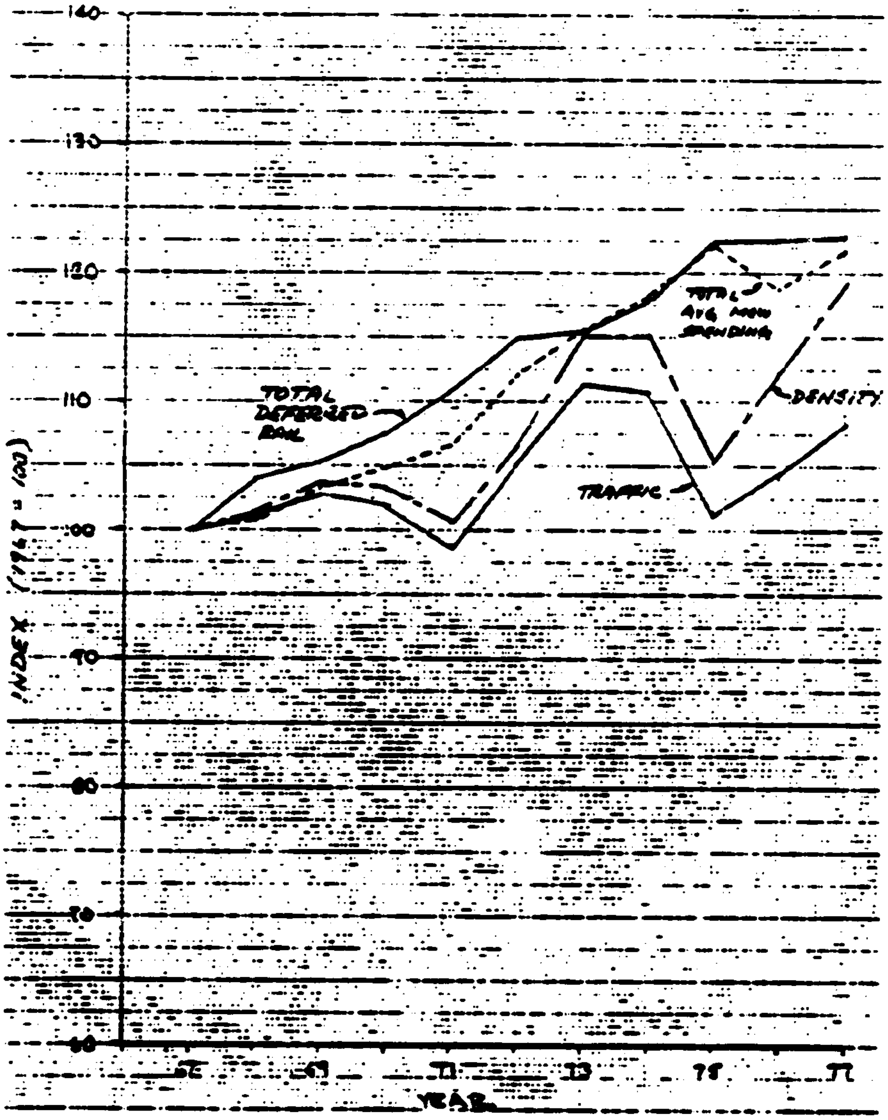

FIGURE 1-2. FURTHER INDEPENDENT VARIABLE TRENDS, 1967-77

Figure 1-3 provides the incremental results for track MOW spending, in $K/equated track mile. It is clear that traffic density is the dominant factor, as expected, because it is both the principal factor providing money and the major determinant of wear. Next greatest contribution is from marginal funds, reflecting the effects of train operating efficiency, rates, and fixed costs other than track maintenance. The effects of track quality (deferred rail), on average, are somewhat less than those due to available funds. The contribution of traffic density, funds and deferred rail increase slightly from the earlier to the later period, due to both shifts in their coefficients (which are constant in each period) and their upward trends over time. In the second subperiod (1973-77), loaded car weights and relative prices are statistically significant and included in the model. These additional variables nearly offset each other, as indicated by their net effect, but together show an increasing trend.

A comparable graph for average speed is provided in Figure 1-4. The situation for speed is somewhat more complex than for MOW spending. The intercept coefficients (constant), in both subperiods, are quite small and negative in sign. However, the coefficients for the average number of tracks/route mile are quite large, relatively. Since the minimum number of tracks/route must be one (unity), it seems reasonable to revise the intercept constant to include the effects of the first main, (revised constant) and show the effects of second and other main separately (extra tracks/route). The revised constant, including the effects of first main track, is a major component of average speed, and registers a substantial increase in the second subperiod. Average haul is the largest component of speed in the first subperiod, but its relative contribution declines in the second. The positive effects of the revised constant, average haul, and extra tracks per route are offset somewhat by the effects of track quality (deferred rail; the contribution of this component also shifts between the two periods. Finally, the

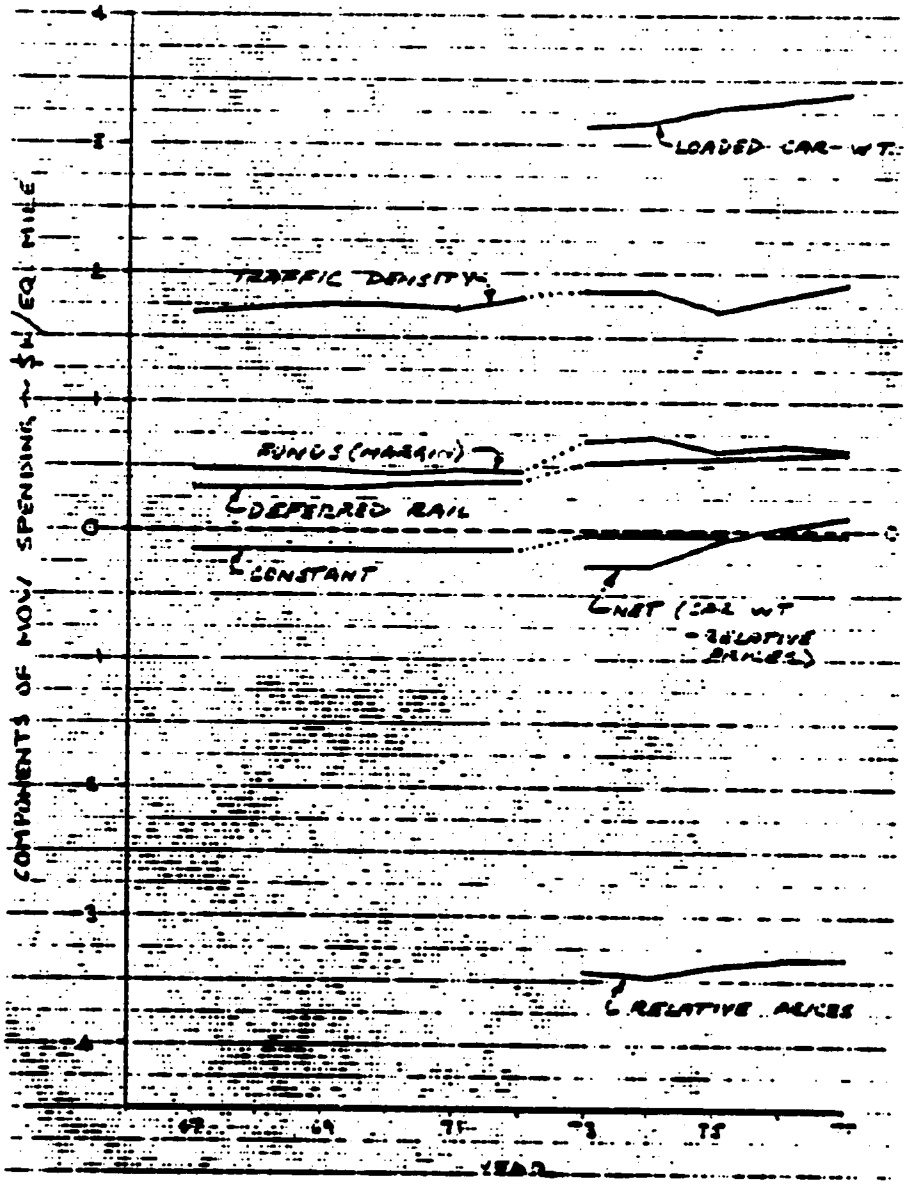

FIGURE 1-3. COMPONENTS OF MOW SPENDING

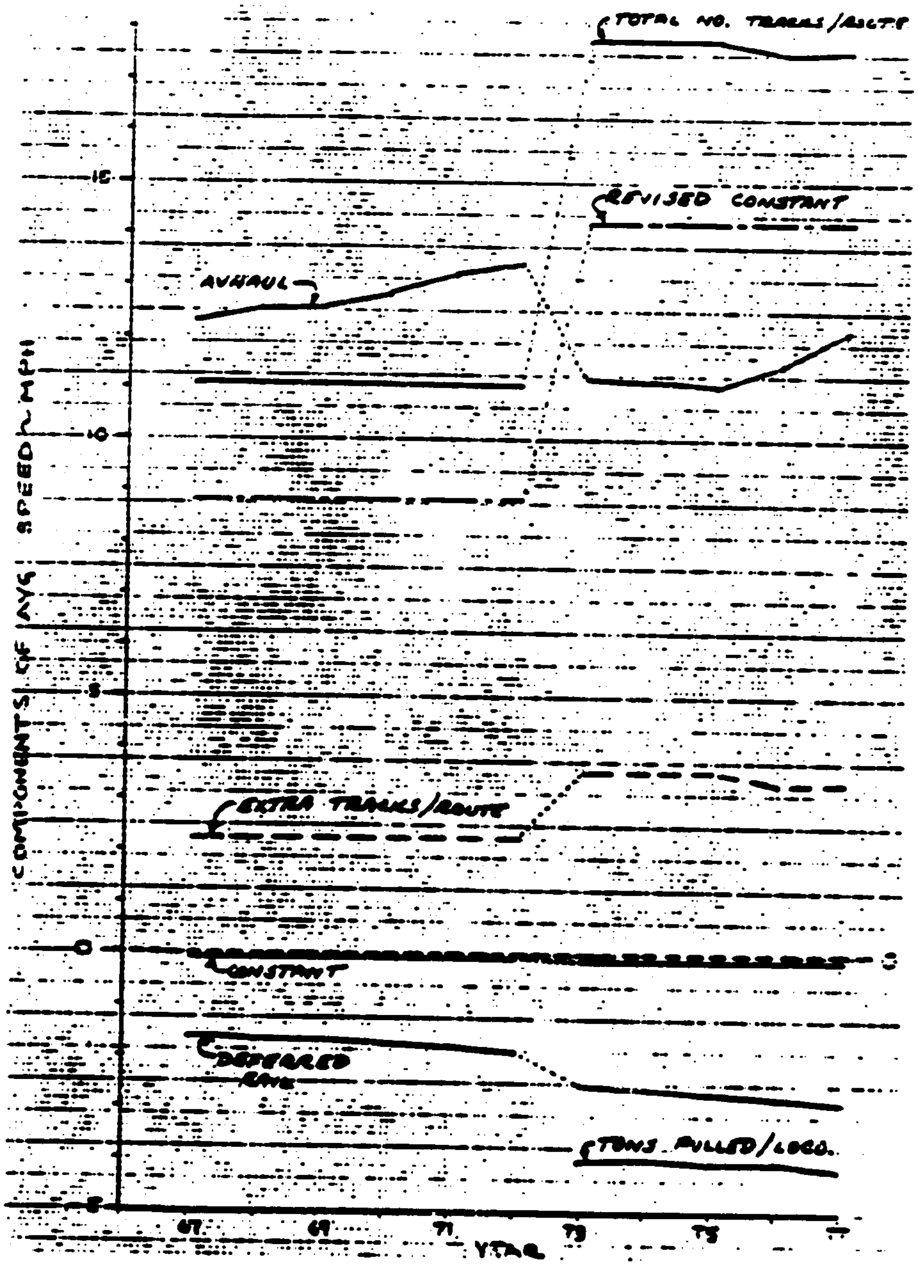

FIGURE 1-4. COMPONENTS OF AVERAGE SPEED

addition of the tons pulled/locomotive factor as a statistically significant variable in the second subperiod together with the downward shift of deferred rail offsets most of the upward shift in the revised constant. The upward shift of the extra tracks/ route component offsets a majority of the reduction in the average haul component. Taken together, the effects of all components over time indicate that average speed does not change very much, illustrating the point made earlier that the likely existance of structural change does not necessarily imply a change in the resultant predicted value of the dependent variable; however, it is evident that the relative contributions of each component are substantially different as a consequence of structural change coupled with the inclusion of another statistically significant variable.

The components of the predicted values for accident rates are presented in Figure 1-5 for running track and Figure 1-6 for combined running and switching track. In the case of running track, long-term track condition (deferred rail) is the largest positive component of the accident, in both sub-periods. However, a major fraction of the contribution of deferred rail is offset by the five year average of prior MOW spending (per mile). In the case of the total track accident rate, loaded car weights have the greatest contribution, offset in major part by the 5-year average MOW spending component; deferred rail has somewhat less importance in this equation than in the corresponding equation for running track. Finally, the pronounced shift in the influence of the intercept constant for total track accident rate is noted.

Comparable graphs for the component contributions for the equations for prediction of the number of accidents are presented in Figure 1-7 for running track and Figure 1-8 for combined running and switching (total) track. These graphs are based on the use of simple average data for the twenty five railroads in the

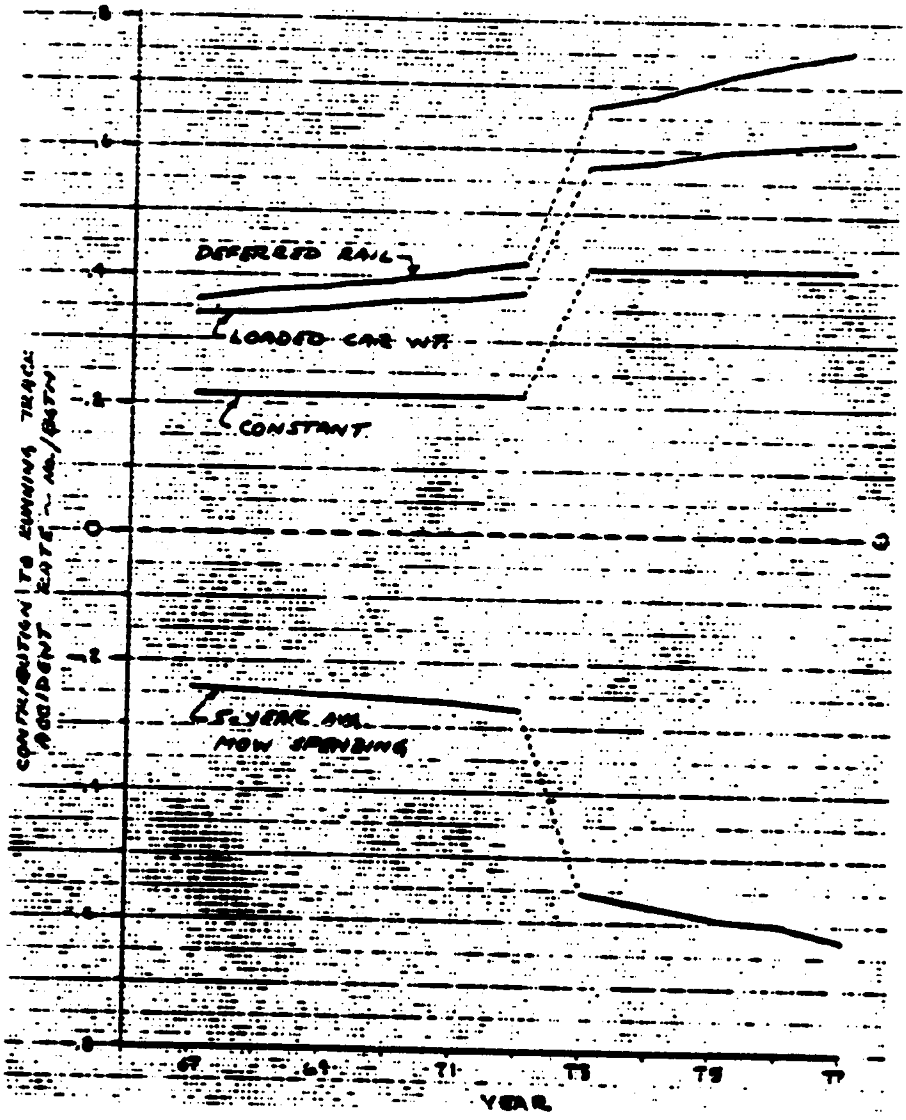

FIGURE 1-5. COMPONENTS OF RUNNING TRACK ACCIDENT RATE, 1967-77

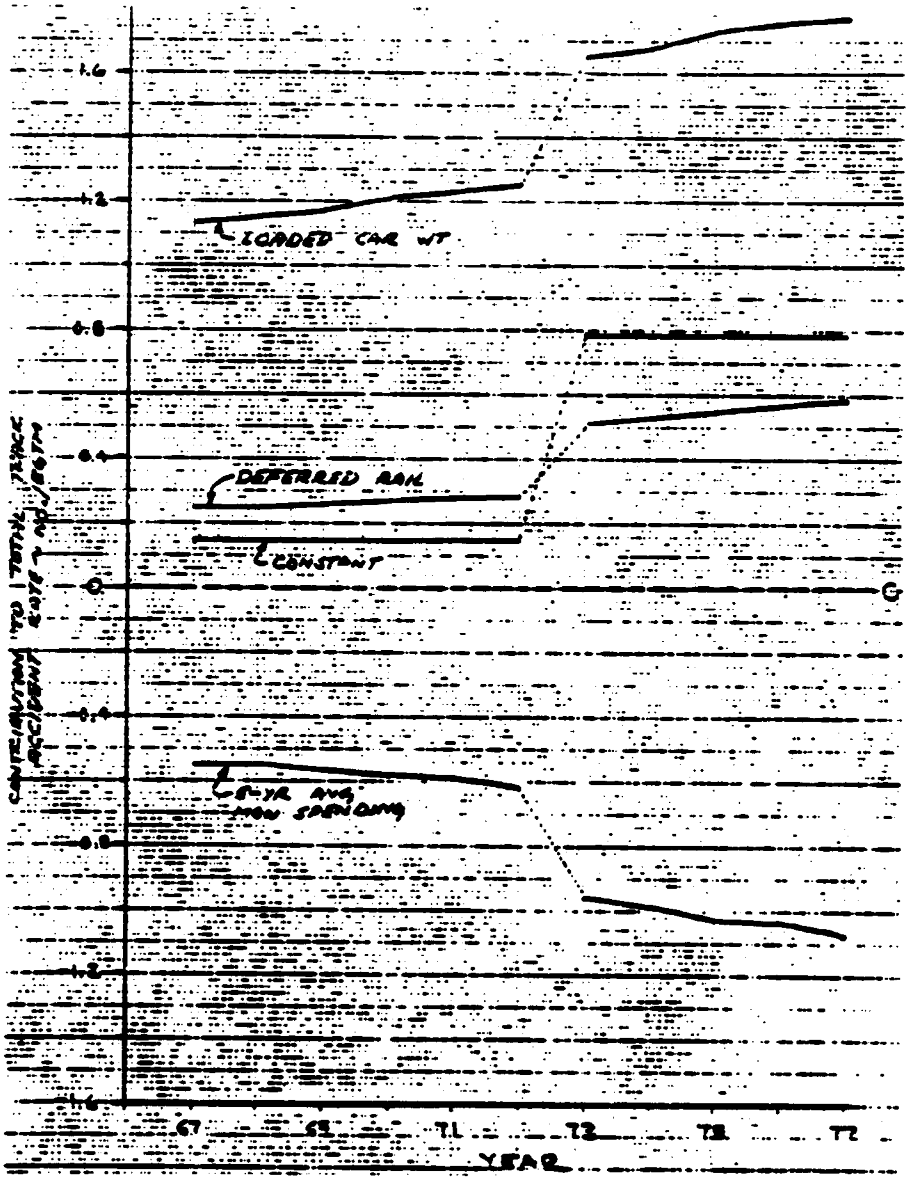

FIGURE 1-6. COMPONENTS OF COMBINED RUNNING AND SWITCHING TRACK ACCIDENT RATE, 1967-77

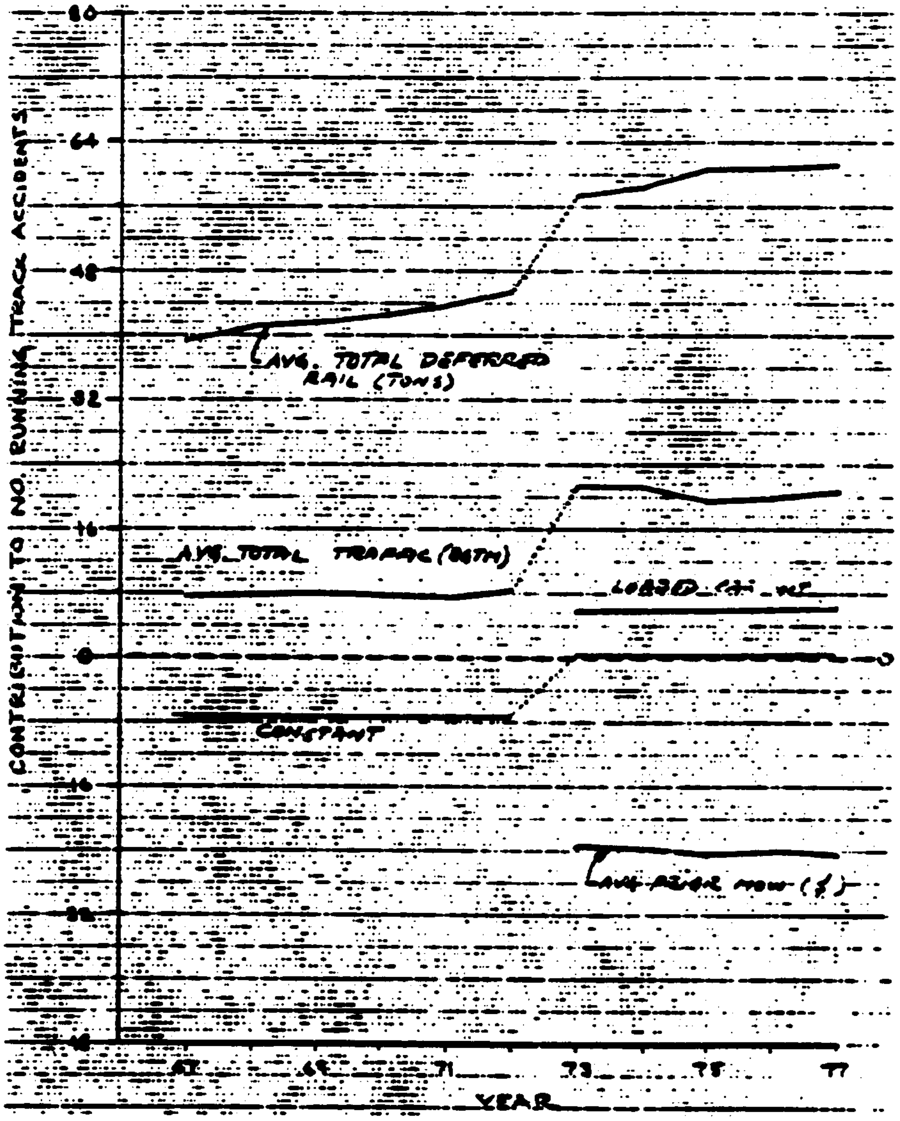

FIGURE 1-7. COMPONENTS OF NUMBER OF ACCIDENTS EQUATION FOR RUNNING TRACK, 1967-77

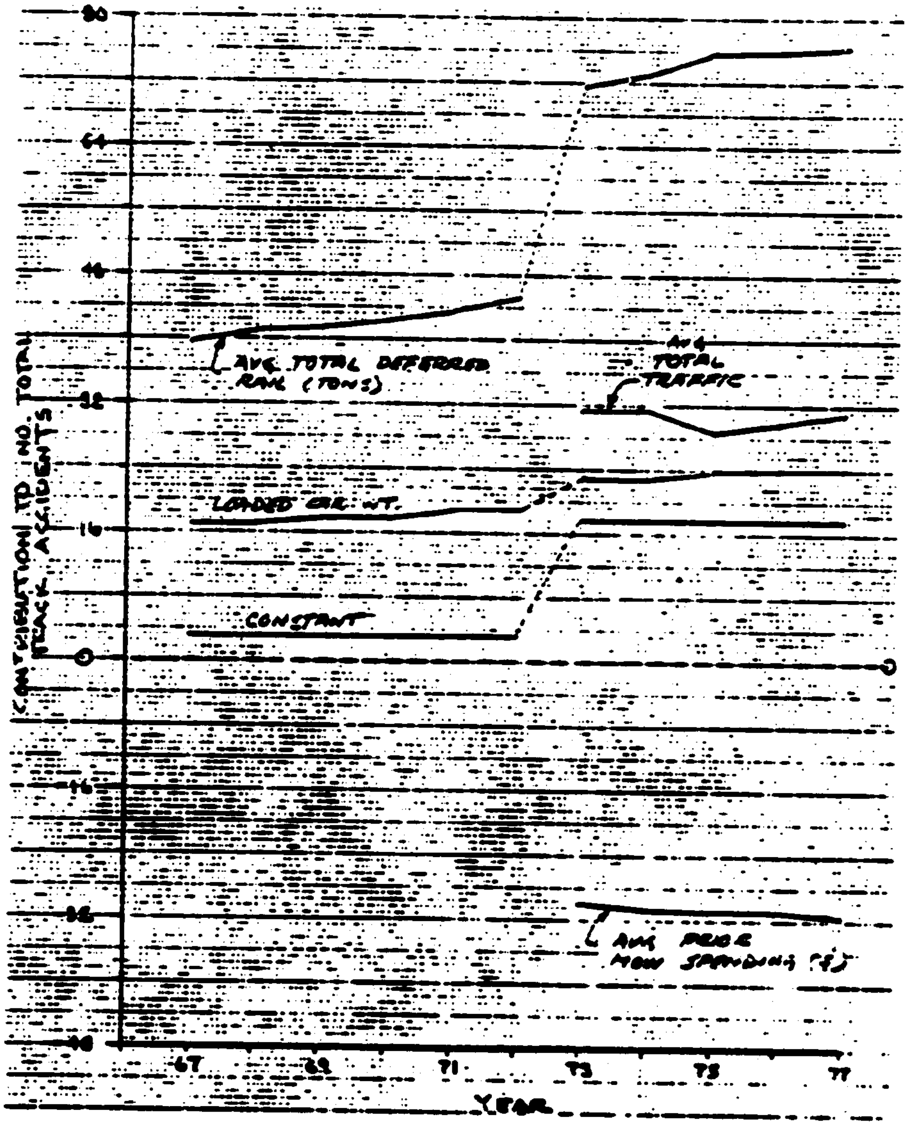

FIGURE 1-8. COMPONENTS OF NUMBER OF ACCIDENTS EQUATION FOR TOTAL TRACK, 1967-77

sample, since the total deferred rail (in tons) and prior 5-year MOW spending (in $) have already been appropriately weighted.

For running track, total deferred rail is the largest positive component of the number of accidents, with the contribution of traffic less than one-fourth that of deferred rail. Loaded car weight and average total MOW spending are significant in the second sub-period, but not the first, with the effect of MOW spending the dominant of the two.

For all track, total deferred rail is again the largest positive component in the equation. In this case, loaded car weight is significant throughout the entire period, while traffic is significant only in the second subperiod, the reverse of the situation for running track. Again, average MOW spending is significant only in the second sub-period, and offsets a major fraction of the effects of the deferred rail component.

In both equations for predicting the number of accidents, there is a substantial shift upwards in the effect of the intercept constant.

It is emphasized that the results presented in Figures 1-3 to 1-8 are based on the industry averages, presented in index form in Figures 1-1 and 1-2. The composition of the relative influence of each of the independent variables will differ for each railroad, in some cases, substantially. On a low density road, for example, the relative contributions of density and deferred rail may well be reversed in the MOW spending equation because low density roads tend to have high deferred rail values. The effects of such variations amongst railroads would be equally important for the other equations.

Finally, the effects of the intensity of federal track inspections and fines claimed upon the railroads were analyzed. Variables for fines and miles inspected per year per mile were included, together with the five explanatory variables already included, in an OLS regression for track MOW spending, for the years 1973-77. The resultant coefficients for fines and inspections were in the right direction, but not statistically significant. That is, the coefficients indicated that greater federal track inspection and fines tend to result in higher track MOW spending. Unfortunately, the number of variables and the small number of years for which data were available precluded use of the full GLS procedure to determine the true statistical significance of fines and federal track inspection.

1.7 INDUSTRY FORECAST

One of the contract requirements calls for use of the predictive model equations discussed above in the development of a forecast of industry results through the year 1990. To facilitate the consideration of a number of scenarios for the independent (exogenous) variables for the 1978-90 time frame, a computer model was developed. In addition to incorporating the predictive equations for the post-1973 period, the forecast model contained an OLS equation to estimate new rail installations based on the forecast MOW spending and four other statistically significant variables; the rail installation equation was used to update the 30 year history of deferred rail used in the calculation of all dependent variables. This approach was taken to enable the examination of the interaction of the MOW spending equation on subsequent results for speed and accidents, as well as future MOW spending itself.

Two basic scenarios were developed for the independent variables. The first postulated that the conditions extant in 1977 would continue unaltered through 1990. That is, track miles, traffic, average rail weights, average haul, tons pulled per locomotive, and the rest (with one exception) would be held constant at their 1977 values. The second scenario postulated that the basic trends evident in the data for 1967-77 (see Figures 1-1 and 1-2) would continue, with slightly increased rate of growth in traffic and a faster decrease in track miles, as might be expected in a deregulated environment. These accelerations in traffic growth and track abandonment, however, were quite modest compared with other forecasts which could be justified. For example, traffic was projected to grow only by 14 percent in total over the 1978-90 period, compared with the 1977 base year value.

Two variations were applied identically to each scenario. The first variation was the application of a continued decline of the FUNDS (gross margin) variable to evaluate the effect of a squeeze on rates; the decline was based on a continuation of the 1967-77 trend. The second variation was a reversal of the squeeze on rates, in which the FUNDS variable was allowed to increase gradually over time, commencing in 1978. These variations in FUNDS were the only change included in the 1977 Status Quo scenario, as mentioned above.

Since the twenty five railroads comprising the sample used for developing the equations contained in the model account for greater than 90 percent of the track miles, traffic, accidents and track MOW spending by all Class 1 roads in 1977, it was decided that the results provided would be representative of the industry as a whole without further adjustment.

The results of the forecast effort were quite interesting. The results produced by the 1977 Status Quo scenario were substantially different than those produced using the 1967-77 Continued Trends scenario. The incremental effects of the variations in FUNDS (rates) were much less in magnitude than the effects of the basic scenarios, as would be expected given the modest contribution of the FUNDS component of MOW spending (see Figure 1-3).

Since the results of the forecast are provided in considerable detail, including graphs over time, later in this report, only the highlights of the forecast will be provided here. Because the forecast model is recursive, with future results dependent on past performance, it is most useful to summarize by scenario rather than by dependent variable.

In the 1977 Status Quo Scenario, MOW spending per mile increases very slowly until it peaks in the late 1980's, at a level nominally about 6 percent or so above the 1977 predicted value. Since track miles are held constant, total MOW spending (in $) exhibits the identical pattern. The effect of the variation in FUNDS is quite modest, reaching a maximum difference of 4.5 percent at the end of the period. MOW spending continues to increase because of the continued increase in deferred rail, because the spending level is not sufficient to cause enough new rail to be installed to overcome the accummulated deferrals over the previous 30 years. The rate of increase is quite slight, as indicated by the very modest growth in annual MOW spending; however, the cumulative effects are important.

Average speed declines by less than 0.5 mph over the 1978-90 time frame, again due to the slight, but continuous growth in deferred rail; variation in FUNDS has negligible effect in speed. Running track accidents continue to increase, peaking in 1988 at a level about 11 percent higher than that predicted for 1977, but just slightly above the actual number occurring in that base year.

Total accidents also continue to increase slowly, also reaching a peak in the late 1980's, at a level 9 percent higher than the value predicted for 1977. For both running and total track accidents, the upward push of the increase in deferred rail is moderated by the increase in the 5-year average MOW spending, which climbs as MOW spending grows.

Due principally to the rather rapid growth in traffic density as a consequence of the simultaneous growth in traffic and decline in track miles, the results of the 1967-77 Continued Trends scenario are markedly more favorable. MOW spending per mile grows by nearly fifty percent by the end of the 1978-90 time frame. Total MOW spending also increased substantially, because the increase in spending per mile is greater than the rate of decrease in track miles. The growth in MOW spending is also driven by a significant increase in loaded car weights as well as density. The FUNDS variation also has an important effect, adding $35 million in total spending in 1990 to the $800 million which would occur if funds continued to decline. (All money values are in 1967 dollars.)

As a consequence of substantially increased MOW spending, and the concomitant reduction in deferred rail, average speed increased by about 1.5 mph or better than six percent by 1990. Part of the increase in speed can be attributed to continued growth in average haul, offset by moderate growth in the number of tons pulled per locomotive. The speed versus time curve exhibits an increasing rate of growth with time, suggesting further improvements as deferred rail continues to be eliminated (track quality improved).

The effect of the 1967-77 Continued Trends Scenario on accidents is much more dramatic than on speed or MOW spending. Accident rates for running track began to decline immediately (1978), and the number of accidents in 1981, the difference in dates due to a faster growth in traffic than decline in accident rates (per BGTM) in this four year period. In 1990, traffic rates drop by 25 percent compared with the 1978 predicted value, while the number of running track accidents decreased by 18 percent, with the difference in percentages accounted for by traffic growth over the period.

Similar, but less dramatic results obtain for total track accidents. However, these results do not appear as credible as those for running track, since the total track equations do not predict the steep slope of the actual number of accidents which occurred in the 1973-77 period.

Based on the results of the forecast scenarios, it is apparent that continuation of the overall trends evident in the 1967-77 time frame will eventually result in an increase in average operating speed and reduced accidents, depending chiefly on the rate of traffic growth to provide the source of MOW spending money and reduction in track mileage to enable those dollars to be more effectively spent. A reversal in the squeeze on gross margins would have minor, but significant impact as well. Reduction in accident rates (or number) by half, however, does not appear to be feasible within this century unless several actions are taken, singly or in combination:

- Maintain or reduce loaded car weights.
- Increase revenue rates substantially, and quickly.
- Reduce track mileage dramatically and rapidly.
- Provide substantial financial assistance for track MOW spending.
- Dramatically improve track MOW productivity.
- Dramatically improve track material durability and strength.

Perhaps except for the first, the above items would likely result in further structural change, such that the predictive model developed here would not longer apply. However, it can be used to explore promising policy alternatives in its present form.

1.8 SUMMARY AND DISCUSSION

Based on the results of prior research and interviews with a reasonable cross-section of industry executives, a set of hypotheses were generated to guide and evaluate the development of predictive equations for track MOW spending, average train operating speeds, and accidents, based on advanced statistical analyses of railroad data representing better than 90 percent of the Class I industry.

The ability to obtain reasonably accurate predictions for individual railroads and the industry as a whole was demonstrated, using equations which seem to capture the key causal factors postulated in the hypotheses. By combining the equations in a recursive fashion with a new rail installation estimator, a forecast model was developed which appears to be quite useful for a variety of policy analysis studies.

The results of the study are limited, however, by the reliance on system aggregate data. While this limitation does not appear to have substantial impact on the speed or MOW spending aspects of the model, the accident equations, particularly those for all track caused accidents, seem to border on the inadequate. A particular problem in the study was the lack of a suitable, definitive and objective measure of track quality and associated industry data. The research team was therefore obliged to try to develop surrogates for track quality, using engineering relationships developed in other prior studies, and aggregate rail and tie installation data to imply track quality based on accident results. This approach was only moderately successful and further research, including other statistical studies using the more detailed track physicals data available, would seem warranted in order to better understand the relationships between MOW spending and speed and accidents.

Due to the number of major events occurring within the seventies affecting railroads, it is difficult to be very definitive regarding the cause of the structural change noted for all of the predictive equations. The imposition of federal track standards, inspection and fines is clouded by the effects of the 3R and 4R Acts, the various ICC actions, and the merger activities of the last two decades. Furthermore, as noted above, the surrogate for track quality noted above is likely somewhat weak, particularly since it does not include the effects of loaded car weights, and consequently the indicated structural change may be simply the result of an inability to specify or measure track quality or to develop the correct form of the explanatory equation. Hence, the significance, in a non-statistical sense, of the structural change should be considered very cautiously.

SECTION 2
INDUSTRY INTERVIEWS

Task 1 was structured to provide information to formulate the hypothetical decision problems in Task 2 and to collect information necessary to formulate the behavioral hypothesis for the quantitative model in Task 4.

2.1 OVERVIEW

The initial concept for the accomplishment of the objectives called for interviews with executives from a number of selected railroads and with FRA field safety inspectors. The concept was modified to eliminate the latter interviews based on an assessment of the cost-benefit trade-off (i.e., potential information benefits which would be derived versus the cost to conduct the interviews). The interviews therefore focused on acquiring relevant information from five railroads whose selection was based on criteria developed in a previous study.

In accordance with the terms of the contract, the findings from the interviews (as presented in this report) will not identify railroads nor individuals by name. It may be noted, however, that the five railroads represent a cross-section of considerations which include size, geographical, operational and financial conditions (see Section 1).

To facilitate subsequent discussions, the railroads whose officials participated in the interviews are codified below:

Railroad A - Large northeastern road
Railroad B - Moderately sized eastern road
Railroad C - Major western road
Railroad D - Major midwestern/southern road
Railroad E - Major northwestern road

The interviews as conducted relied heavily on the railroad executives' perspectives as opposed to quantifiable data. The interview framework was structured to provide insight to (1) methodologies used by railroads in the allocation of resources for maintenance-of-way expenditures; (2) the identification of the factors taken into consideration, either explicitly or implicitly; (3) the weight these factors carry; (4) interplay among the influencing factors and (5) how and to what degree the decision-making process is influenced by federal regulations.

2.2 METHODOLOGY

The methodology employed is shown graphically in Figure 2-1. Principal activities included:

- Identification of interviewees - "The Pocket List of Railroad Officials" was used as the source document for identification of chief maintenance officials by name. These officials were our initial contact point with each railroad. Interviews were ultimately conducted with:

  Railroad A - Staff Assistant to Chief Engineer, and Director, Maintenance of Way (MOW) Rehabilitation
  Railroad B - Vice-President, Engineering
  Railroad C - Chief Engineer
  Railroad D - Chief Operations Planning Officer
  Railroad E - Director of Maintenance Planning

- Background Material Research - Background material was assembled in order to provide a comprehensive understanding of each railroad. The material included information generally available to public, such as Moody reports, trade journals, industrial publications, and selected studies. All materials were reviewed

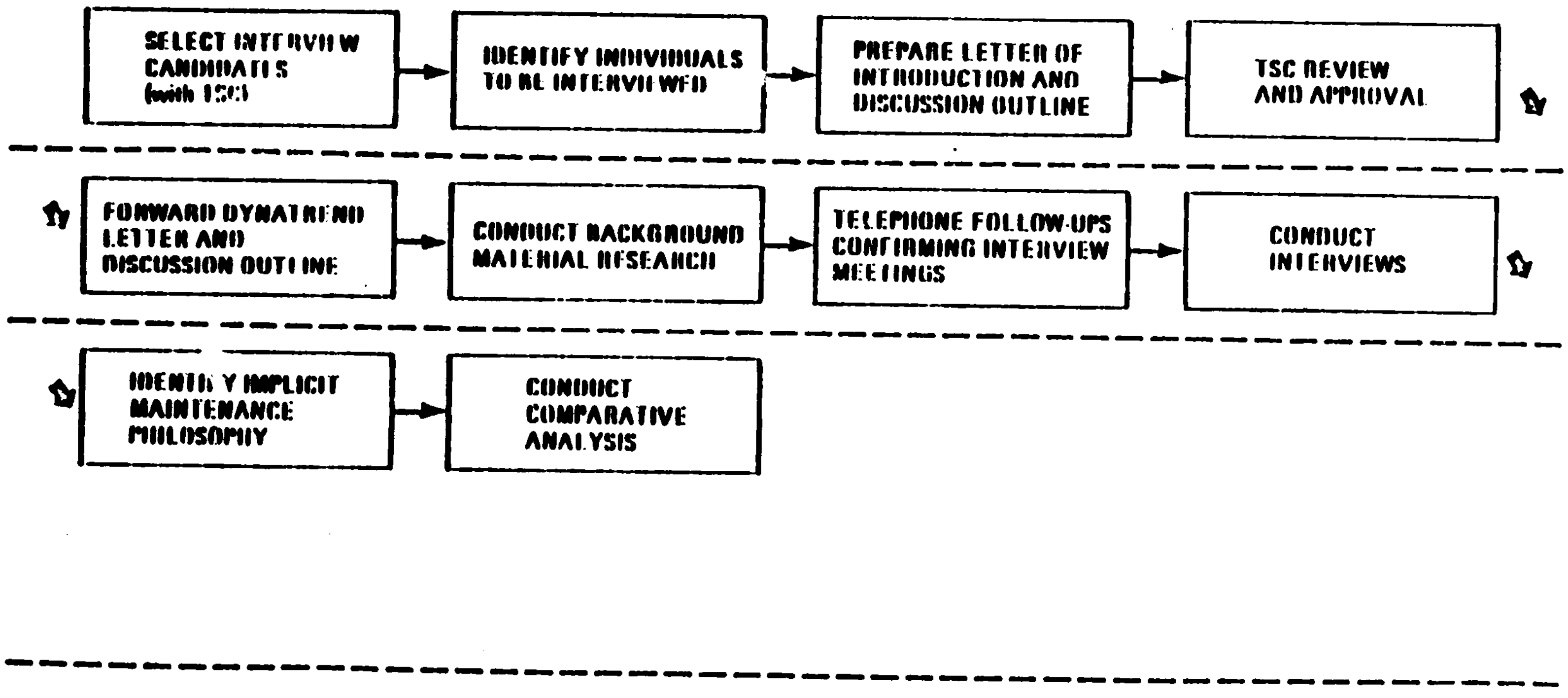

FIGURE 2-1. FLOW SEQUENCE FOR INTERVIEWS

and individual summaries prepared, with particular attention given to defined areas of interest.

- Letter of Introduction and Discussion Outline - A letter of introduction and a discussion outline were prepared for each railroad selected for interview. The intent of the letter and outline was to succinctly describe the study objectives and enumerate the general areas for discussion.

- Conduct Interviews - The interviews were conducted by a two-person team during the period August through November 1979.

The interviews were scheduled in two phases. Initial discussions were held with two railroads with the dual objective of eliciting information as required within the scope of Task 1 and to validate our interview approach. The results from these interviews allowed us to refine our approach to the discussion question areas for the second interview phase with the remaining railroads.

2.3 INTERVIEW RESULTS

The information elicited from individuals interviewed provides insight to executive/managerial philosophy regarding MOW activity as well as to the internal decision-making process. While the findings may not be particularly surprising, they are a confirmation of the attitudes within the railroad industry which must be considered in the development and later use of MOW predictive models.

This sub-section provides an overview of the individual interviews conducted with representatives of the five railroads who participated in the Task 1 Industry Interviews. All references to railroads and individuals have been eliminated in order to maintain our confidentiality understanding with the interviewees.

It is emphasized that the views expressed within this section are those of the railroad representatives interviewed and not necessarily those of Dynatrend.

2.3.1 Railroad A

Officials interviewed: (1) Staff Assistant to Chief Engineer
(2) Director, MOW Rehabilitation

General

The principal participants in the MOW budget development process (outside of Maintenance Engineering) are: Marketing, Finance, Operations, and Strategic Planning. Two prime inputs are (1) Revenue Forecasts, and (2) Operating Costs. Interactive discussions are held relative to the impact of the MOW budget. These discussions are conducted at the headquarter staff level. Divisions become involved only when it comes to the site-specific project decisions.

MOW Considerations

Speed, maintaining class standards, etc., enter into the MOW decision process at the time of project budget allocations.

Track safety inspection impacts are assessed on a site-specific basis with consideration of impact on operations. Generally, there is enough latitude within regions to handle problems such as slow orders, etc., without the problem affecting basic MOW budget decisions (i.e., handled within the non-discretionary budget allocations).

Field input budget requests include information such as:

- Speed if maintenance project is performed or not performed.
- Traffic types on the particular track segment
- Rail condition
- Derailment history
- Defect history from detection cars
- Tonnage

An ROI formula is then used to address the above with point weights (safety considerations are also assigned point weights).

Track Inspections FRA track inspections do not (appear) to have any significant impact on the overall budget process, although it can be part of the input in program/project request and selection. As previously indicated, a division can handle certain deficiencies with the local work force; however, if the magnitude of the problem can not be handled within available division resources, it will be surfaced to higher levels as a project request (described in foregoing paragraph).

Changes: There is a procedure fcr budget and program schedule changes/substitution. The approval levels for such changes relate to the dollar level involved. The process can be as quick as one week.

Slow Orders and Fines: Speed and traffic density are key factors in the MOW decision "formula" for project prioritization ranking/scoring. Fines appear to have negligible (if any) impact and are probably not considered in the prioritization process.

Non-discretionary Maintenance: A "zero-based" budgeting scheme was developed for the planning of how many people per track mile would be required for non-discretionary maintenance. The procedure (which was never implemented) involved the identification of over 100 work elements. They were then discussed with track supervisors for the determination of which elements were required for respective track sections. The elements were then computed against work unit costs. The "traditional" (historical data with inflation factors) methods are currently employed.

MOW Budget Development - Original Approach

In earlier years, Railroad A used the level of production capability as the primary tool in sizing the total MOW budget. Production capability was developed from the production history of the railroad in each of the subsystem areas; for example, the number of miles of CWR installed, the number of ties that could be replaced, or the number of miles of surfacing that could be accomplished in a year (based on the labor force, equipment, and material available) all went together to determine MOW production capability. In turn, the MOW budget was developed by the application of the respective unit costs. This was the primary input in developing the MOW "program," which represented the discretionary rehabilitation work. Other factors included unit costs times the number of turnouts and roadcrossings which were required in the work to be done in a given year. The total budget required by the MOW department was increased by modifications to the work unit production capabilities. This was done by improving efficiences in each of the work areas; therefore, if it was felt that they could lay more CWR than in prior years due to improvements in effectiveness in both equipment and the work force, the MOW budget would likely go up in that area as more could be accomplished for the same commitment of dollars. In this way, the total MOW budget was really developed by what could be done by the work force with the given equipment.

MOW Budget Development - Current Approach

Railroad A's discretionary maintenance (rehabilitation) program is considerably above their normalized maintenance level. It is felt that it will bring them to a point (in several years) where they can move to a normalized maintenance activity and still maintain the railroad in "proper condition" to conduct their business. They now feel that rather than maintenance capability driving budget development, the railroad's business planning and its revenue forecasts drive the development of the MOW budget. Anticipated traffic levels and revenues and their decreasing ability to borrow money are now primary determinants in the MOW budget process. For example, they feel that currently they are on a temporarily reduced rehabilitation program dictated by decreased anticipated revenues. However, during this period of reduced discretionary maintenance, they plan to maintain a substantial surfacing program while they insert fewer ties and install less rail in order that the surfacing work will allow them to retain the benefits of work already done.

Moving into this era where the total MOW budget is developed based on anticipated revenue levels and business considerations, the total budget made available to MOW comes from Chairman of the Board. It is developed at a gross level through inputs to the Board from the Vice President of Finance and officers in Operating, Marketing, and Strategic Planning who are reviewing traffic forecasts, anticipated revenues, costs of operating other departments, and other business and economic parameters. The Chief Engineering Officer and Chief Engineer's input to this process entails work assessments (what can be accomplished) for several different budget levels. This is an iterative process which takes place between the Engineering Department and the

Executive Department. (The Executive Department similarly has inputs from all other groups within the railroad.) This iterative process then produces a total MOW budget made available to the Engineering Department. It is then allocated to selected projects across the railroad.

MOW Budget Allocation

The allocation of the MOW budget is performed through an annual rehabilitation program plan. This program is developed in a traditional manner and produces a firm MOW plan for the upcoming year. It is done traditionally in that field information from Division Engineers and Regional Engineers is passed to the Chief Engineer's office. This allows ranking of all work recommended from the field so that the Engineering Department management can select what will be done (and what will not be done) based on a prioritization of projects.

The prioritization is developed through a point ranking system where points are awarded to each recommended project for a number of different characteristics. The information necessary to award points to each project comes to the Chief Engineer in the form of field input forms. Generally, this information includes what the railroad will receive in benefits if a given project is undertaken, whether it be surfacing, tie replacement, bridge work, or rail renewal. Specific considerations used in scoring points for a project include the history of the railroad in the site specific area, (e.g., defects and derailments); the hazardous material and total traffic over the segment; the current speeds over the segment; the anticipated speeds after the proposed work is done; and candidates for other work in the area. (This latter characteristic is important to their budget allocation process as the railroad is interested in asset protection. Example: if work is recommended in a given area, such as replacement of stick rail with CWR, it is important that the condition of the ties be determined. That is, tie replacement at the same time would provide "asset protection" in that deteriorated ties will cause the newly installed CWR to wear faster than it would were serviceable ties present.)

Additional considerations which are developed in determining the point scoring of a project are: projected car per diem savings, crew savings, changes in revenue, and strategic planning inputs on the future of a branchline or mainline (is the track to be abandoned, is it redundant, should it be downgraded; should it be upgraded?)

All inputs go toward assigning ranking points which are the most important general indicator of the necessity of undertaking a project. All projects are scored as above and are displayed with their total score and the cost of doing the work. A threshold is then located which includes all work which can be done for the total discretionary MOW budget, starting with the most important project and working downward.

The railroad has an individual in each region called the Regional Superintendent of Operations Improvement (RSOI). This individual, who is a member of the operating department, is a specialist in developing "non-MOW" inputs to the ranking process and would be responsible for reporting on the future of the line, the anticipated changes in revenue, crew costs, per diem costs, etc. Also, there is a regional budget manager within each region who also inputs to the decision process.

Other Considerations

There are other factors which are not easily quantifiable and are established by the technical relationships between the recommended projects in a region. If the prioritization process shows that there are a number of projects in a given region that are of extreme importance, it must be understood that they cannot be undertaken at the same time or the heavy track access requirements would shutdown the railroad; therefore managerial judgement must be applied. Other factors are: the necessity to maintain the core route and routes involving contractual agreements with (e.g., commuter service and Amtrak) and contracted services for state-reimbursement programs; the requirement to move hazardous materials over the core routes and to maintain the railroad to a level sufficient for safe movement of same; future plans which require the downgrading of a route in order to move traffic over to a main stem which is considered to have better potential in the long run; projected return on investment for work planned on a given segment; and "political pressure." (While ranking points are not awarded for the latter, political activity can cause a project to be undertaken sooner than it might otherwise have been.)

Safety/Regulatory Considerations

Safety considerations are taken into account, but only as required to maintain what is desired overall -- there is little explicit consideration of safety implications (in the regulatory sense) in the MOW resource allocation process. However, on the site specific level, safety is taken into account as it might cause a project to be recommended for inclusion in the annual rehabilitation program plan; for example, in order to maintain track class (and thereby a desirable track speed), branchline tie replacement may well be required. This would cause the person in the field (division engineer or track supervisor) to recommend, via a field input form, that a project be accomplished during the given year. In this way, safety regulations do have impact in the field in determining what projects are recommended, but only to the extent that requirements must be met which could affect revenue-making and general railroad operation.

Federally-imposed fines for safety defects in the track structure do not enter into the program development process. They serve only as a source of pressure at the local or site specific level where the track supervisor or division engineer might be encouraged to submit projects for inclusion in the program plan. Federal penalties apparently do not have any more impact than the local individuals' desire to maintain track speeds on a segment of railroad in order to get the trains over the railroad and therefore produce maximum revenues.

Program Plan

The Program Plan is considered to be fixed after it is initially developed and they attempt to adhere to it through the maintenance year. However, there are change procedures which allow the substitution of one project for another. It is necessary in the change process to match the dollars and units of work with those of the project to be replaced. It also requires extremely high level approvals to make a change: the Vice President of Operations and the President must approve changes up to a certain level, beyond which it requires the Chairman of the Board's approval. Despite the high level of approvals required, it was stated that a change can be made processed in one week from the time it is initially submitted until approvals are received.

Project Performance

The central maintenance of way group carefully monitors production on a daily basis in all areas of track maintenance and is aware of the status of each project in the Program Plan in terms of the production scheduled versus production completed to date, dollars expended versus dollars budgeted, material planned versus material consumed, and labor planned versus labor expended.

2.3.2 Railroad "B"

Official Interviewed: Vice-President, Engineering

General

The feelings expressed relative to federal involvement with MOW issues included:

- "The federal government ignores the revenue issue (relative to RR operations); if RR's were allowed to run their business in a free enterprise environment, the track problem would go away..."
- Federal track safety inspections do not impact MOW decisions.
- "Inspectors do not spend much time on main lines, rather, they concentrate on branch lines and 'aggravate'...issue citations/fines which cause expenditures on track which the RR's do not even wish to keep in operation."
- "Slow orders are not a significant factor in MOW operations..."
- "That some of the actions which might be taken through performance standards could be disastrous; for example, if track ultrasonic inspections were tightened and applied to branch lines, with a given level of fines, the results would place RR's in an untenable financial position."

MOW Budget Development

The MOW budget is developed in the Engineering Department and consists of a basic budget plus a prioritized project listing. The basic budget represents resources for the nondiscretionary work which will be done during the year; the prioritized project listing is the program (discretionary) work. (The total MOW budget is usually developed independently in the Engineering Department to a figure which approximates the final MOW budget approved by the Executive Department.) Engineering is continually aware of the corporate and marketing strategy with respect to individual lines.

It was stated that fines imposed by the Federal track inspectors are not "effective" nor do they impact the budget development process, but that any fine does raise a "flag" for the legal department, the Board, and of course, for the Engineering Department. Fines are currently considered insignificant in comparison to the order of magnitude of repair costs which would be required to correct the conditions identified by Federal track inspectors.

In the budgeting process, the Chief Engineer MOW receives written plans from the roadmasters. They submit material, manpower and equipment requirements for projects in each of their districts. Engineering allocates the budget among the bridge and building, signal, and track departments together with the projects selected (by Engineering) from the prioritized listing.

The project selection (accomplished by Engineering from among the projects submitted by the roadmasters) is made in two areas of operations: mainlines and branchlines. The mainlines, which are the core of the system, do not require marketing, operating, or traffic department inputs as the future of these lines is well known to the Engineering Department. In the case of the branchlines, however, there are three classifications and the allocation of MOW resources is made based on the projected future of each type of line. The first type of branchline is considered the "loser", where no marketing input is required to the Engineering Department decision-makers as the line has no potential for increased revenue and would be abandoned as soon as possible. Another type of branchline is the "winner" which requires careful consultation with operating personnel as to the required running time, the timing of maintenance work, the benefits/ detriments of incremental investments versus a onetime investment, etc. The third type of branchline is the one with the uncertain future which also requires careful consideration and input from the Traffic, Marketing and Operating Departments.

2.3.3 Railroad "C"

Official Interviewed: Chief Engineer

General

Discussion with this official provided the same basic philosophy found to be a common among all senior railroad officials interviewed, namely, that "Federal track safety standards and track inspection are irrelevant to MOW activity. The railroad is in business to make money and to that end MOW supports operations. Internal pressures for effective MOW are much more severe than Federal requirements."

The interviewee felt that the work of the Department of Transportation (DOT) on the development of performance standards is constructive (although he expressed reservations about how one measures compliance with the standards once developed). He also expressed satisfaction relative to the FAST program and indicated that their personnel do draw on the technological information available through FAST.

MOW Considerations

The two key concerns expressed relative to MOW project activity were:

- Speed, and related
- Tonnage.

Influencing characteristics such as climate, soil conditions, etc., are considered in conjunction with the above.

Speed is not considered a MOW factor subject to trade off with other factors on main line activity since they maintain their mainlines to established speeds to support operations.

Slow orders on main lines would receive immediate attention in order to maintain their established maximum speeds; it was emphasized that slow orders would not be tolerated by operations (to whom the Chief Engineer is organizationally responsible). The action to eliminate/avoid such conditions is in response to operational objectives (which include safety), therefore, effective maintenance is inherent in the operations/MOW business objectives. Federal track safety standards and track safety inspectors are superfluous insofar as MOW is concerned.

This official did not indicate any particular concern with branch line operations other than the need to meet shipper requirements (which apparently includes speed; however, to a much lesser degree than on main lines).

Speed does become a factor in situations such as a desire to eliminate a 2-crew requirement on a particular run.

MOW Budget Development

It was indicated that formal analytical techniques are not used in the budget development process. There is a "bottom-up" input process (annual) from the Division level relative to track project planning. Inputs are submitted using a project form. The assessments are conducted at headquarters with representatives from key areas (i.e., Operations, Finance, Engineering, Marketing). Additional information required relative to project inputs is acquired through dialogue with appropriate Division representatives.

Tie project planning is based on tie-gang inspection reports.

2.3.4 Railroad "D"

Official Interviewed: Chief Operations Planning Officer

General

The Chief Operations Planning Officer (interviewee) is organizationally responsible to the Senior Vice-President, Operations. He opened the discussion with a statement of several MOW "givens" which dictate both specific longer-term planning activities and day-to-day MOW operations:

- "deferred maintenance on this railroad is horrendous;
- the primary MOW goal is to maintain the 'main trunk' or 'backbone' corridor (40% of the traffic is generated along this corridor); and,
- the remainder of the MOW spending goes where it can be justified economically and branch lines get what is left, if anything."

MOW work consists of both program work and non-discretionary work. The railroad is a recipient of Federal assistance and employs this funding in improving the condition of the North-South main line.

It was indicated that Federal Track Standards are irrelevant to MOW considerations. Insofar as the federal track inspection program is concerned, the comment was that it (the program) deals with the symptom, not the problem. It is felt that the track inspectors concentrate on branch lines, and by doing so, they are draining management and financial resources from more economically viable areas. The revenue is in the trunk lines and that is where maintenance must be concentrated. Given limited resources, the branch lines must necessarily suffer.

It was acknowledged that <u>fines</u> do cause corrective action, but in essence they divert funds from areas where the railroad would realize a better pay-off.

The Vice President-Chief Engineer is integrally involved in the allocation of MOW resources, even down to the project-by-project selection process. It was stated that the Vice President-Chief Engineer receives inputs both from the field and from other departments (operating, marketing, etc.) in order that he can assign priorities to the projects being considered: "He knows what projects are most needed."

<u>MOW Considerations</u>

The "system" which is evidently used to allocate resources to the MOW Department (among others) and, later within the MOW organization, proceeds as follows:

- There is continuing informal communication between those who monitor/predict tonnage movements, develop revenue forecasts, and project node-to-node movements.
- These activities ("monitor/predict tonnage...etc.") are used to determine total forecast revenues so that departmental allocations can be made; but within the MOW Department, little additional use is made of information from these activities.
- MOW Department does make subjective use of forecasts: if grain movements are going to increase, "they know what to do because they know where their grain movements occur."

In evaluating a specific segment of track for the purpose of estimating work required, a number of technical variables are assessed:

Primary Variables:

- current and projected axle loadings
- current and projected annual tonnage

Key Variables:

- tie condition to distribute load (regardless of speed)
- surface (to handle load)
- ballast condition (to handle load)

The interviewee's opinion is that the track structure's ability to handle anticipated tonnage (both in terms of axle loadings and annual tonnage) is of primary importance, as track which is maintained to safely carry planned-for tonnages can safely carry trains at any reasonable speed. Example: A specific line handles unit coal trains. As unit coal trains don't run over 40 mph anywhere on their system, maintaining to FRA Track Standards is irrelevant "because if the track structure can handle the tonnage, then it can handle the speeds."

MOW Decision Problem Considerations

The following example of a MOW decision scenario was provided:

- A specific line runs thru freight traffic daily; it is slow-ordered due to surface and tie conditions.
- Marketing has presented an opportunity to haul coal on the line.
- The required MOW actions to support the coal haul activity will not consider speed nor Federal Track Safety Standards. The standards might in fact allow a lesser condition than is felt to be required for the tonnage to be handled; e.g., the track class could allow 67% "bad" ties ... that would not be acceptable from the railroad's engineering view.
- Required MOW action will focus on the anticipated tonnage and car weights and will assess:
    - Ties
    - Ballast
    - Surfacing
    - Rail (will review the defect records and bolt holes as part of the assessment)

Other

- MOW cost items are available in detail through a computerized data base.

- The railroad has a predictive model for revenue forecasting. Forecasts are by commodity; they do not identify specific lines over which the commodities are transported; however, associated operational and maintenance requirements would be implicit. That is, it is known which point to point lines carry what commodities and therefore volume change forecasts provide appropriate planning information.

The prime use of the revenue model is to forecast/anticipate dollars available, and thus (would appear) support the overall budgeting process.

2.3.5 Railroad "E"

Official Interviewed: Director of Maintenance Planning

General

This individual's function may be viewed as a "bridge" between the engineering and financial considerations in the MOW budget development process. His organization consists of two staff people (with four authorized). Analysis activities are not computerized.

It was noted during the discussion that even within the railroad there is sometimes a lack of complete understanding between the Engineering and Financial functions; e.g., a particular maintenance funding requirement such as for rail might be questioned as to necessity (by Finance). This necessitates a more analytical approach to justify specific expenditures; as in the case of rail, justification involves a presentation/analysis based on life-cycle cost. The latter, life-cycle cost (LCC), appears to be a foundation for the analysis conducted by the planning group in support of MOW activities.

MOW Budget Development

The MOW budget is, generally speaking, a given amount to Engineering. It is based on available funds after Marketing, Finance, and Operations have established their requirements. This is not to say that Engineering does not develop an independent estimated budget, for they do perform an assessment of maintenance which must be accomplished and that which they would "like" to perform. However, the prime governing factor is that they must respond to the market/operations requirements. They must support the operating requirements established with the commensurate level of maintenance needed for such elements as speed and load capacities on given lines, etc. Within this environment, operational priorities take precedence over Engineering project prioritization.

Budget development follows a process which involves Marketing, Operations, Finance, and Engineering.

Finance	Marketing	Operations	Engineering
Integrate overall financing considerations	Provide revenue forecasts, sources, shipper requirements, etc.	Establish operating requirements	Maintenance requirements to support Operations and other maintenance projects

Marketing provides revenue forecasts, sources of revenue (shippers), and any special shipper requirements. This information is provided to both Finance and Operations. Finance integrates additional information such as debt obligations and all other pertinent financial data elements. Operations assess their requirements to support the anticipated shipping volumes, etc., and defines both their operations budget requirements and the levels of maintenance required to support operations. Engineering is provided a budget from Finance based on the Marketing and Operations inputs. This budget is used, together with physical work requirements, to establish project budgets.

The MOW budget development process is an iterative one with considerable interaction among the participants. Engineering performs an analysis of projects (with emphasis on life cycle costs where appropriate) in order to justify their budget requests to Finance.

Additional MOW budgetary requirements evolve from inputs prepared at the Division level. Semi-annually, track is inspected by Engineering and Operations. Identified maintenance is then documented using the Maintenance Priorities form. The forms are color-coded to indicate the level of priority. This form is then forwarded to Operations (at Division level). A companion form, Operating Impact Statement also is prepared. Both forms are then forwarded for approval and become an input element for the MOW budget. These forms are also used on an "as-required" basis. Also, the procedure may be initiated through the Operating Impact Statement, with the Maintenance Proirities then being prepared to reflect the required maintenance effort required to support the operations request.

Questioned as to key elements which should be considered in the MOW resource allocation process, the following were suggested:

- The gross tonnage expected and how much is to be carried in 100 ton (or over) cars. The rationale is that:
    - rail life cycle is impacted; for the same gross tonnage, carried totally in 100 ton cars as opposed to lighter loads, the rail life cycle is 1/2.
    - tie wear is also affected, although not as dramatically.
- Weight of rail
- Ties and spacing
- Quality of ballast (clean, etc.) affecting performance
- CWR or jointed rail
- Considerations such as curves, grades, alignments; what defects requiring action are anticipated from ultrasonic testing (i.e., forecast for testing); and, track geometry car data.

Also discussed was a manual system project prioritization technique which was used by this railroad in 1975 only. The lessened activity during the 1975 recession period allowed the technique to be used. Increased volume precludes its use. Specifically, two indexes were applied:

(1) dollars per minutes of running time
(2) dollars per million gross ton miles (GTM)

The interviewee believed that these indexes are key to project economic return assessment and therefore extremely useful for MOW project prioritization.

Slow Orders

This railroad has a computer program which is used to analyze the impact of slow orders (miles per minute); a "slow order minutes" report is provided to management to assist in the determination of slow order impacts.

Track Inspectors

The attitude expressed toward the Federal track inspection program was basically non-committal. It would appear that whatever deviations and/or violations are cited, are addressed at the working (Division) level. It is possible, however, that a major project, such as a tie replacement project, could surface as a result of track inspections.

Other

Traffic density information is computerized; track defects data is still handled manually.

SECTION 3
PREDICTIVE MODEL DEVELOPMENT

The principal purpose of this research contract was the development of a model which can be used to predict maintenance of way (MOW) spending and its interaction with average speeds and accidents, for individual or groups of railroads, including the industry as a whole. A secondary purpose was to investigate whether the imposition of federal track safety standards or other federal actions resulted in discernible change in the relative influence of the factors affecting the principal items of interest, namely, speed, track MOW spending and accidents.

This section provides a summary discussion of: (1) the hypotheses developed as a consequence of the interview efforts described in the previous section and other prior research (Task 2); (2) the data base (Task 3) employed in the development of the predictive equations; and, (3) the statistical analysis methodology and explicit results achieved, together with a discussion of their utility.

3.1 BACKGROUND

Over the period examined in this study, the number of track related accidents has been rising rapidly.[1] During the 11 years covered in the study (1967-1977), track-related train accidents on running track increased by 98 percent, for the 25 large railroads included in this study, after adjustment for inflation and threshold changes. This result is comparable to the increase in track related train accidents reported by Shulman and Taylor[2], for the 1967-74 period. In their report, Shulman and Taylor also reported that there was no change in miscellaneously-caused accidents and approximately a 15-percent decrease in both equipment and human factor-caused accidents. Over this time span (1967-74), track-caused accidents as a percentage of total train accidents nearly doubled, increasing from 21.0 percent of the total in 1966 to 39.9 percent of the total in 1974. Thus, track-related train accidents are of major concern and provide the focal point of our study.

For the 25 major Class I roads analyzed in this study, Figure 3-1 shows the trend in track related train accidents over the period 1967 to 1977. These accident data have been adjusted for inflation, accident reporting threshold changes and normalized for traffic (gross ton miles). These accidents resulted in at least $2300 per accident (1977 dollars) damage to track and equipment. They impose a private cost on railroads and shippers as wreck clearing costs increase, railroad property is damaged, cargo is damaged or lost, and service deteriorates. Accidents on running track may cause re-routing of other trains leading to slower deliveries and reduced service, while accidents in yards cause congestion which may slow down train departures. This reduction in service will induce shippers to seek the services of other railroads or other modes of transportation. Additionally, there are further social costs if the railroad involved in an accident is carrying hazardous materials and the accident results in death or sickness to those in the vicinity, or if massive evacuation is necessary.

Over the same period, the funds that railroads have had available to spend on maintenance-of-way activities has been squeezed. Railroad operating costs, exclusive of maintenance-of-way spending, have been increasing faster than operating revenues. This reduction in available funds over time is seen in Figure 3-2.

The rate of return on net transportation property has been declining over the period 1967 to 1977. Railroads have responded to the decline in rate of return by reducing their plant size and by slowing down the replacement rate of worn out track materials. The first response is seen in Figure 3-3, which shows the decline in running track miles operated from 1967 to 1977. The second response has led to a diminished track quality, resulting in

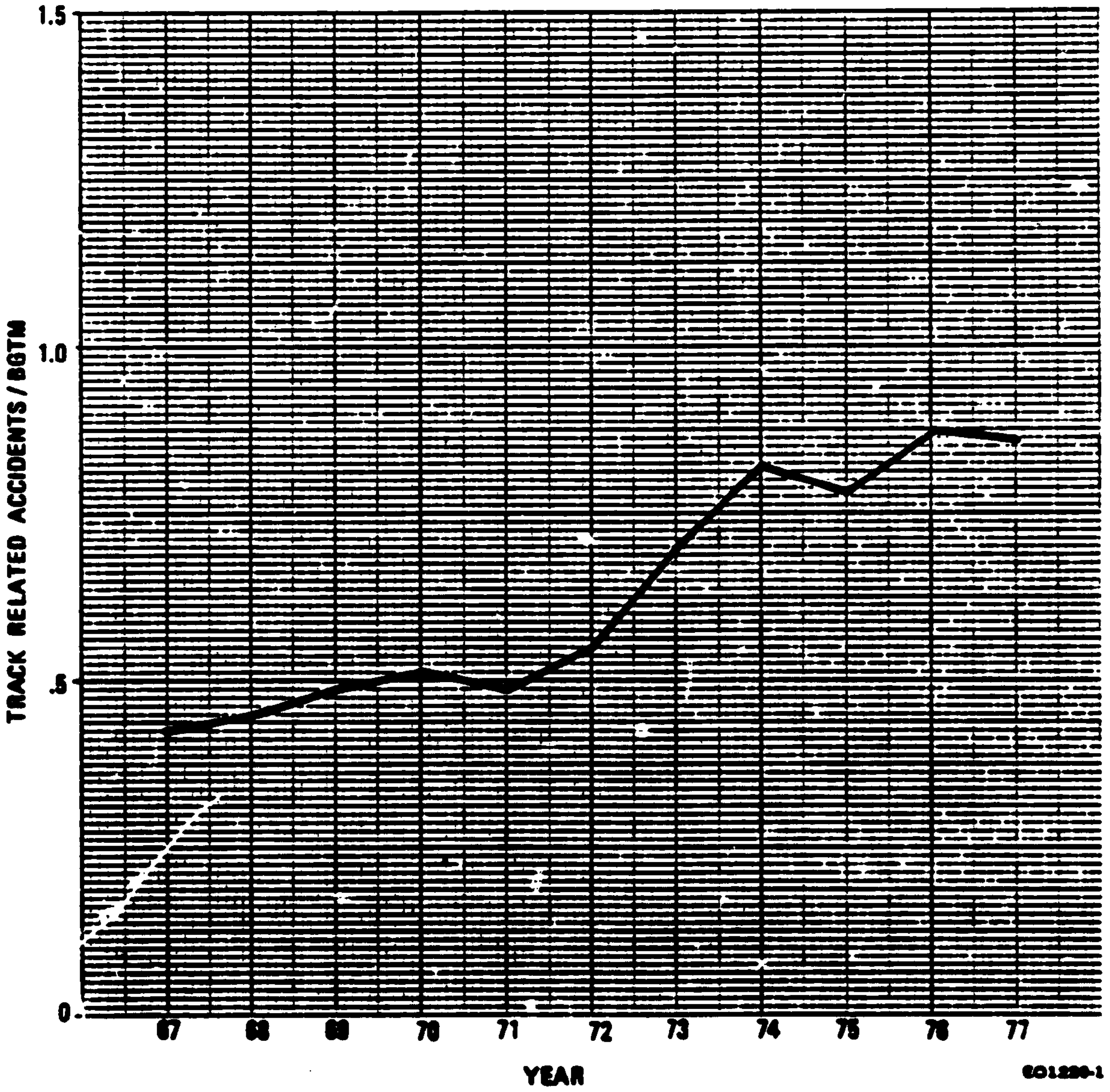

FIGURE 3-1. ACCIDENTS ON RUNNING TRACK, PER BILLION GTM, 25 LARGE RR'S, 1967-1977

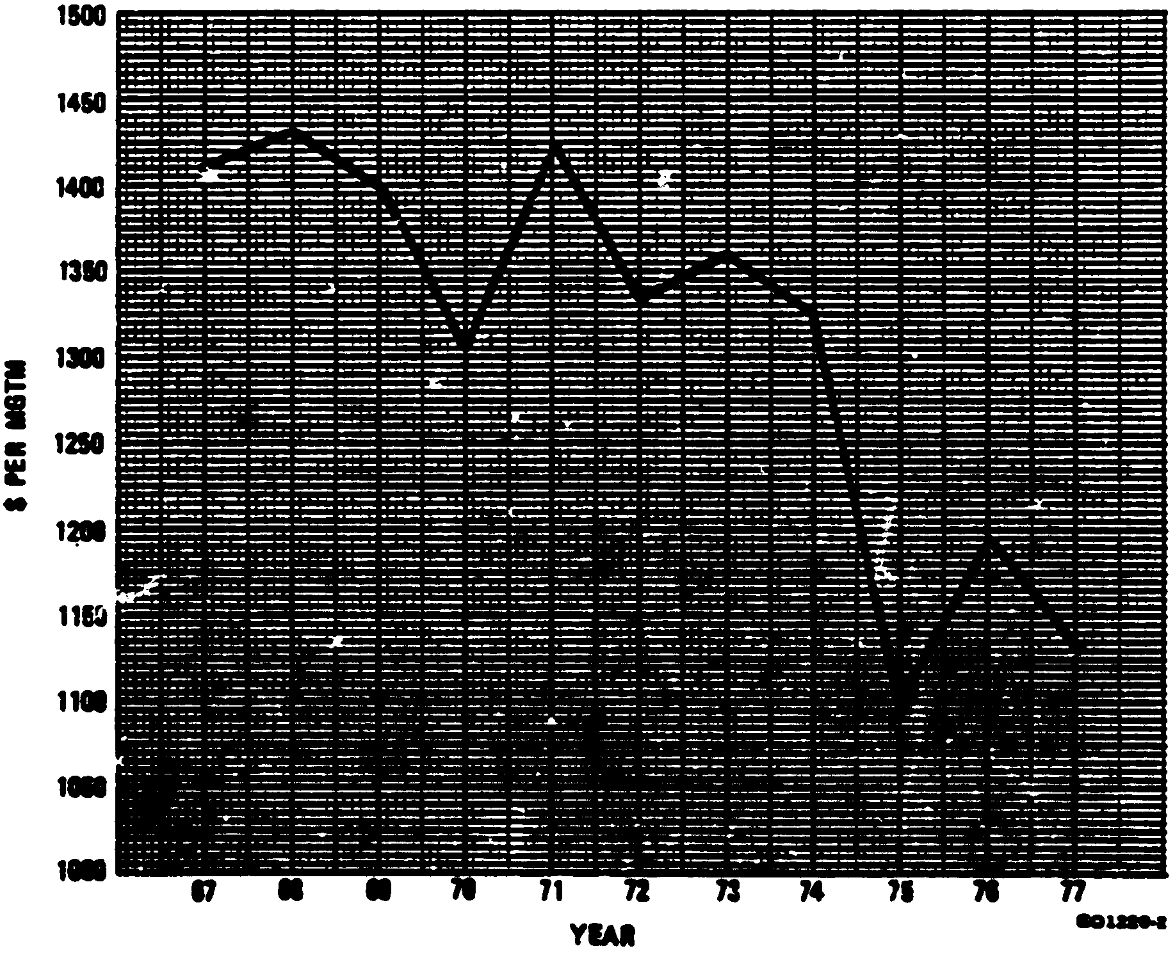

FIGURE 3-2. MARGINAL REVENUE BEFORE MOW, PER MGTM, 25 LARGE RR'S, 1967-1977

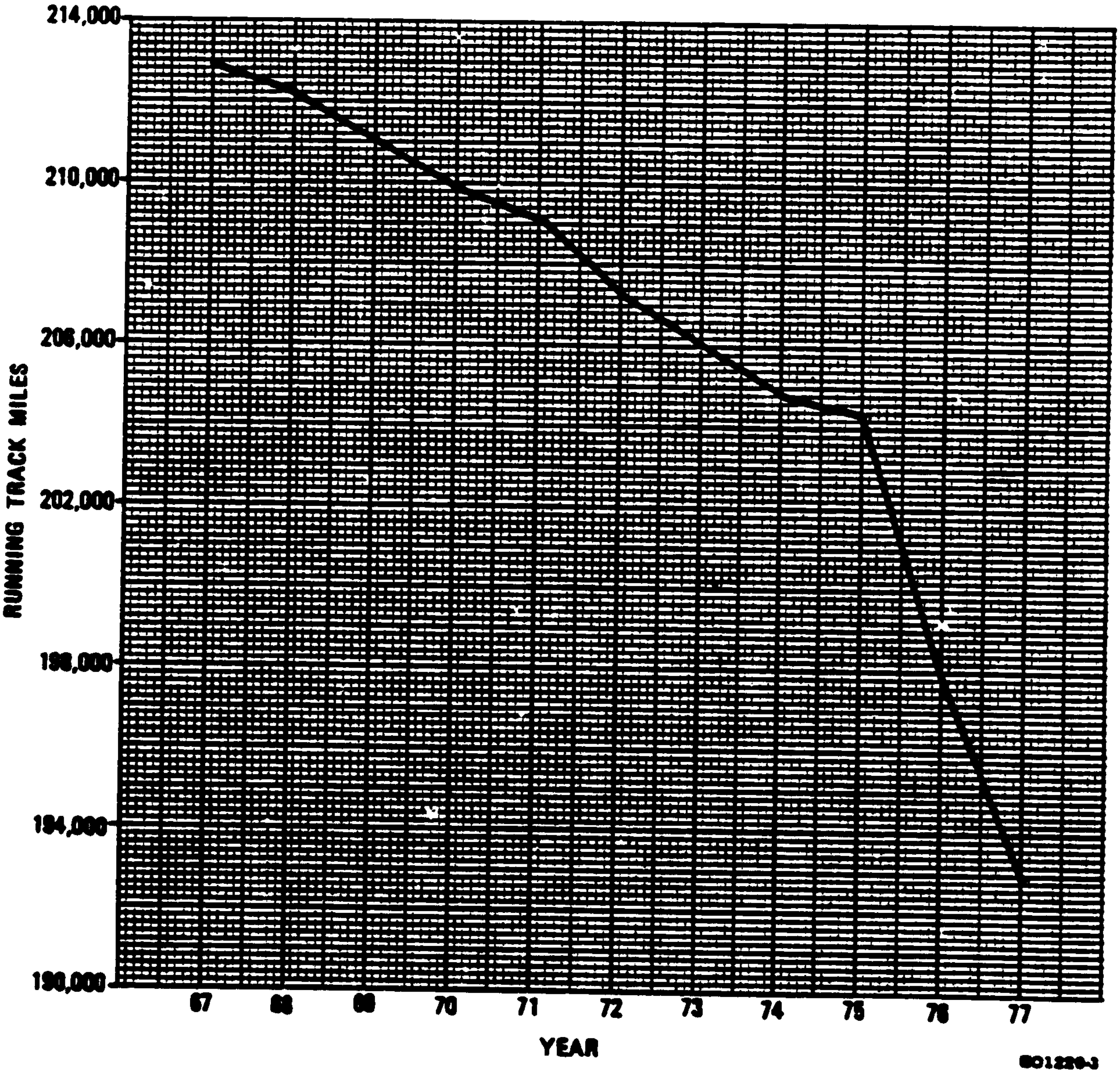

FIGURE 3-3. RUNNING TRACK MILES OPERATED BY 25 LARGE RR'S, 1967-1977

increased track-related accidents and eventually in the establishment of federal track safety standards. The decline in track quality is shown in Figure 3-4, by the trend in rail deferrals from 1967 to 1977. The derivation of the variable is discussed in Section 4.4 on the data base and variable definitions.

Maintenance-of-way expenditures are recorded as operating expenses by railroads as required by the I.C.C. Uniform System of Accounts. Maintenance, in this study, is considered to be an investment rather than an expense. Maintenance is the deliberate employment of resources in the form of labor and materials to preserve the operative state of capital goods. As such it is a form of investment which entails certain costs and in return gives rise to a stream of future benefits.[3]

Typically, management will rehabilitate a section of track and then perform different levels of maintenance, trading off maintenance expenditures against running times and the increased costs that slower times imply in the form of greater crew costs, and poorer utilization of freight cars and locomotives, which may be offset somewhat by reduced fuel costs.

There are two broad types of track maintenance: (1) rehabilitation or discretionary maintenance, and (2) routine or basic maintenance. Discretionary maintenance is more mechanized and subsequently can be performed at a lower unit cost. Routine maintenance is more labor intensive and is performed at a higher unit cost. Management will adopt a mix of these two maintenance procedures in order to minimize costs. Track will be allowed to deteriorate to a certain state and then be rehabilitated.

Railroads have different standards of maintenance, based upon their profitability and other factors such as traffic density, axle loads, etc. High density systems may have higher standards of maintenance as they are inherently more profitable. Studies

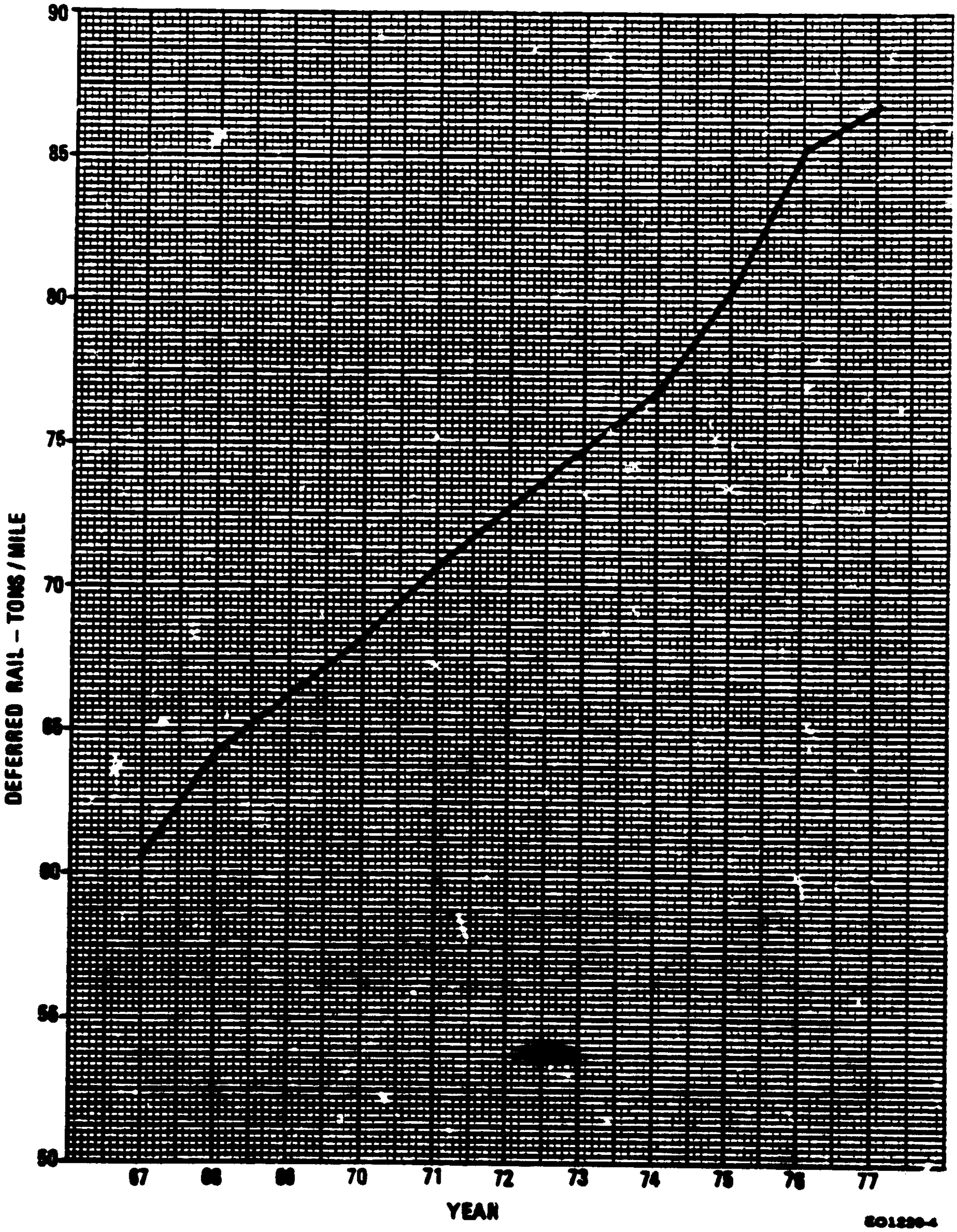

FIGURE 3-4. RAIL DEFERRALS, TONS PER MILE, 25 LARGE RR'S, 1967-1977

have shown that there are economies associated with increased traffic densities.[4] As density falls, cost per MGTM rises and railroad operations become less profitable. As maintenance-of-way standards are lowered, service deteriorates and business is lost. This reinforces the decrease in density and establishes a basis for a vicious cycle resulting in a downward spiral of track condition, traffic, and profits.

Federal safety standards were implemented in 1972, becoming fully effective in 1973, in response to the increasing number of accidents. Railroads may respond in either of two ways to the standards; 1) they may change the amount spent on maintenance of track and/or 2) they may reduce freight speeds. In this study, statistical analyses are performed to determine whether there are significant changes between the pre and post standard periods.

The data base used to estimate the model was derived from R-1 reports filed with the ICC from 1934-77 and accident reports submitted to the FRA, covering the period 1967 to 1977. Data from railroads that were involved in mergers were combined in years prior to the merger to form a consistent time series. The data are aggregated over all line segments in the railroad system, which is viewed as a limitation of the study. It would have been better to have data by line segment or link, but data on this micro-level were not available.

Section 3.2 is a description of the model detailing the equations, the independent variables and the hypothesized relationship between them and the dependent variables. Section 3.3 is a short description of the data base and a definition of the model variables; 3.4 provides a summary of the methodology employed. Section 3.5 provides the results of the analytic procedures, and Section 3.6 concludes this section with a discussion of the results. Application of the model to the industry and the development of a forecast to the year 1990 are provided in Section 4.

3.2 MODEL DESCRIPTION

A few comments on the nature of econometric modelling may be appropriate at this time. A model is an abstraction from reality and is necessarily a simplification of the complex underlying process. It isolates the key variables that affect the variable in question, e.g., maintenance-of-way spending. A model cannot possibly contain all the variables that affect the dependent variable. Its usefulness lies in its simplicity.

Implicit in the development of a model is that the explanatory variables have a causative effect upon the dependent variable. This model assumes that, although railroads may seem to be diverse in their characteristics, there are common "rules" that govern their behavior. This assumption is tested by estimating the parameters (coefficients) of the model. A null hypothesis is established that the parameters are equal to zero. An alternative hypothesis states the opposite case, i.e., that the parameters are different from zero. By taking the ratio of the estimated coefficients to their respective standard errors, we are able to either reject the null hypothesis or accept it, depending on the value of this ratio. If it is outside some critical range, then we are able to reject the null hypothesis at some stated level of statistical significance. The overall model is comprised of six basic equations. The first equation explains maintenance-of-way spending and the second explains freight speeds. The third and fourth equations explain running track-related accident rates per billion gross ton-miles and number of accidents, respectively. The fifth and sixth equations explain accident rates per BGTM and number of accidents for running and switching track combined.

Maintenance-of-way spending is hypothesized to be determined by expected traffic and other expected operating characteristics, such as freight speeds and loaded car weight; availability of funds; and a railroad's need to perform maintenance as indicated by track quality. Average speeds are expected to be determined by average haul, track quality, the amount of switching, railroad overall accident experience, and route characteristics such as train density, congested operating environments, etc. Track-related accidents are expected to be governed by track quality, current maintenance-of-way spending and other railroad operating characteristics, such as loaded car weights. Figure 3-5 shows these relationships.

3.2.1 Maintenance-of-Way Spending

The functional equation for maintenance-of-way (MOW) spending is expressed as:

(1) MOW = f(DENSITY, CARWT, FUNDS, DEFRAIL, RELPRC)

where MOW[1] is maintenance-of-way spending per equated mile of track; DENSITY is millions of gross tons; CARWT is loaded car weight; FUNDS is net revenue before MOW per gross ton-mile; DEFRAIL is a measure of rail deferrals in tons per mile; and RELPRC is a price ratio of MOW activities to transportation activities.

Functional equation (1) is a behavioral equation as it tells us what factors motivate railroads' expenditures on maintenance-of-way. We expect to find a positive relationship between maintenance-of-way spending and system density. With increased utilization, the track will wear out at a faster rate, which will necessitate a higher level of maintenance. Additionally, as density increases, maintenance-of-way per gross ton mile will decrease, partly because some maintenance-of-way costs are fixed; as density increases, fixed maintenance expenditures are spread over a larger output. This will widen the gap between average revenue, which doesn't change with increased density, and average

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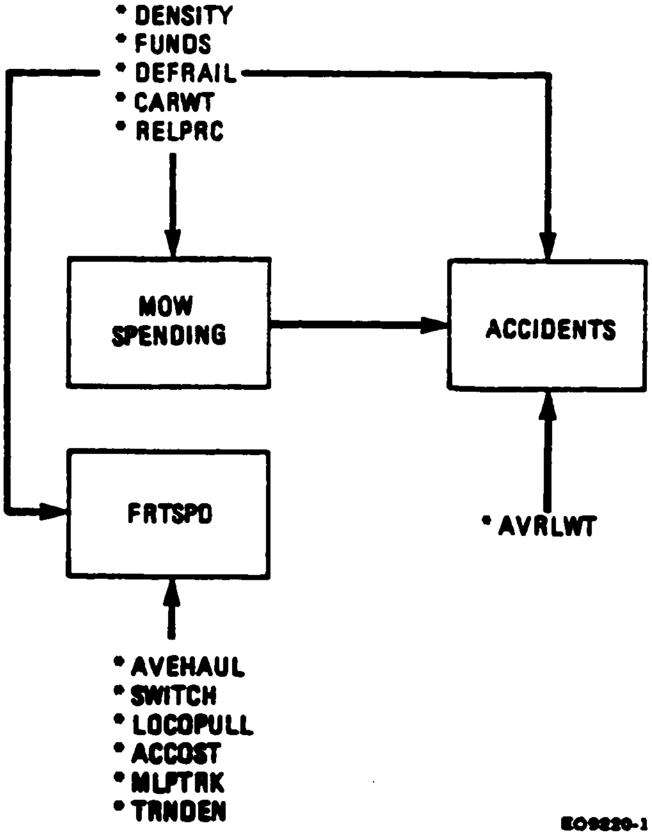
[1] Variable definitions are provided in Section 3.3.



Where:

FUNDS - Dollars available for MOW / MGTM

DEFRAIL - Measure of track quality

CARWT - Loaded car weight input

RELPRC - Index of mow input prices to transportation input prices

FRTSPD - Average freight speed

SWITCH - Measure of switching activity

LOCOPULL - Load pulled per locomotive

ACCOST - Accident costs

MLPTRK - Ratio of all running track to first main

AVRLWT - Average rail weight

FIGURE 3-5. MOW MODEL

* - indicates exogenous variables
Endogenous variables are represented by rectangles
Arrows indicate direction of causation

costs, thereby increasing net revenue. As higher density roads are inherently more profitable, it is expected they will maintain their tracks at a higher standard. Finally, traffic density is the principal contributor to available dollars per mile for track MOW spending.

Loaded car weight is included as an explanatory variable as railroads that operate with heavier loaded car weights are expected to spend more per mile on maintenance. Heavier cars are expected to put a greater stress on the track structure, causing it to deteriorate at a faster pace, all else held equal.

The availability of funds is hypothesized to have a positive impact on maintenance-of-way spending. In the absence of a corresponding rate increase, a rise in non-maintenance-of-way expenses constricts the amount of funds available for maintaining the roadbed. Maintenance activities are postponable, whereas such activities as fueling trains are not. In 1974, the price that railroads paid for such fuel doubled, thereby decreasing the availability of funds for maintenance activities.

Another important variable in the running track investment equation is the condition and quality of the track. It is a common practice of many railroads to defer maintenance, or not to replace the track structure at the same rate that it is consumed. For most railroads, deferred maintenance has been increasing steadily since the peak in maintenance-of-way activity during and immediately following World War II. Deferred maintenance, as used in this study, is defined as the deviation between actual installation of ties and rails and installation rates that would leave fifty percent life in track materials. This definition, developed by Thomas K. Dyer[5] is objective and thus comparable amongst railroads. Railroads report measures of deferred maintenance to the Interstate Commerce Commission (ICC) as required by Ex Parte 305; however, these measures are deficient for comparative purposes, since the ICC did not provide a standard measure to assure uniform and consistent reporting.

Deferred rail or ties represent a need for more maintenance-of-way spending and is expected to have a positive impact on such spending.

The ratio of price indices of maintenance-of-way activities to transportation activities is expected to be negatively related to maintenance-of-way spending. If maintenance-of-way and transportation activities are considered inputs in the production process or factor inputs, an increase in the price of one relative to the other may lead to the substitution of that factor whose price has dropped for the other factor.

In summary, density has a positive effect upon maintenance-of-way spending for the following reasons. First, higher density systems wear out the track at a faster rate. Second, they have more funds available for maintenance spending because the greater utilization of the fixed plant makes them more profitable. Third, and related to the second reason, higher density railroads are more willing to spend money on track replacements as their rates of return on these investments are higher. Heavier loaded car weights are expected to have a positive effect upon track MOW spending, as they may require increased expenditures on track replacements. The ratio of prices of maintenance-of-way labor and materials to transportation labor and fuel is expected to have a negative impact on maintenance-of-way spending. Deferred rail is a constructed variable that is a surrogate for track quality. As the amount of deferred rail increases, track quality declines, and the deterioration in track quality may put upward pressure on maintenance-of-way spending.

3.2.2 Average Speed Equation

The functional equation postulated to explain variations in average system speed is:

(2) FRTSPD = f(AVEHAUL, SWITCH, ACCOST, MLPTRK, LOCOPULL, DEFRAIL)

where AVEHAUL is revenue ton miles divided by revenue tons; SWITCH is the ratio of train switching plus yard switching locomotive miles to total car miles; ACCOST is accident cost and is the sum of property damage and wreck clearing costs per million gross ton-miles; MLPTRK is the ratio of all main running track to first main running track; LOCOPULL is the average load pulled per locomotive and is obtained by dividing gross ton-miles trailing by locomotive miles in road service; and DEFRAIL is the amount of deferred rails in tons defined in functional equation (1).

Railroad average speeds are expected to be positively related to the length of average haul. Longer haul railroads, generally, operate in less congested areas, have less on-line switching and pass through fewer intermediate yards. Thus lengthening the average haul is expected to have a positive impact on average freight speeds.

Average speeds are expected to be negatively related to the amount of yard and way switching activity. Trains are held up while cars are set out or picked up at intermediate yards and industry along the route.

Freight speeds are hypothesized to be negatively related to the railroad's overall accident experience. The greater the number of accidents, the more delays that are encountered and slower freight speeds are the result. The railroads' accident experience is measured by the sum of property damage and wreck clearing costs per million-gross ton-miles. (These costs are taken from the ICC R-1 reports and are not those reported to the FRA for each accident.)

Track quality should have a negative effect upon freight speed. The more bad ties and rail, the slower the speeds trains will be able to operate at safely. Track quality is measured by the sum of deferred rail in tons over the average life of rail as calculated by rail consumption equations developed by Thomas K. Dyer.

The average load per locomotive is expected to have a negative effect on freight speeds. Heavier loads retard train speeds, especially during acceleration and on up-grades, everything else equal.

A measure of route capacity is the ratio of all main track to first main track. An increase in route capacity is expected to be positively related to average freight speeds, since less time (train-hours) are spent waiting in passing sidings or for clear signals, all else held constant.

Summarizing functional equation 2, switching activity, accident costs, weight pulled per locomotive, and deferred rail (surrogate for track condition) should have the effect of reducing freight speed, while increases in average haul and the miles of track operated per mile of first main should have the opposite effect.

3.2.3 Accident Equations

Functional equation (3) expresses the track-related accident rate equation for running track, while (4) is the equation for number of accidents/year:

(3) ACCID = f(DEFRAIL, AVMOW, CARWT, AVRLWT)
(4) NACC = f(TDEFRAIL, TAVMOW, GTM, AVRLWT, CARWT)

where ACCID is the number of track-related accidents per billion GTM; where DEFRAIL is the amount of deferred rail in tons/mile; AVMOW is a 5-year moving average of prior maintenance-of-way spending per equated mile; CARWT is loaded car weight; and AVRLWT is average rail weight. TDEFRAIL and TAVMOW are the total deferred rail (in tons) and prior MOW spending (in dollars) for a particular railroad, and are obtained by multiplying DEFRAIL by running track miles and AVMOW by equated track miles.

It is expected that an increase in rail deferrals will have a positive relationship with the track-related accident rate. Poorer quality track would be expected to result in a higher accident rate. The condition or quality of the track was expected to have a very significant effect upon the track-related accident rate. One difficulty with our model is that track quality can only be approximated by our measure of deferred maintenance, which measures the deviation between actual rail or tie installations and those installations needed to keep fifty percent remaining life in track materials. The quality of the track is actually characterized by the number of defective ties and rail, gauge, cross-level, warp (rate-of-change of cross level), alignment, track deflection under load, etc. Conrail and the FRA are collaborating on a study to quantify track quality and the results of this study should be forthcoming shortly[6]. Nevertheless, an increase in the amount of deferred maintenance should be positively related to the accident rate.

The trend to heavier cars or axle loadings should also result in a higher accident rate due to greater stresses and wear on the track structure, in the absence of a rebuilding to carry heavier loads. Thus loaded car weight should be positively related to the accident rate.

Maintenance-of-way spending is assumed to be negatively related to the accident rate. All else held constant, an increase in MOW spending should have a dampening effect on the accident rate. While deferred rail is used as a surrogate for long-term maintenance, after adjustment for traffic density and rail weight, the five year moving average MOW spending is intended to capture the effects of shorter-term maintenance activities such as lining and surfacing, cleaning of ditches and ballast shoulders, etc.

Average rail weight is expected to have a negative effect upon the track-related accident rates. Heavier rail should result in fewer rail defects due to the added stress on rail from heavier car loads. In addition, heavier rail results in longer rail life, density held constant, and hence lower deferred rail.

Summarizing functional equations (3) and (4), track-related accidents are assumed to increase with deterioration in track quality and heavier loaded car weights and to decrease with increases in maintenance-of-way spending and average rail weights.

The same functional form is postulated to apply to both running track accidents alone and accidents on all track combined. The rationale for this approach is that railroads tend to place MOW spending priority on mainline track and less on switching track to about the same degree. Furthermore, rail cascading practices result in most new rail being applied first to mainline track, with used rail cascaded to lower density running track and switching track. Since deferred rail is based on installation of new rail only, the cascading effect is expected to be captured by this variable for the entire system.

3.3 DATA BASE

The data base used to estimate the model was derived from R-1 reports filed annually by all Class I railroads with the ICC and accident reports filed with the FRA. The R1-ICC data base used in this study includes financial, operating and physical data on all Class I railroads over the 16-year period, 1962-1977. Additional physical data (rail and tie installations and total track and traffic data from 1934-77) were obtained from Thomas K. Dyer Associates, and provided by TSC. Accident data were extracted from the Federal Railroad Administration-Railroad Accident Incident Reporting System (FRA-RAIRS) data base; these original data included dollar damage to track and equipment and details regarding the particular accident, but only annual sums were used in this study. The data are described in more detail in Appendix A.

Maintenance-of-way spending, in this study, is defined as the number of dollars spent per equated track mile for track materials and labor costs. Equated track mileage is obtained by weighting running track by 1.00 and switching track by 0.32. These weights are the same as those used by the railroads in allocating their expenditures between running and switching tracks for ICC reporting purposes.

The five year average MOW spending (AVMOW) is the simple average of the MOW spending (per equated track mile) for the prior five years immediately preceeding the year associated with each data point.

Maintenance-of-way spending was obtained by summing the following expense accounts - roadway maintenance (202), tie (212), rail (214), other track material (216), ballast (218), and track laying and surfacing (220). Accounts 202 and 220 represent primarily labor expenses; the other accounts record materials expense. In addition, if heavier rail is installed, the incremental cost of the heavier rail is capitalized under the betterment accounting principles practiced by most, if not all, of the Class I railroads for the period of our study. Thus, to obtain a more accurate measure of tie and rail expenditures, the capitalized portion of rail and tie expenditures (provided by TSC) were added to the expense accounts. These data were then converted to constant 1967 dollars, using Association of American Railroads (AAR) inflation indices (see Appendix A).

Figure 3-6 shows the trend of maintenance-of-way spending per mile during the period 1967-1977. Maintenance-of-way activity is also measured in physical terms; these data were obtained from the Dyer-R1 data base, which includes data on tie and rail installations from 1934 to 1977, and are described in Appendix A. The rail installations are by type of track - running and switching - and the tie data are for all types of track. One problem with this data base is that rail and tie installation include not only replacements in existing track, but also installations in new track and extensions to existing lines. However, since the amount of net investment over the period is not large, this does not appear to be a serious problem. The data on cross ties were not broken down by type of track. Thus, estimates of ties laid in each type of track were calculated based upon the relative proportions of each in track miles. Figures 3-7 and 3-8 show rail and tie installations per mile from 1967 to 1977.

Average speed (FRTSPD) is determined by dividing freight train miles by freight train hours. It is not an ideal measure, as running speed is the variable that we are trying to capture. Average freight speeds include not only running speed, but also idle time while freight cars are being switched, either on-line or in intermediate yards. Running speed is really the factor that enters the maintenance-of-way decision process and influ-

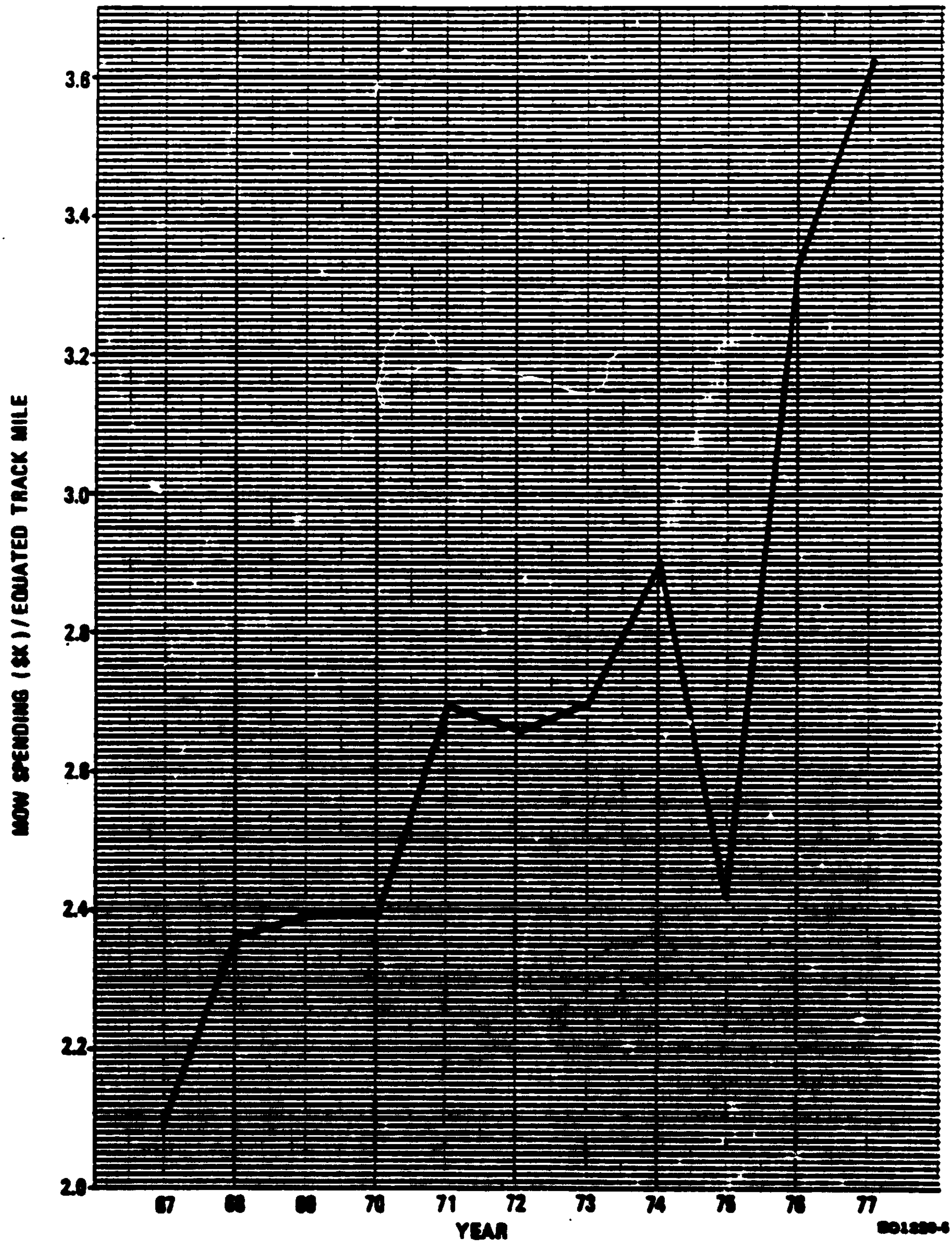


FIGURE 3-6. MOW PER EQUATED TRACK MILE, 25 LARGE RR's, 1967-1977

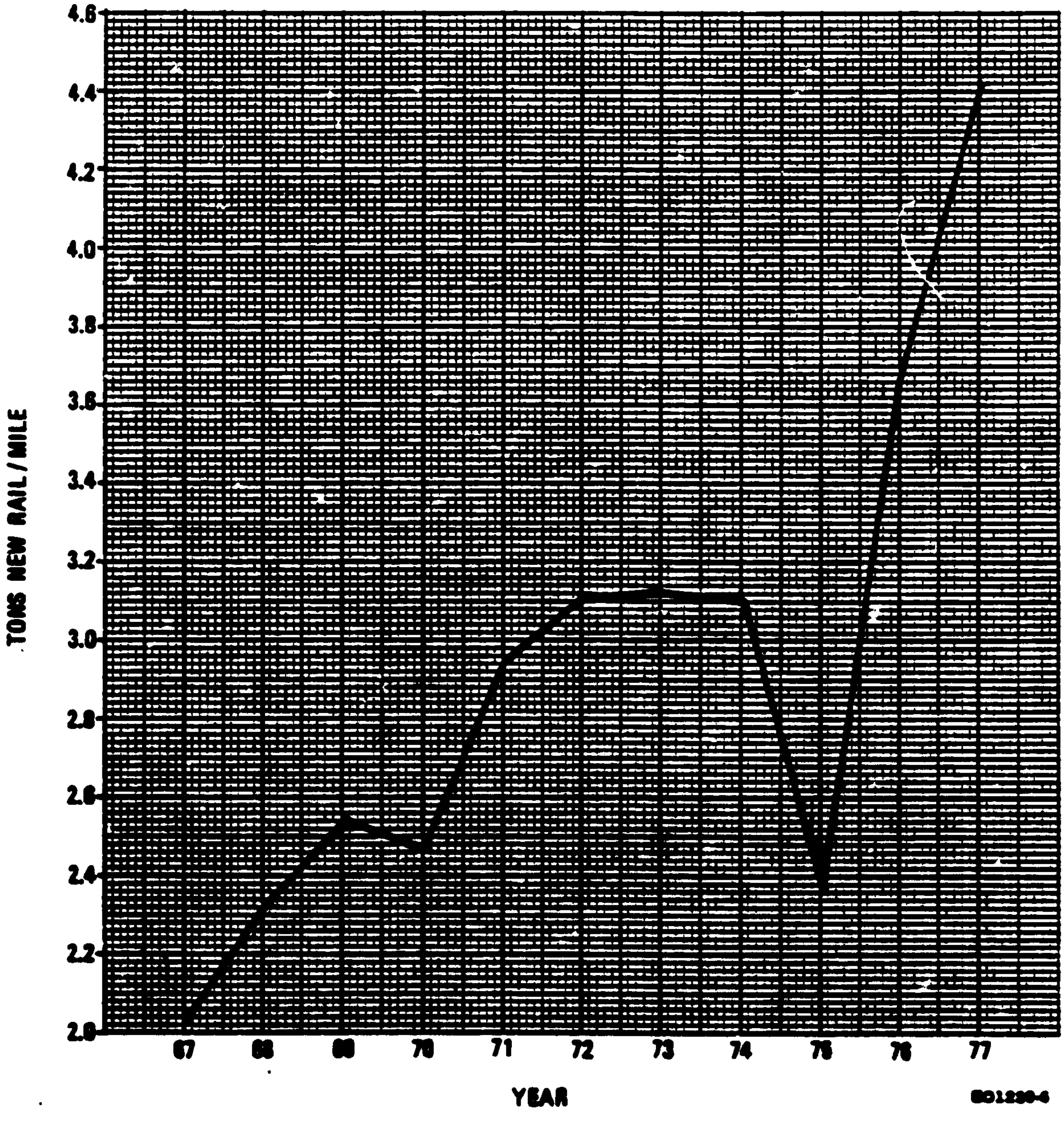


FIGURE 3-7. TONS OF NEW RAIL INSTALLED, PER MILE, 25 LARGE RR'S 1967-1977

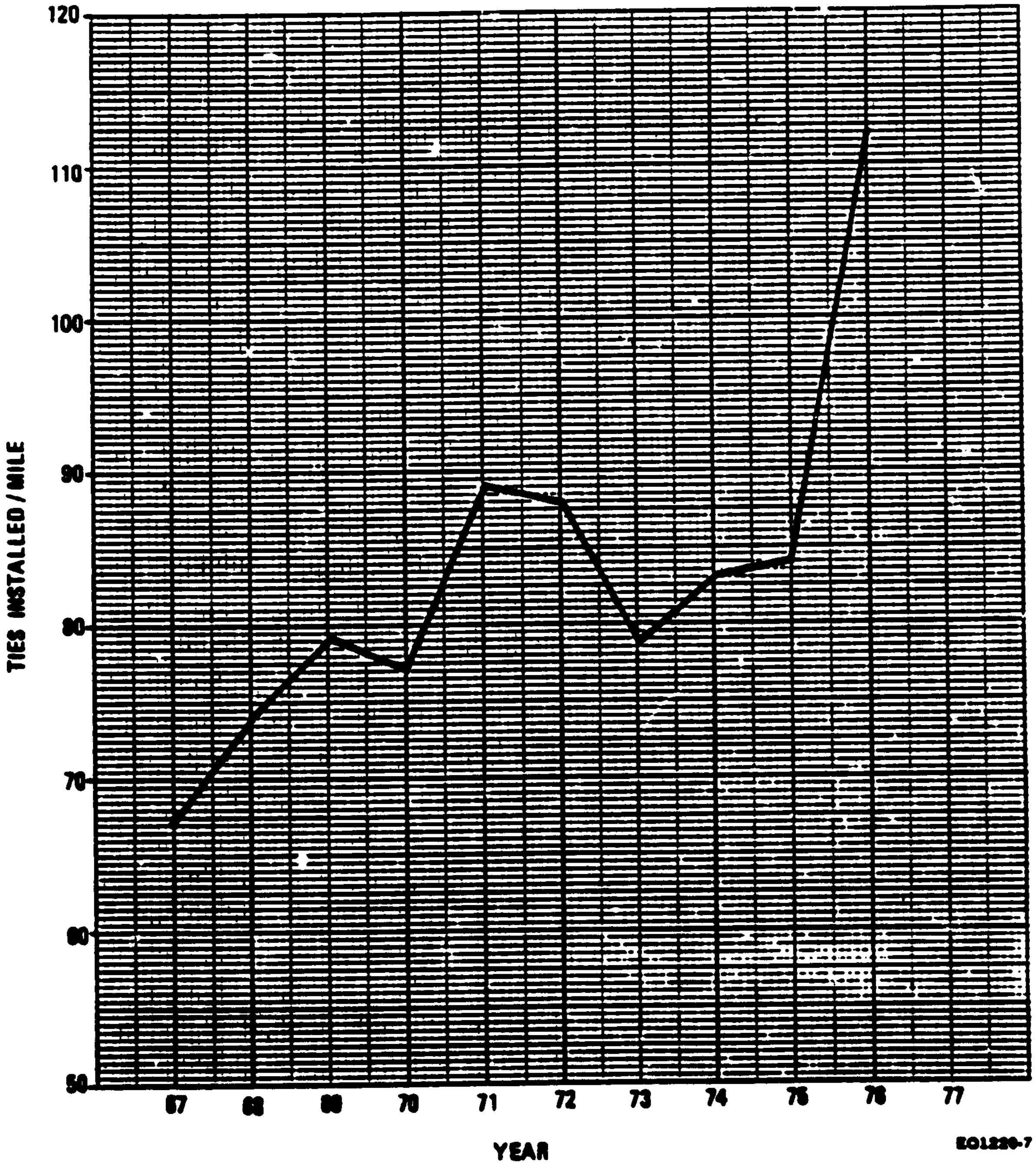


FIGURE 3-8. TIES INSTALLED PER MILE, 25 LARGE RAILROADS, 1967-1977

ences track related accidents. However, running speeds and average system speeds are probably linearly related and the latter may be used as a surrogate for the former.

In this study, an attempt is made (reasonably successfully) to account for switching effects on speed, as well as other factors previously discussed. However, due both to lack of readily available data and an inability to devise a single measure of "average" grade and curvature (beyond that used for deferred rail) for each railroad, these factors were not included in the speed estimation equation.

Loaded car weights (CARWT) are determined by adding (revenue ton-miles divided by loaded car miles) to (gross ton miles trailing minus revenue ton miles) divided by total car miles). The first term in this expression measures the average load weight per loaded car and the second term measures average (unloaded) car weight. Their sum is loaded car weight.

Density (DENSITY) is derived by dividing gross ton-miles by running track miles. Net revenue (FUNDS) before maintenance-of-way, per gross ton mile, is determined by subtracting operating costs less maintenance-of-way (as defined in this study) from operating revenues, and then dividing this result by gross ton-miles.

The relative price (RELPRC) of maintenance-of-way activity to transportation activities is arrived at by dividing a weighted price index of maintenance-of-way labor and materials by a weighted price index of labor and fuel costs from the transportation cost accounts. The weights are the relative expenditures on each of the categories of materials, fuel and labor. The precise formulation of this variable is provided in Appendix A.

Deferred rail (DEFRAIL) is a measure of track quality. Using available data, track condition or quality could not be determined directly. Track quality is related to a number of factors, including the number of defective ties and rail, track geometry, and condition of the ballast and sub-grade. In this study track conditions are approximated by measures of deferred maintenance as defined by Dyer.[7] Deferred maintenance in any given year is the deviation between actual rail and tie installments and the amount necessary to keep fifty percent remaining life of track materials, at the density and rail weight extant in that year. Presumably, as deferred maintenance increases, track quality deteriorates. Thus, track quality is approximated by the number of tons of rail or cross ties per mile needed to restore 1/2 life remaining to track materials.

Annual rail and tie requirements are determined by dividing the number of units of track material in the track by the average life of the track material. The number of cross ties in the track for each year is given in the data base, while the number of tons of rail in the track can be determined from the original data. The average life of rail and ties can be determined from the engineering equations that are provided in Dyer's study.[8] These equations relate rail life to rail weight, track curvature, gross tons and miles of welded rail. Tie life is related to gross tons, rail weight, miles of welded rail, rainfall, temperature, frost and track curvature.

The number of tons of rail in the track for any given year is determined by the following equation, TONS = (RW * 1760 * MT)/1000, where RW is average rail weight and MT is track miles. The equations used to determine tie and rail age are given in Tables 3-1 and 3-2. Dyer's report contained values for rainfall and other variables, not included in the R-1 data base for each of the railroads used in the study.

TABLE 3-1. AVERAGE SYSTEM TIE LIFE

Main Track Tie Life

Less than 10 MGT $L_{TJ} = (37.4 - .37G)\left(\frac{W}{71 + 5.2G}\right)^{.67}$

10 MGT but less than 20 MGT $L_{TJ} = (37.4 - 37G)\left(\frac{W}{109 + 1.4G}\right)^{.67}$

20 MGT and over $L_{TJ} = (35.0 - .25G)\left(\frac{W}{137}\right) .67$

Adjustment for Welded Rail

$$L_T = \frac{L_{TJ} \cdot (M_T + .04Mw)}{M_T}$$

Yard and Switching Track Tie Life

$$Ly = 39.16 - 0.1G$$

Adjustment for Rainfall, Temperature, Frost and Track Curvature

$$X = \left[\frac{9,945.38}{11,319.89 + RF^2} + \frac{24.7}{71.11 + T} - \left(\frac{1.55}{T} - .0231\right)^*\right]^{\frac{4.42 + K}{5}}$$

*When T is equal or greater than 67, this term = 0

Average System Tie Life

$$L_S = X\left[R_M L_t = RyLy \left(\frac{5}{4.42 + K}\right)\right]$$

where: L_{TJ} = Main track jointed rail tie life in years

L_T = Main track average tie life in years.

W = Average weight of rail in main track in Lbs/Yd.

G = Average gross tons/main track mile (in millions)

M_T = Total system track miles less miles operated under trackage rights

Mw = Miles of welded rail

TABLE 3-1. AVERAGE SYSTEM TIE LIFE (CONTINUED)

Ly = Yard and switching track tie life (has been reduced 5% for life lost due to derailments, etc.)

X = Climate factor

RF = Average Annual Rainfall in inches

T = Average annual temperature in degrees (F)

K = Curve factor

L_s = Average system tie life

R_M = Ratio of main track cross ties to total cross ties in track

RY = Ratio of yard and switching track cross ties to total cross ties in track

L_t = Applicable main track tie life

TABLE 3-2. AVERAGE SYSTEM RAIL LIFE (from installation new until removal for salvage)

$$L_{RJ} = \frac{WK}{G^{337}} + \frac{2.97}{G + 5}$$

$$L_R = \frac{L_{RJ}\ M_T + M_W\ (C - 1)}{M_T}$$

where:

L_{RJ} = Jointed rail life in years

L_R = Average system life of new rail

W = Weight of rail in Lbs/Yd.

G = Gross tons/main track mile (in millions)

K = Curve factor

M_T = Total system track miles less Class 5

M_W = Miles of welded rail

C = Factor for life increase due to welded rail

	K	C
Heavily Curved	.53	1.13
Moderately Curved	.55	1.15
Lightly Curved	.58	1.17

The deferred rail variable used in this study is the sum of the deferred rail values computed for each year, totalled over a period of the thirty years immediately preceeding the sample year. Since thirty years is roughly the useful life of ties, rail, OTM and ballast, in reasonably active service, the initial conditions at the start of each thirty year period have little effect on the overall value of the 30-year sum.

Alternative measures of track quality were developed and tested to see if better statistical results could be obtained. Average track class, which DYNATREND had available for one year, was used as an explanatory variable in the accident equation. In a cross sectional analysis for that year, average track class and deferred rail gave similar results in the accident equation. Other variables used to represent track quality were tie and rail age, cumulative tonnage on ties,moving averages of lagged installations of ties and rail, and quantities of "good" rail and ties based upon polynomial deterioration curves. Perhaps we are getting ahead of ourselves, but the statistical results obtained by using these variables were similar. The ordinary least squares (OLS) coefficients of determination, R^2, were usually around 0.40, and the coefficients on the rail variables were statistically significant and in the hypothesized direction. The coefficients on the tie variables were sometimes significant, but usually in the wrong direction; their incremental contribution to the overall explanatory power of the equation was small.

The engineering relationships used in the TOPS study to compute tie and rail age where also used. The equations taken from this study were the initial relationships used to determine rail and tie life, before being modified as a result of their findings. The deferred rail in tons per mile using Dyer's equation was selected as a track quality index, since it provided the best statistical results.

Average haul (AVEHAUL) is determined by dividing revenue ton-miles by revenue tons. Switching activity (SWITCH) is represented by the ratio of way plus yard switching locomotive miles to total car miles. Track capacity (MLPTRK) is arrived at by taking the ratio of all running track miles to miles of first main operated. Accident costs (ACCOST) is determined by dividing the sum of property damage and wreck clearing costs by gross ton-miles.

The source of accident data is the RAIRS accident data base. The accident data are derived from accident reports filed with the FRA, over the period 1967-1977. The data base format changed in 1975, and in order to form a consistent series of track related accidents, the accident cause codes in the old data base (prior to 1975) were mapped into their equivalents in the new data base in accordance with FRA guidelines.[9]

Since reportable accidents are defined with reference to a minimum (threshold) amount of dollar damage to track and equipment, and since this limit is only revised periodically, train accidents were defined for purposes of this study to have a minimum value of $2300 (1977) or approximately $900 (1967). All accident damage was converted to 1967 dollars and only those cases over $900 were included in the accident data base used in this study. Data for individual accidents were not employed in this study; rather, the number of accidents and associated damages, in several categories of track type and cause code groups, were totalled for each prime railroad for each year.

3.4 ANALYTIC METHODOLOGY

The data base contains observations on 47 Class I railroads existing in 1977. Merges of railroads occurring prior to 1967 were handled by consolidating the data for the merger partners to provide a consistent series over time. Railroads that were not in business over the entire period and which were not merged into other railroads were excluded. Railroads which lost their Class I status due to re-definition of Class I roads were also dropped. Non-freight orientated railroads such as AMTRAK, Auto Train and the Long Island Railroad were excluded.

It was felt that inclusion of all of the remaining (47) Class I roads in the sample would lead to uncharacteristic results. The remaining 47 railroads in the original data base are of a very diverse nature. They vary in the nature of the service they perform, as some are primarily short-haul railroads that provide extensive switching services and operate in congested areas, while others are characterized by long hauls and little switching activity. Most rail traffic flows from west to east and south to east. Western and southern roads originate tonnage for the eastern roads to deliver. Some railroads are small and part of a system for which they provide bridge services to other roads in the system. Others are owned by manufacturing concerns and provide transportation services to those firms. Some roads are high density and thus fairly profitable; others are low density, and not so profitable.

Other researchers have stratified railroads into different groups for the purposes of their analysis. Wycliff divided his sample by length of haul;[10] Griliches,[11] Healy[12] and Harris[13] divided their samples by size. Since a model that does not take into account the heterogeneity and diversity of railroads may be mis-specified, it was felt that inclusion of the smaller, more specialized roads would obscure the behavior of the larger roads, which account for most of the activity and assets in the industry. Thus, it was felt that the model could be strengthened by eliminating the smaller roads, and only roads with 1000 or more miles of track operated were retained in the sample. These railroads had 96% of the gross ton-miles in 1977 and 97% of the running track accidents. Dividing the sample at this point, 25 railroads in the higher track mile category were retained to comprise the sample, and the remaining 24 smaller roads were eliminated in the lower track mile group.

The data used to estimate the model were annual for each of the 25 Class I railroads over the period 1967 to 1977. These time series and cross section data were combined (pooled) for estimation. This causes no particular statement problems as the model contains explanatory variables that vary over time as well as over cross sectional units. It was necessary to limit the years in the sample to those in the 1967-77 period to permit calculation of the five year moving average of prior MOW spending ('62-'66, inclusive). In the absence of the 5-year moving average requirement, the remaining constraint is the availability of accident data commencing in 1967, and the thirty year sum of deferred rail; the latter prevents use of any annual data point in the sample prior to 1965, since rail and tie installation data were available only from 1934 on, through 1977.

The estimating technique is generalized least squares (GLS), as it is assumed that our model is cross-sectionally heteroskedastic and time-wise autoregressive.

Heteroskedasticity occurs when the error of the predictive equation varies with the value(s) of one or more of the independent variables in the equation, and is frequently related to size effects (such as track miles or ton-miles in this study). To minimize the effects of heteroskedasticity in the initial ordinary least squares (OLS) estimates, normalized variables (such as MOW spending per mile, rather than MOW spending alone). Heteroskedasticity generally results in the OLS coefficient of determination (R^2) being underestimated; that is, the explanatory power is really greater than that indicated by the value of R^2.

Autocorrelation is expected because individual railroads change and respond to their environment only slowly over time. Hence, results for any year are usually not substantially different from the prior year, and reflect random variation around a trend. Thus, data for successive years will be highly correlated and hence autoregressive. OLS regression procedures are based on the assumption that all data points (one year for each railroad, in this study), are independent of each other, which is at least in part violated by the high autocorrelation for successive years for each railroad. Because of autoregression, the error indicated by the regression results is unrealistically low, and the associated R^2 is overestimated.

Kmenta [14] provides a sound statistical approach for eliminating the consequences of both heteroskedasticity and autocorrelation on the results obtained from regressions performed on pooled time series and cross-sectional data.

The procedure requires, as the first step, running ordinary least squares (OLS) on the NT observations, where N is the number of railroads and T is the number of time periods.

The residuals are then used to obtain the autocorrelation coefficient which is used to adjust the data for autocorrelation. Each variable is thus adjusted for autocorrelation using the following expression:

$$X^* = X_{i,t} - (RHO_i)(X_{i,t-1})$$

where: X = Variable
i = Railroad
t = Current year
t-i = Previous year
RHO = correlation of residuals for i-th railroad

The autoregressive corrected data is then used to obtain the estimated variance of the residuals for each one of the N railroads. These variances are used to further adjust the data for heteroskedasticity. Each variable is thus further adjusted for heteroskedasticity by dividing X* by SEE_i, the standard error of the estimate for each individual railroad, using the OLS procedure applied to the variables which have been adjusted for autocorrelation. At this point, the data have been corrected for autocorrelation and heteroskedasticity, and the OLS procedure can now be applied to the N(T-1) observations, using the transformed variables.

Separate estimation of the coefficients, (squared errors, and R^2 are made for the period as a whole (1968-77) and the two sub-periods (1968-72 and 1973-77) individually. (Note that the data for 1967 are not used directly in the final regression because the first year must be dropped in the autocorrelation adjustment procedure.) These regression results are then used directly in the Chow (F) test for structural change, which is described in further detail later in this section.

Two additional steps are necessary to develop the final predictive equations for use (with untransformed original) in subsequent policy analyses or forecasts. First, the statistical validity of each coefficient in each must be analyzed, and second, the bias in the intercept constant (introduced by the autocorrelation adjustment step of the GLS procedure) must be eliminated.

Each coefficient in the initial GLS equation containing the full set of variables is subjected to Student's t-test, using the 0.1 level of significance, and examined for appropriate algebraic sign. Those variables with t-statistics less than the critical values for their coefficients or the wrong sign are dropped, and the final OLS regression re-performed on the remaining transformed variables. The revised results are then verified for statistical significance using the new t-statistics.

Multivariate regression proceeds on the assumption that each explanatory variable is independent of all other explanatory variables contained in an equation. Generally, however, this condition is not wholly true, and multicollinearity will exist to a greater or lesser degree. One possible consequence of multicollinearity is that the algebraic sign for a particular variable will be opposite to that expected, due to the inclusion of another variable in the equation. The computer program (SPSS) used in this study attempts to eliminate the effects of multicollinearity by employing multiple partial correlation values in selecting the next variable to be entered in the step-wise procedure. By examining these partial correlation coefficients, the degree and nature of the multicollinearity extant in the results can be better understood and appropriate decisions can be made regarding the variables to be retained when re-performing the final OLS regressions. Generally, the analyst would prefer that the most important variables, from a policy rather than a statistical point of view, be retained in order to support future applications of the model. Hence, when multicollinearity is strong, the analyst may select the variables most relevant to potential applications of the model. To a limited degree, this discretionary selection flexibility was employed in determining the variables to be retained in the final predictive equations.

When the results of the GLS procedure are applied to transformed data, the predictions are unbiased. However, when the equation is applied to original, untransformed data, the predictions are biased due to the adjustments for autocorrelation. The coefficients for each of the statistically significant independent variables may be used as-is with untransformed data, because the total bias resides in the intercept constant. This bias was removed by using the average values of the dependent and independent variables, in conjunction with their coefficients, to compute the value of the intercept constant. This is equivalent to adjusting the GLS intercept to yield a sum of the errors equal to zero. After the intercept constant is adjusted, the R^2 for the final predictive equations was computed by calculating the sum of the squared error (SSE), using the revised equation and the untransformed data, and the sum of the squared deviations (SST) from the mean of the dependent variables, and using those values to determine R^2 (= 1-SSE/SST). Typically, this R^2 for the untransformed data was substantially less than the corresponding value using transformed data, indicating that the autocorrelation effects were important in the GLS process. The R^2 for the final GLS predictive equations, with bias corrected, are directly comparable to the original OLS results. In addition, the coefficients in those GLS equations containing the full set of variables can be compared one-for-one with the original OLS coefficients to understand the effects of applying the GLS process to the initial OLS results.

All of the equations are estimated in linear form. During the study, analyses were conducted using log-lines and polynomial forms, but their results were no better, and in some cases worse, than the results achieved using the linear form.

3.5 SUMMARY OF RESULTS

This subsection provides the specific results of the statistical analyses discussed in the preceding subsection. A separate table and associated discussion is provided for each dependent variable of interest:

- Average Speed (Table 3-3)

- MOW Spending/Equated Track Mile (Table 3-4)
- Running Track Accident Rate-No./BGTM (Table 3-5)
- Number of Running Track Accidents (Table 3-6)
- Total Track Accident Rate-No./BGTM (Table 3-7)
- Number of Total Track Accidents (Table 3-8)

Each table provides the details of the original OLS equation, the total and subperiod GLS results incorporating all of the variables in the base OLS equation, and the GLS results incorporating only those independent variables which are both statistically significant and in the right direction (i.e., appropriate algebraic sign); these latter equations are denoted by a double asterisk placed to the left of the equation number.

The results of the speed regressions are given in Table 3-3. Each equation is identified, at the left, with a number to facilitate references in the text. Column 1 indicates whether the equation was estimated using generalized least squares or ordinary least squares; Column 2 is the period of estimation; and Columns 3, 4, 5, and 6 give the number of degrees of freedom, the standard error of the estimate, the coefficient of determination, and the Durbin-Watson statistic, respectively. The t-statistics are given in parentheses below the coefficients.

For those GLS equations containing the full set of variables included in the original OLS equation, the standard error, R^2 and intercept constants are associated with the transformed data. For those GLS equations containing only those variables which are both statistically significant and of the correct sign, the standard error, R^2 and intercept constants are associated with the original, untransformed data. In a few instances, the

TABLE 3-3. AVERAGE SPEED REGRESSION RESULTS, MILES PER HOUR

NO.	TYPE (1)	PERIOD (2)	DF (3)	STD ERROR (4)	R^2 (5)	D.W.[1] (6)	CONSTANT (7)	AVEHAUL (miles) (8)	SWITCH (see AppendixA) (9)	LOCOPULL (k-tons) (10)	DEFRAIL (tons/ mile) (11)	ACCOST (1967$ /mgtm) (12)	HLPTRK (No. Trains/ Rte-Mile) (13)
(1)	OLS	67-77	268	1.8031	.8454	.4551	26.719	.0171	-.4911	-4.7669	-.0342	-.0234	1.3993
(2)	GLS	68-77	243	4.1497	.9551	.5886	-.4664	.0266 (14.22)[4]	-.5346 (-5.58)	-2.2617 (-3.46)	-.0088 (-1.29)	.0039* (.33)	16.574 (12.39)
**(3)	GLS	68-77	245	2.7544[2]	.6485[2]	.6120	.0404[3]	.0313 (17.66)	N.I.	-1.9591 (-2.9)	-.0286 (-4.78)	N.I.	11.8014 (11.09)
(4)	GLS	68-72	118	3.9891	.9584	1.027	-1.4844	.0281 (10.35)	-.8146 (-5.37)	-1.0380 (-1.01)	.0074* (.62)	.0391* (2.39)	16.257 (8.23)
**(5)	GLS	68-72	121	2.7719[2]	.6260[2]	.8749	-.0592[3]	.0345 (13.04)	N.I.	N.S.	-.0250 (-2.69)	N.I.	8.8463 (7.94)
(6)	GLS	73-77	118	4.1649	.9552	N.A.	.4203	.0260 (8.63)	-.4197 (-2.82)	-2.3581 (-2.51)	-.0058 (-.50)	-.0247 (-1.39)	15.887 (8.63)
**(7)	GLS	73-77	120	2.8653[2]	.6474[2]	.7171	-.1004	.0280 (11.45)	N.I.	-2.9243 (-3.11)	-.0331 (-3.87)	N.I.	14.211 (8.59)

NOTES:

[1] Durbin-Watson statistic.

[2] The standard error of the estimate and R^2 are re-computed in the untransformed data and placed in parentheses.

[3] Adjusted constant.

[4] t-statistics are given in parentheses below the coefficients.

* Wrong sign.

**Equation includes only those variables whose coefficients are statistically significant and of the correct sign. See text.

N.I. - variable omitted from regression run.

N.S. - was not statistically significant.

coefficients for all of the original OLS variables in the GLS results are both statistically significant and of the correct sign; in these situations, the values for the standard error, R^2 and intercept constants associated with the original, untransformed data are provided in parentheses below their corresponding, initial GLS values associated with the transformed data values.

The regression results reported in equation 2 (total period, full set of variables, GLS) for the period 1968-1977 indicate that average train speeds will increase by approximately 2.6 miles per hour for each 100 mile increase in average haul. Longer hauls are characterized by less switching, and less congested operating areas. Average speeds will decrease by .009 MPH for each one ton per mile increase in deferred rail, the surrogate variable for track quality. Thus, a reduction in track quality will have a negative effect upon average speeds. Average speed will decrease by approximately 2.26 miles per hour for a one thousand ton increase in the load hauled per locomotive.

Equation 2 indicate that average speed will increase by approximately .004 miles per hour for each dollar increase in accident hosts per million gross ton-miles. Accidents may cause bottlenecks in the system, especially in single-track territory. Thus, the estimated results are in the opposite direction to the hypothesized results. All else equal, average freight speed will be approximately 16.57 miles per hour when the ratio of all running track to first main is one. Multiple track territory allows trains to proceed in opposite directions simultaneously, without one waiting for the other to pass. Again, ignoring the constant term, and holding all other variables constant, when the ratio of switching locomotive miles to total freight car miles is one, the effect will be to reduce average freight speeds by approximately .53 miles per hour. Switching activity, whether on-line or in intermediary yards, causes trains to wait. Thus, an increase in switching activity should reduce average freight speeds.

Regression results for maintenance-of-way spending are reported in Table 3-4. Maintenance-of-way spending is measured in thousands of constant dollars (1967) per equated track mile. Equation 9 implies that an increase in density of one MGT increases maintenance-of-way spending per equated track mile by approximately $192. An increase in density means an increase in track utilization which implies greater maintenance-of-way spending because 1) a higher utilization rate will wear out track components faster; 2) a higher return on investment will induce greater spending; and 3) more dollars are available, on a per mile basis, for MOW spending. Maintenance-of-way spending will increase by approximately $22 per mile for a one ton increase in loaded car weights. Heavier cars put greater stress on track components causing them to wear out faster. An increase in funds available for maintenance-of-way per million gross ton miles of $1000 implies an increase in maintenance-of-way spending of $449. An increase in the funds available for maintenance-of-way spending should have a positive effect on that spending. The coefficient on the price ratio variable implies that when this ratio is one and ignoring all other variables, maintenance-of-way spending will decrease by $1693 per mile.

It was hypothesized that an increase in deferred rail would have a positive effect upon maintenance-of-way spending. Deferred rail is a surrogate for track quality and presumably a deterioration in track quality represents a need to perform maintenance-of-way activity. Maintenance-of-way spending will increase by approximately $6 per mile for each ton per mile increase in deferred rail.

TABLE 3-4, MAINTENENCE-OF-WAY SPENDING REGRESSION RESULTS, THOUSANDS OF 1967 $/EQUATED TRACK MILE

	TYPE	PERIOD	DF	STD ERROR	R^2	D.W.[1]	CONSTANT	DENSITY (mgt)	CARWT (tons)	DEFRAIL (tons/ mile)	FUNDS ($/mgtm)	RELPRC
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
(8)	OLS	67-77	269	.627	.609	.9452	.8935	.1863	.0278	.0044	.3875	-2.9400
**(9)	GLS	68-77	244	1.8939 (.6361)^2	.964 (.6154)^2	1.5847	-.2099 [-.0935]^3	.1920 (17.06)^4	.0217 (4.57)	.0057 (1.97)	.4486 (6.47)	-1.6930 (-5.81)
(10)	GLS	68-72	119	1.6212	.9715	1.6532	-.1614	.2125 (13.94)	.0104 (1.20)	.0079 (1.92)	.3225 (3.30)	-1.0217 (-1.94)
**(11)	GLS	68-72	121	.5912^2	.6773^2	N.A.	-.1546	.2012 (24.96)	N.S.	.0049 (2.29)	.3367 (3.44)	N.S.
**(12)	GLS	73-77	119	2.0605	.959	1.7890	-.3701	.1915 (11.18)	.0396 (4.63)	.0068 (1.67)	.5522 (5.39)	-3.413 (-4.96)

NOTES: [1] Durbin-Watson statistic.

[2] The standard error of estimate and R^2 are re-computed with untransformed data and placed in parentheses.

[3] Adjusted constant.

[4] t-statistics are given in parentheses below the coefficients.

**Equation includes only those variables whose coefficients are statistically significant and of the correct sign. See text.

N.S. - not statistically significant.

N.A. - not available.

The results of the accident equation are given in Tables 3-5 to 3-8. Equation 14 implies that a one ton per mile increase in deferred rail will increase the accident rate by approximately .008 accidents per billion gross ton miles. An increase in average rail weight of one pound per yard decreases the accident rate by approximately .003 accidents per billion gross ton-miles. Heavier rail should reduce the probability of rail defects due to the stress effects of heavier cars. However, the coefficient is not statistically significant at the 95% level. An increase in loaded car weights of one ton increases the accident rate by approximately .008. Heavier cars place greater stress on rail leading to a greater wear and more defects if the rail is not replaced sooner, thereby increasing the probability of an accident occurring. An increase in the five year average maintenance-of-way spending per equated track of $1000 decreases the running track accident rate by approximately .123. Increased maintenance-of-way spending in the short run (five years) implies an improvement in track quality which reduces the number of accidents per billion gross ton-miles.

Structural Change

To test for the effects of FRA safety regulations and other federal actions, the model was re-estimated over two sub-periods, 1967-1972 and 1973-1977, representing the periods before and after imposition of the federal track safety standards, which were phased in during 1972-73. A Chow test was performed to determine if there was structural change in the model. The test indicates whether or not there is any significant difference in the squared errors resulting from use of the total period equation vis a vis the combined sub-period equations; the test is equivalent to examining the coefficients of the independent variables (as a group) for significant differences. A null hypothesis is established that the squared errors produced by the total period equation is the same as that produced by the two

TABLE 3-5. TRACK-RELATED ACCIDENTS PER BILLION GTM, RUNNING TRACK REGRESSION RESULTS

	TYPE (1)	PERIOD (2)	DF (3)	STD ERROR (4)	R^2 (5)	D.W.[1] (6)	CONSTANT (7)	DEFRAIL (tons/ mile) (8)	AVRLWT (lbs/yd) (9)	CARWT (tons) (10)	AVMOW (1000$ /mile) (11)
(13)	OLS	67-77	270	0.7323	.3869	.4487	.9986	.01552	-.0229	.0199	-.1470
(14)	GLS	68-77	245	1.4365	.596	1.5587	.1899	.0081 (6.96)[4]	-.0027 (-1.25)	.0079 (2.67)	-.1233 (-2.99)
**(15)	GLS	68-77	246	.8052[2]	.2687[2]	N.A.	.2808[3]	.0079 (6.84)	N.S.	.0049 (2.79)	-.143 (-3.75)
(16)	GLS	68-72	120	1.2426	.5269	1.7226	.0982	.0062 (3.88)	.0035 (-1.11)	.0086 (-2.12)	-.0815 (-1.37)
**(17)	GLS	68-72	121	0.6759[2]	.2021[2]	N.A.	.2132[3]	.0056 (3.73)	N.S.	.0049 (2.13)	-.1149 (-2.23)
(18)	GLS	73-77	120	1.4892	.6680	1.3937	.6131	.0079 (4.63)	.0052* (1.58)	.0020 (.48)	-.2649 (-4.46)
**(19)	GLS	73-77	121	0.8765[2]	.3291[2]	1.4248	.4149[3]	(.0086) (5.14)	N.I.	.0072 (2.81)	-.2226 (-4.17)

NOTES: [1] Durbin-Watson statistic.

[2] The standard error of estimate and R^2 are re-computed in the untransformed data and placed in parentheses.

[3] Adjusted constant.

[4] t-statistics are given in parentheses below the coefficients.

* - wrong sign.

**Equation includes only those variables whose coefficients are statistically significant and of the correct sign. See text.

N.A. - not available.

N.S. - not satistically significant.

N.I. - not included.

TABLE 3-6. TRACK-RELATED ACCIDENTS ON RUNNING TRACK, REGRESSION RESULTS

	TYPE (1)	PERIOD (2)	DF (3)	STD ERROR (4)	R^2 (5)	D.W.[1] (6)	CONSTANT (7)	TDEFRAL (tons) (8)	GTM (mgtm) (9)	CARWT (tons) (10)	AVRLWT (lbs/yd) (11)	TAVMOW (1000$) (12)
(20)	OLS	67-77	269	33.12	.6318	.5050	-144.44	.0976	-.2989*	1.1227	.7413	-.4956
(21)	GLS	68-77	244	1.8516	.7614	.9397	-.1569	.0699 (8.29)[4]	.3317 (1.83)	.1533* (2.07)	-.1894 (-1.42)	-.4756 (-2.56)
**(22)	GLS	68-77	245	37.99[2]	.5423[2]	N.A.	-1.14[3]	.0720 (8.64)	.1015 (1.57)	.0778 (2.51)	N.S.	-.3679 (-2.17)
(23)	GLS	68-72	119	1.4600	.8229	1.2983	-.3297	.0455 (3.86)	.0278 (.27)	.3258 (1.18)	-.1925 (-1.01)	.4521* (1.07)
**(24)	GLS	68-72	122	28.01[2]	.4825[2]	N.S.	-7.33[3]	.0600 (8.08)	.1090 (2.43)	N.S.	N.S.	N.S.
(25)	GLS	73-77	119	1.9859	.7584	.8464	-.0352	.0923 (6.05)	.2150 (1.86)	-.2471* (-.93)	.2450* (1.22)	-.8970 (-3.44)
**(26)	GLS	73-77	120	44.44[2]	.5662[2]	.8313	0.29[3]	.0900 (5.93)	.2660 (2.46)	.0733 (1.55)	N.I.	-.9889 (-3.95)

Where: TDEFRAL - Tons of DEFERRED RAIL.
GTM - Millions of Gross Ton-Miles.
TAVMOW - Average MOW (Thousands of 1967 Dollars)

NOTES: [1] Durbin-Watson statistic.
[2] The standard error of estimate and R^2 are re-computed with untransformed data and placed in parentheses.
[3] Adjusted constant.
[4] t-statistics are given in parentheses below the coefficients.
* - wrong sign.
**Equation includes only those variables whose coefficients are statistically significant and of the correct sign. See text.
N.A. - not available.
N.S. - not statistically significant.

TABLE 3-7. TOTAL TRACK-RELATED ACCIDENTS PER BILLION GTM, REGRESSION RESULTS

	TYPE (1)	PERIOD (2)	DF (3)	STD ERROR (4)	R^2 (5)	D.W.[1] (6)	CONSTANT (7)	DEFRAL (tons/ mile) (8)	AVRLWT (lbs/yd) (9)	CARWT (tons) (10)	AVMOW (1000$ /mile) (11)
(27)	OLS	67-77	270	1.1841	.4125	.4535	-.9634	.0292	-.0254	.0468	-.2348
**(28)	GLS	68-77	245	1.4858 (1.3853)[2]	.4752 (.2278)[2]	1.1727	.3398 [.4862][3]	.0056 (1.96)[4]	-.0089 (-2.10)	.0281 (-4.61)	-.2321 (-3.63)
**(29)	GLS	68-72	121	1.2047 (0.9668)[2]	.4637 (.1854)[2]	1.3201	.1041 [.2464][3]	.0038 (1.17)	*	.0165 (3.82)	-.2605 (-3.17)
(30)	GLS	73-77	120	1.5845	.5157	1.1954	.8083	.0066 (1.46)	-.00084 (-.13)	.0218 (2.5)	-.3776 (-4.33)
**(31)	GLS	73-77	121	1.6265[2]	.2431[2]	N.A.	.7818[3]	.00667 (1.48)	N.S.	.0209 (4.24)	-.3837 (-5.21)

NOTES: [1] Durbin-Watson statistic.

[2] The standard error of the estimate and R^2 a parentheses.

[3] Adjusted constant.

[4] t-statistics are given in parentheses below the coefficients.

* F-test on coefficient too insignificant to allow variable to enter equation.

**Equation includes only those variables whose coefficients are statistically significant and of the correct sign. See text.

N.A. - not available.

N.S. - not statistically significant.

TABLE 3-8. TOTAL TRACK-RELATED ACCIDENTS, REGRESSION RESULTS

	TYPE (1)	PERIOD (2)	DF (3)	STD ERROR (4)	R^2 (5)	D.W.[1] (6)	CONSTANT (7)	TDEFRAL (tons) (8)	CARWT (tons) (9)	GTM (mgtm) (10)	AVRLWT (lbs/yd) (11)	TAVMOW (1000$) (12)
(32)	OLS	67-77	269	64.71	.6526	.6506	-364.41	.1874	2.5448	-.5022*	1.8383*	-.8351
(33)	GLS	68-77	244	1.5181	.7030	1.2859	-.0147	.0908 (3.83)[4]	.8791 (3.14)	.0318 (.23)	-.4531 (-2.2)	.2007* (.37)
**(34)	GLS	68-77	246	73.88[2]	.5679[2]	N.A.	4.5278[3]	.1040 (6.66)	.8679 (3.13)	N.S.	-.4477 (2.2)	N.S.
(35)	GLS	68-72	120	1.0355	.7670	1.8078	-.1058	.0614 (2.34)	0.2671 (3.69)	-.0934* (-.56)	***	.5216* (.62)
**(36)	GLS	68-72	122	57.87[2]	.5874[2]	N.A.	3.1921[3]	.0717 (4.63)	.2509 (3.73)	N.S.	N.S.	N.S.
(37)	GLS	73-77	120	1.6664	.7292	1.1402	.4367	.1078 (2.93)	***	.4003 (1.91)	.2239* (3.31)	-1.3162 (-1.82)
**(38)	GLS	73-77	120	88.92[2]	.5151[2]	N.A.	17.69[3]	.1127 (3.10)	.2876 (3.22)	.3948 (1.88)	N.I.	-1.2738 (-1.76)

Where: TDEFRAL - tons(k) of deferred rail.
GTM - millions of gross ton miles.
TAVMOW - average MOW in Thousands of 1967 dollars.

NOTES: [1] Durbin-Watson statistic.
[2] The standard error of estimate and R^2 are re-computed and placed in parentheses.
[3] Adjusted constant.
[4] t-statistics are given in parentheses below the coefficients.
* wrong sign.
** Equation includes only those variables whose coefficients are statistically significant and of the correct sign. See text.
*** F-test statistic too small to allow variable to enter equation.
N.A. - not available.
N.S. - not statistically significant.

subperiod equations combined. An F-statistic is then calculated. If the value of this statistic exceeds its critical value, then the null hypothesis can be rejected at the stated level of confidence. If the F-statistic is less than the critical value, then the null hypothesis is not rejected.

The unrestricted sum of squares of the residuals of these two sub-periods was compared with the restricted residual sum of squares for the equation covering the entire period. The ratio of these two magnitudes has an F-distribution with k+1 and n_1+n_2-2k-2 degrees of freedom. If the value of this F-test exceeds a critical value, then there has been a significant reduction in the value of the unexplained sum of squares by using the two sub-period equations instead of the total period equation. To obtain the unrestricted residual sum of squares, we estimate each equation separately, get the residual sum of squares for each, and then add them. This has the degrees of freedom $(n_1- k-1) + (n_2-k-1)$ or, simplifying, (n_1+n_2-2k-2). The restricted residual term of squares is obtained from a regression over the entire sample period and has degrees of freedom (n_1+n_2-k-1). Then we apply the F-test

$$F = \frac{(RRSS-URSS)/k+1}{URSS/(n_1 + n_2 - 2k -2)}$$

which has an F distribution with degrees of freedom (k+1), $(n_1 + n_2 - 2k - 2)$[15], and where n and k refer to the number of observations and explanatory variables, respectively.

The results of the Chow Tests are presented in Table 3-9. Structural change is indicated in all of the equations. The F-test statistic for the freight speed equation is 2.233 which exceeds the critical value of 2.01. Thus, the null hypothesis of homogeneity of the coefficients is rejected at the 95% level of

TABLE 3-9. ANALYSIS OF STRUCTURAL CHANGE

DEPENDENT VARIABLE	NO. IND. VARIABLES	RESTRICTED RSS (68-77)	UNRESTRICTED RSS 68-72	73-77	SUM	F-RATIOS CRITICAL	CHOW	STRUCTURAL CHANGE
SPEED	6	4184.5	1877.7	2046.9	3924.6	2.01	2.233	Yes
MOW	5	875.17	312.78	505.24	818.02	2.10	2.771	Yes
RUNNING TRACK: ACCID/BGTM (RATE)	4	505.6	185.3	266.1	451.4	2.21	5.763	Yes
RUNNING TRACK: NO. ACCID	5	836.6	253.66	469.29	722.95	2.10	6.236	Yes
ALL TRACK ACCID/BGTM (RATE)	4	540.9	175.6	301.3	476.9	2.21	6.44	Yes
ALL TRACK NO. ACCID.	4	562.3	128.7	333.2	461.9	2.21	10.433	Yes

Where: RSS is the Residual Sum of Squares.

significance. In the maintenance-of-way equation, the calculated F-ratio is 2.771 and the critical value is 2.10, and the existence of structural change is indicated. Comparison of F-tests in the accidents equations with their respective critical values indicates that structural change also is likely to have occurred. In the running track accident rate equation, the value of the F-ratio is 5.763 compared to the critical value of 2.21. Some possible reasons for the structural change are discussed below.

One cannot infer, without reservation, that the structural change is due to the imposition of safety standards; the strongest statement that can be made is that standards may have affected maintenance-of-way spending, average freight speeds, and accidents.

Structural change implies that there is at least one coefficient in the model that is statistically different in the two time periods. Referring to Table 3-3, equations 4 and 6, we can compare coefficients in the two time periods. The coefficient of SWITCH is reduced by approximately one-half from the first period to the second, going from -.81 to -.42. Given industry average values for SWITCH in the two periods of 9.070 and 8.667, this implies a relative increase in average freight speeds of approximately 3.75 miles per hour. Switching activity declined over time and the relative effect of switching on freight speeds declined similarly.

The coefficient of LOCOPULL more than doubled in the second period, increasing from -1.04 to -2.36. Given average values of LOCOPULL of 1.268 and 1.303, respectively, average freight speed would decrease by approximately 1.51 miles per hour in the second period. The reason for this is not clear, but it is probably not due to the imposition of safety standards. The coefficient of DEFRAIL changed from .0074 to -.0058. Given industry averages of

68.463 and 80.781, respectively, average freight speed would decrease by approximately .98 miles per hour. Thus, the reduction in average freight speeds is due to a decrease in track quality as reflected by an increase in DEFRAIL and a relatively greater reduction in speed for a one ton increase in deferred rail in the second period. This reduction may be due to the imposition of safety standards. However, in neither period was DEFRAIL statistically significant, when all of the variables in the original OLS equation are included.

The coefficient of ACCOST changed from .0391 in the first period to -.0246 in the second period. Given industry averages of $21.664 per MGTM in period 1 and $24.516 in period 2, average freight speeds would decrease by approximately 1.45 miles per hour. This coefficient must be interpreted, cautiously, as it has the wrong sign in period 1, and although it has the correct sign in period 2, it is statistically insignificant. The constant term changed from -1.12 to -.10, implying a 1.02 increase in average freight speeds.

Comparison of model coefficients in the maintenance-of-way equation can be made by reference to equations 10 and 12 in Table 3-4. The coefficient of CARWT is approximately four times larger from 1973 to 1977 than from 1967 to 1972, going from .01 to .04. Using industry averages for loaded car weights in the two periods of 73.2 and 81.9 tons, maintenance-of-way spending would increase by approximately $2544 per mile. The use of heavier cars of capacities approaching 100 tons requires rebuilding the track structure to a higher standard. The coefficient of FUNDS increased by approximately 2/3, increasing to .5522 in period 2, from .3367 in period 1. Using industry averages for FUNDS of $1.424 and $1.262 per MGTM, respectively, maintenance spending would increase by $220 per track mile. This increase in spending may be due to the imposition of federal safety standards, despite the profit squeeze indicated by the decline in available funds per unit of traffic.

The coefficient of RELPRC more than tripled, increasing to -3.4130 in period 2 from -1.0217 in period 1. Using industry average values of 1.023 and .983 in the two periods, maintenance-of-way spending would decrease by $2,300 per track mile. The change in spending is not a result of safety standards, but probably due to a change in the ability of railroads to substitute maintenance-of-way inputs for transportation inputs in the production process. The constant term, which represents the effects of all omitted variables, changed from -.16 in period 1 to -.04 in period 2. This implies a relative increase in maintenance-of-way spending of $120 per track mile.

The structural change in the running track accident rate equation may be analyzed by reference to equations 16 and 18 in Table 3-5. The coefficient of AVMOW changed from -.08 in period 1 to -.26 in period 2. Given industry averages of $2.206 and $2.676 per thousands of dollars per mile of track, respectively, the track related accident rate on running track would decrease by .53 or 48 percent, all else equal. The coefficient of CARWT decreased from .009 to .002. Using industry average values for CARWT of 73.237 and 81.943 tons, respectively, the accident rate would decrease by .50, all else equal. The increase in the constant from .20 to .46 implies that the accident rate would increase by .2451.

The reasons for structural changes in the accident equation are difficult to determine. Part of the explanation may be due to better and more conscientious reporting as a result of the attention given to track related accidents by the FRA. Another reason for structural change may be due to variations in track quality that are inadequately measured by our proxy variable, DEFRAIL. A re-allocation of expenditures from high density lines to low density lines may result in more accidents if the increase in accidents on the high density lines is not offset by the decrease in accidents on the low density lines.

Table 3-10 shows the effects of FRA enforcement activity on maintenance-of-way spending. The variable FINES represents the dollar amount of claims opened against the railroads per mile of track. The coefficient on fines indicates that enforcement activities have had a positive effect on maintenance-of-way spending. The coefficient on FINES indicates that for a one dollar increase in fines per mile, MOW will increase by approximately $28 per mile. The ratio of track miles inspected to total running track miles (TRMLSINS) was used to test for the effects of enforcement activity. The coefficient of TRMLSINS indicates that when this ratio is 1 and the effect of all other variables is held constant, maintenance-of-way spending will be increased by $890 per track mile. t-statistics are not presented in Table 3-10 as the standard errors of the coefficients may be biased downward because of autocorrelation. An insufficient number of years of data prohibited the use of GLS as an estimating technique for this equation.

In summary, structural change was detected in all equations in the model. In the speed equation, changes in the coefficients of variables related to freight train running time may be due to federal safety standards. Changes in the coefficients of deferred rail and average train load pulled per locomotive imply a decrease in average freight speeds, possibly due to standards. In the maintenance-of-way equation a change in the coefficient for funds available for maintenance-of-way per gross ton-mile indicate that a greater portion of these funds are now spent on maintenance-of-way. Again, this change in spending may be due to the safety standards. Structural change in the accident equation may be due to better reporting or due to measurement error in the

TABLE 3-10. OLS ESTIMATES OF MOW SPENDING, 1974-1977, INCLUDING EFFECTS OF FRA ENFORCEMENT ACTIVITIES

DEPENDENT VARIABLE	INDEPENDENT VARIABLES								
	CONSTANT	DENSITY	FUNDS	RELPRC	TRMLSINS	CARWT	DEFRAIL	FINES	R^2
MOW	-.6655	.2092	0.9685	-3.1886	.2239	.0191	.0059	.0281	.54

explanatory variable deferred rail. Deferred rail is a crude approximation of track quality and may not capture changes in track condition adequately. Additionally, there is some evidence that FRA enforcement activity has some positive impact on maintenance-of-way spending.

3.6 DISCUSSION

A model was developed to assess the impact of Federal safety regulations on railroad behavior. In developing the model, careful attention was given to the development of various hypotheses of railroad behavior. Maintenance-of-way spending was hypothesized to be determined by traffic, availability of funds, loaded car weights, relative prices, and the need to perform maintenance as indicated by track quality. Freight speed was hypothesized to be determined by operating characteristics, track capacity and track quality. The track-related accident rate was determined by loaded car weights, average rail weight, maintenance-of-way spending and track quality.

A considerable amount of time and effort went into developing a variable to represent track quality. A number of track quality variables were tried as this variable was important to the model. Deferred rail, as defined by Dyer, provided results that were at least as good as any other variable used to represent track quality, and offered the ability to combine traffic, rail weight, and rail installations over time in a single variable.

The data base was carefully reviewed for incorrect data. Missing data or incorrect data were corrected for the 25 large railroads included in the sample.

Generalized least squares was used to estimate the model, rather than ordinary least squares, to eliminate the dual problems of autocorrelation and heteroskedasticity. The model was estimated over two sub-periods, 1967 to 1972, and 1973 to 1977, and a Chow test conducted to test for structural change in the model coefficients. Structural change was detected in all of the equations in the model.

A railroad's response to safety standards is to either increase its maintenance-of-way spending, reduce freight speeds, or simply ignore them. The implication of this study is that railroads, on an average, have chosen to increase maintenance-of-way spending and also possibly reduce freight speeds, but not necessarily solely in response to imposition of the federal track safety standards.

The results of this study have to be interpreted with some caution. First, the test for effects of Federal safety standards is an indirect test in that there is no variable in the model that specifically represents safety standards. Second, there were several other federal actions which occurred in the same time frame, roughly, as the imposition of the safety standards. These include the 3R and 4R Acts, the latter providing funds for track maintenance and upgrading for CONRAIL and other roads, and various ICC actions, at least one of which was aimed at increasing track MOW spending and revising the squeeze on rates. The effects of these other federal actions may well be equal to or greater than the effects of the safety standards. Finally, there is at least some indication, gained during the industry interviews, that increased MOW spending was diverted to low density branch-line track, against the preference of railroads to rehabilitate mainline track.

A second note of caution regards the data base used to estimate the model coefficients. A model is only as good as the underlying data base used in its estimation. The data used in this study represents aggregation over all lines and segments in a railroad system. The maintenance-of-way spending process probably can be best understood at a micro-level, working with data on a line segment basis. The effects of freight speed and loaded car weight on maintenance can be determined more accurately using site specific data. High density lines will require more maintenance due to greater wear than low density lines. Track quality can be represented more accurately on a site specific analysis than using a crude measure such as system wide deferrals. Additionally, the accident phenomena could better be understood using site data.

At the time of this writing, the railroad industry is undergoing drastic change. The ICC has softened its opposition to mergers and the industry is swiftly restructuring. Additionally, legislation deregulating railroads, i.e., the Rail Act of 1980, has passed Congress and its enactment would give railroads greater flexibility in pricing their services. Deregulation would help the railroads in two ways; (1) it would enable railroads to charge competitive prices, and (2) it would enable railroads to increase prices in accordance with increases in costs. Mergers would allow railroads to increase density through reduction in excess trackage, and in the case of end-of-end mergers, the longer haul should improve service by reducing switching. This service improvement could increase density by increasing traffic. The importance of average traffic density on accident rates, via its influence on MOW spending, is shown in Figure 3-9. The lower curve represents 17 railroads whose densities are greater than 8 MGT annually, while the upper curve represents eight roads with densities less than 8 MGT. The accident rates for the high density roads are both lower and have much less growth, in absolute terms, than the low density roads. Thus, it is clear that traffic density plays a key role in the context of track safety as well as railroad profitability. The key impact of traffic density on future industry track MOW spending, average speeds, and accidents, will be evident in the 1978-90 forecasts, which are discussed in the next section.

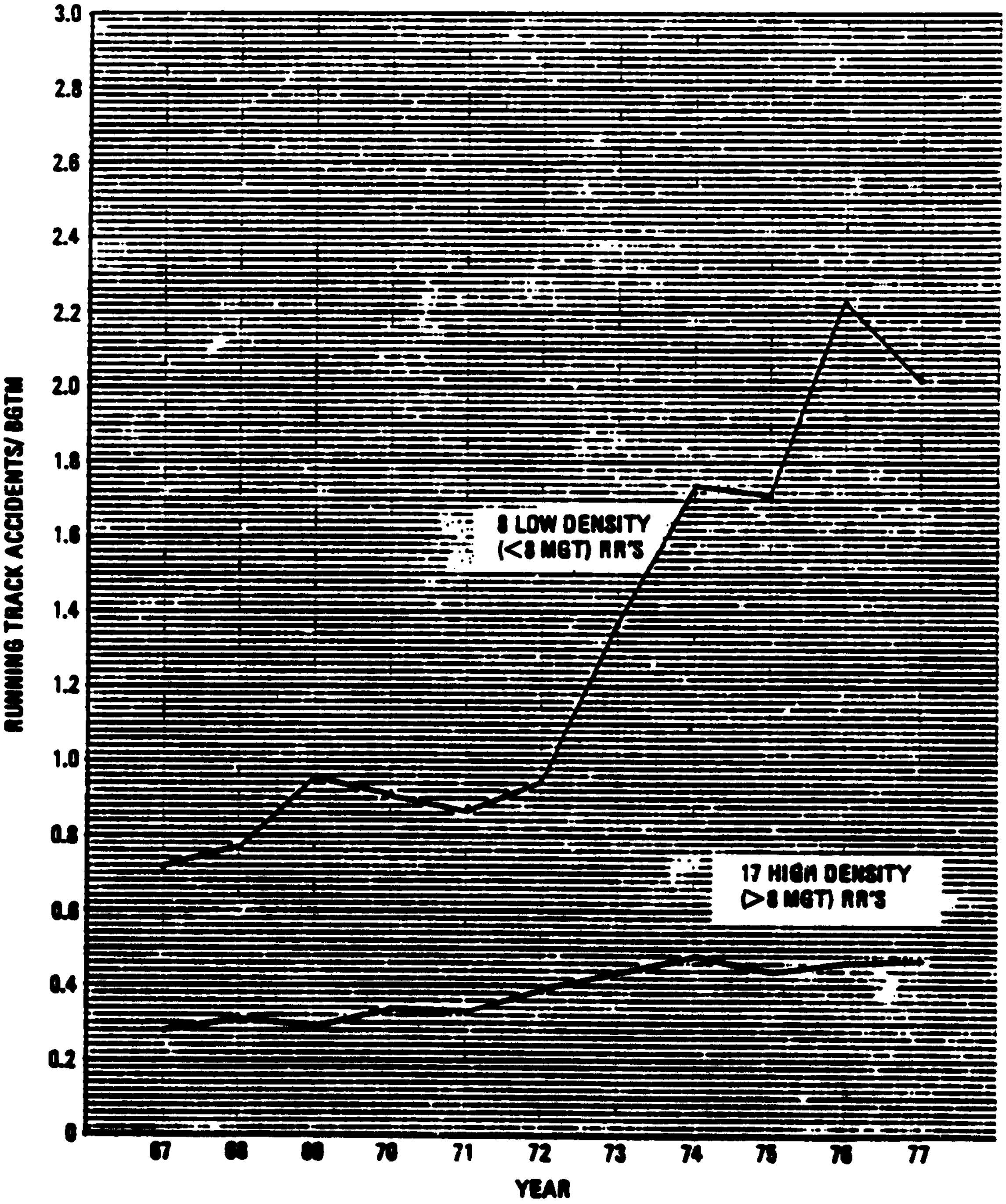


FIGURE 3-9. COMPARATIVE RUNNING TRACK ACCIDENT RATES, LOW VERSUS HIGH DENSITY RAILROADS, 1967-77.

SECTION 4

INDUSTRY RESULTS AND FORECAST

The contract required the development of a forecast of speed, track maintenance spending, and accidents through the year 1990 for the Class I railroads "industry". The twenty five major railroads used as the basis for development of the models previously discussed account for ninety percent of more of the traffic, track miles, and accidents associated with all Class I roads. In addition, the recent ICC change in the definition of a Class I railroad, which raised the operating revenue threshold from $10 million to $50 million, has eliminated about fifteen, or more than half, of the smaller roads from the ranks of Class I railroads. Hence, it would seem reasonable to base the "industry" forecast on averages derived from the same data for the 25 major roads as was used for model development, recognizing in advance that total track maintenance spending and the number of accidents forecasted may be slightly understated.

4.1 COMPARISON OF SIMPLE AVERAGE PREDICTED VERSUS ACTUAL VALUES: 1967-77

Before proceeding to the discussion of the 1990 forecast and the data and model used for its development, it is useful to provide a comparison of the 1967-77 actual values of each of the key variables of interest (speed, track maintenance of way (MOW) spending per equated track mile, and track-caused accident rates) with the results obtained from the predictive models for an "average" railroad. Since the predictive equations for average speed, track MOW spending, and accident rates were based on use of normalized data, the "contribution" of each railroad to the final predictive equations was essentially weighted equally in the regression analysis process. Thus, for direct comparison of actual versus predicted values for an "average" railroad, a simple, unweighted average of the values of each of the independent variables for the 25 roads is most appropriate.

For the sake of comparison, the simple average values for each of the independent variables was calculated for each of the years 1967-77. These average values were applied to the predictive (adjusted-GLS) equations to derive an average predicted value of the dependent variables of interest, for comparison with the similarly computed simple average actual values. The predictive equations used in this comparison were the generalized least-squares (GLS) equations containing only those exogenous variables for which the coefficients were both statistically significant and in the right direction (i.e., of the correct algebraic sign), and whose intercept constants had been adjusted to eliminate the bias introduced by the GLS process, as previously discussed. For the purpose of providing a complete comparison, the calculations were performed using the equations for both the full period ('67-'77) as well as the individual equations for each of the sub-periods ('67-'72 and '73-'77).

The results of the calculations using the simple average values for each variable are portrayed graphically in Figure 4-1. (The reader is reminded that the differences between actual and predicted values is exaggerated due to the expanded scales used, and the fact that the vertical scales do not continue to the origin). Average actual values are connected by a solid line, while the predicted values calculated using the full period equations are connected by a dashed line, and the values predicted using the sub-period equations are indicated by the dotted lines. The equation numbers included in Figure 4-1 identify the specific equations used for the indicated predicted values, with reference to the equation summary tables presented in the preceding section.

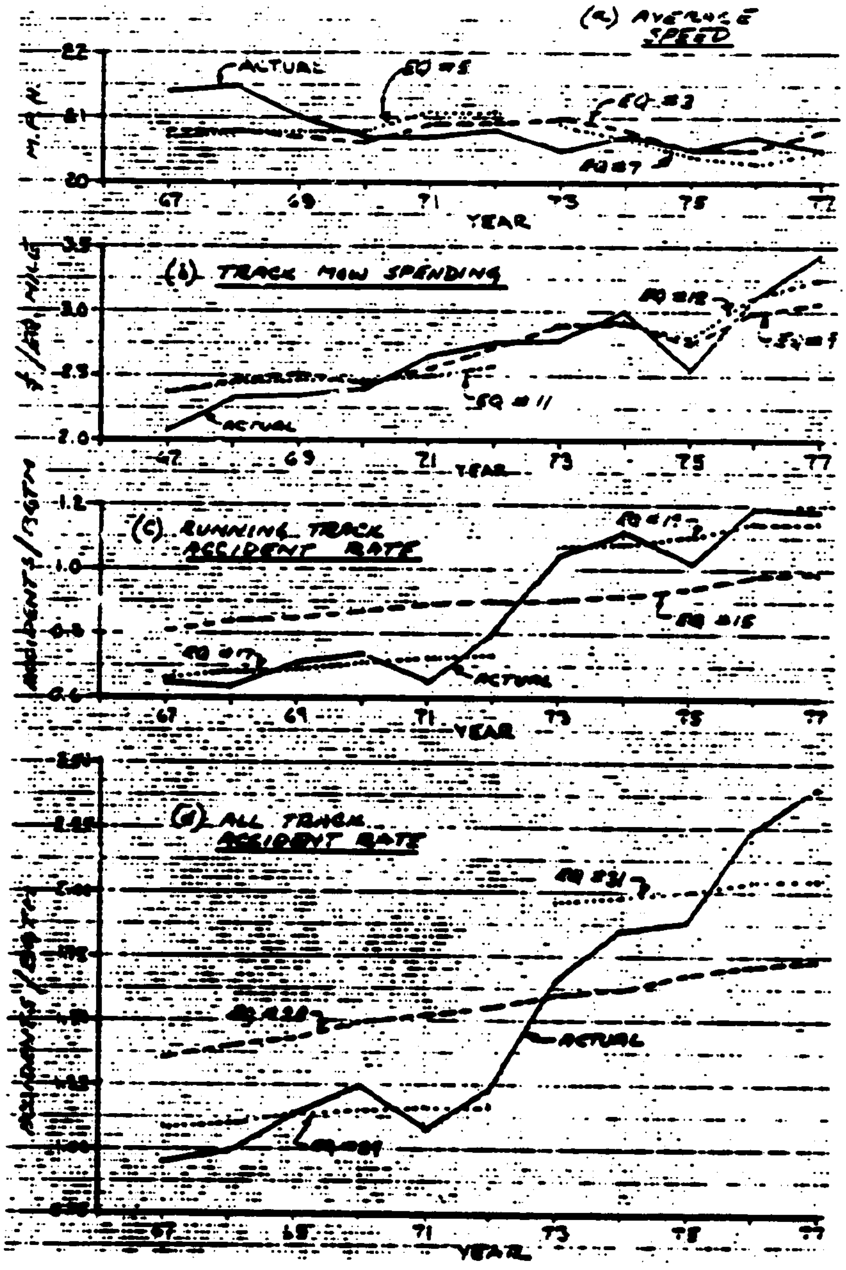


FIGURE 4-1. COMPARISON OF SIMPLE AVERAGE PREDICTED AND ACTUAL RESULTS, 1967-77

The actual and predicted values for both speed (Figure 4-1(a)) and track maintenance spending (Figure 4-1(b)) are in reasonably good agreement, for both the full period and sub-period equations. The results predicted by the full period equation do not differ substantially from the results predicted using the sub-period equations. The maximum error (difference between actual and predicted values) for average speed is 0.7 mph, or about 3.3 percent, in 1968. For maintenance of way spending, the biggest error occurs in 1967, with a difference between actual and predicted of about $290 (0.29K)/equated track mile; in relative terms, the maximum error is about 12.3 percent. No consistent bias is apparent in either the speed or the MOW spending results.

The results for running track accidents are shown in Figure 4-1(c). In this instance, it is much clearer that the effects of the structural change are far more pronounced than those for speed or MOW spending. The full period predictive equation is biased high for the 1967-72 period and low for the 1973-77 period, while the results for individual sub-period equations more closely correspond with the actual values, without consistent bias. The maximum error (in 1971) for the early sub-period is 0.07 accidents/billion gross ton-miles (BGTM)or about 10.8 percent, while for the late sub-period the largest error is 0.08 accidents/BGTM or about 7.8 percent, in 1975, during a recession.

Somewhat similar results obtain for the total track-caused accident rates (Figure 4-1(d)), which include those accidents occurring on both running and yard, industry and way-switching track. Again, the full period equation is consistently biased for each of the subperiods (1967-72 and 1973-77). While the results using the sub-period equations are not obviously biased, the equation (#31) for the 1973-77 sub-period does not reflect the much steeper slope of the actual values; in fact, Equation #31 overestimates the total track-caused accident rate in the earlier part (1973-75) of the subperiod and underestimates the accident rate in 1976-77. The largest error for the early sub-period (in 1967) is about 0.14 accidents/BGTM or about 14.7 percent; for the later sub-period, the largest absolute error (in 1977) was 0.35 accidents per BGTM, or about 14.6 percent.

On the whole, then, the predicted results for an "average" railroad and using the sub-period predictive equations agree reasonably well over the 1967-77 time frame. Use of a single equation for the entire 11 year period provides reasonably good correspondence between average actual and predicted values for both speed and MOW spending, but relatively poor results for accidents. The principal deficient predictive equation is that for the total (running and switching) accident rate for the 1973-77 time frame, which fails to capture the much greater increase in accident rate versus time.

The effects of structural change indicated by the Chow test, described previously, are more dramatically evident with regard to accident rates than with speed or MOW spending; this result could reasonably by expected given the relative strength of the Chow F-test on the accident rate equations compared with the more marginal statistical (F) test results for speed and MOW spending.

4.2 1967-77 WEIGHTED AVERAGE AND 1978-90 FORECAST RESULTS

The comparative results discussed above indicate the relatively good estimating capability of the regression equations for an "average" railroad reflecting the normalized basis for their development. It would seem reasonable to conclude that the equations comprising the predictive model would provide fairly accurate predictions for individual railroads with comparable characteristics.

4.2.1 Data Weights

However, it is not necessarily true that use of simple average values will yield the best estimates for the "industry" as a whole, since the heterogeneity of the railroads has been eliminated (at certainly reduced substantially) by the normalization process. To account for variations in size, both in terms of traffic and track mileage and their combined effects on traffic density (in GTM), weighted average values for each of the independent variables should be employed, thus correcting the normalized results for the relative contribution of considerable variation in size of the 25 railroads comprising the data base upon overall industry results.

The weighted values average values used in the forecast were developed using the weighting factors indicated below:

Independent Variables

Variable	Weighting Factor
Average Haul	BGTM (Billion Gross Ton-Miles)
Tons Pulled/Locomotive	BGTM
Deferred Rail	Running Track Miles
No. Tracks/Route Mile	Running Track Miles
Loaded Car Weight	BGTM
Available Funds	BGTM
Relative MOW/Transportation Prices Ratio	Equated Track Miles
Traffic Density	Running Track Miles
5-Year Average $MOW Per Equated Track Mile	Equated Track Mile
Rail Weight	Running Track Miles

Dependent Variables

Average Speed	BGTM
$MOW/Equated Track Mile	Equated Track Mile
Accident Rates	BGTM

4.2.2 Model Equations

The predicted values for speed, track MOW spending, and accident rates were calculated using the same sub-period equations identified in Figure 4-1 previously, for comparison with the weighted average actual values for the 1967-77 time frame. In addition, the values for MOW spending per mile were extended (multiplied) by equated track miles to estimate total track MOW spending for the 25 railroad "industry", and accident rates were extended using BGTM to estimate the number of running track and total track caused accidents. Finally, the number of running track and total track caused accidents was estimated directly, (using GLS equations #36 and #38 for the 1967-72, and 1973-77 sub-periods, respectively) and estimated weighted average accident rates derived by dividing the number of accidents by the total gross ton-miles for the "industry". The results of this process, to be presented later, for the 1967-77 period provide a basis for evaluating the forecasted results for the 1978-1990 time frame.

4.2.3 Forecast Model Structure

To accomplish the 1978-1990 forecast, a relatively simple computer model was developed. The computer model operates on forecasts of the following variables over time:

- Running Track Miles
- Continuous Welded Rail (CWR) Track Miles
- Switching Track Miles

- Weighted Average No. Tracks/Route Mile
- Total Traffic (in BGTM)
- Weighted Average Haul
- Weighted Average Tons Pulled/Locomotive
- Weighted Average Loaded Car Weights
- Weighted Average Funds
- Weighted Average Relative MOW/Transportation Price Ratio
- Prior 30 Years Annual Weighted Average Deferred Rail/Mile
- Prior 5 Years Annual Weighted Average $MOW/Equated Track Mile

Since deferred rail depends on track MOW spending and other variables and hence should not be forecast independently, it was necessary to develop an estimating equation for rail installed each year. The following equation was developed using ordinary least squares operating on the 25 railroad data base for the years 1973-77:

$$\begin{aligned}\text{AVRAILIN} &= -3.7415 + 0.11022\ \text{DENSE} + 0.72665\ \text{MOW}\\ \text{(Tons/Mile)}\ &-0.017745\ \text{DEFRAIL} + 0.1357\ \text{SPEED} + 0.035408\ \text{CARWT}\end{aligned}$$

The dependent variable in the above equation used a 3-year moving average to reduce the substantial random year-to-year variation in rail installations. The equation includes all independent variables believed to affect rail installations and the coefficients for all variables were statistically significant at the 0.1 level or better.

The forecast model employs only the GLS equations for the 1973-77 time frame, and assumes that further structural change will not occur. A schematic overview of the forecast computer model is presented in Figure 4-2. Note that the model is recursive in

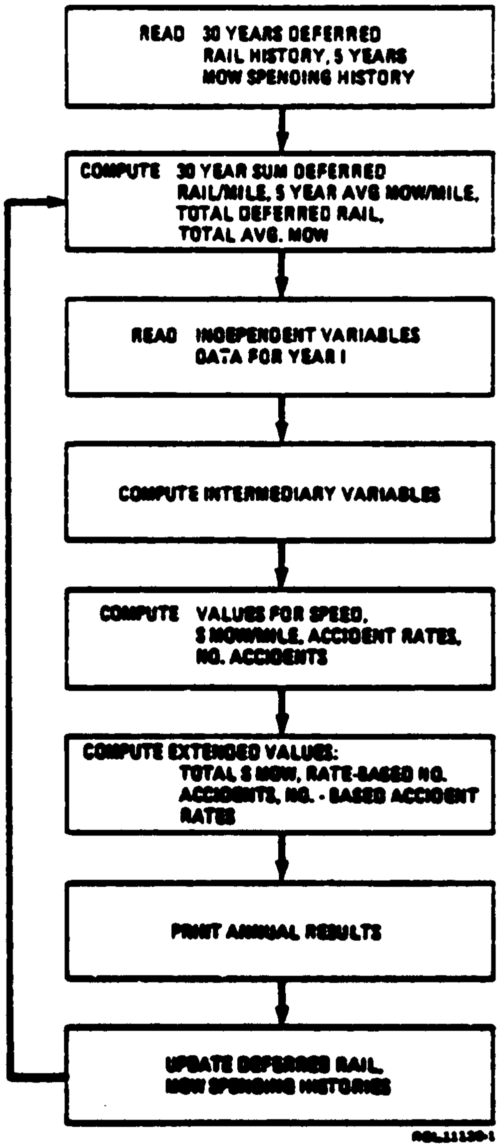


FIGURE 4-2. FORECAST COMPUTER MODEL SCHEMATIC

that the 30 year history of deferred rail and 5 year history of MOW spending are updated annually and the 30 year sum of deferred rail and 5 year average MOW spending re-computed for use in calculating the results of interest (speed, etc.).

Several additional points regarding the forecast model depicted in Figure 4-2 should be mentioned at this point. First, the intermediary values computed are traffic density (MGT), total track miles and equated track miles. Structuring the model in this fashion permits independent estimation of running track miles, switching track miles and total traffic to be used as input data, and thus provides greater flexibility in use of the model.

Next, it is noted that two modes for calculating accident results are used, for both running track and total track. In the first mode, prediction equations are used to directly estimate (weighted) average accident rates, which are then extended to compute the total number of accidents via multiplication of the average accident rates by BGTM. In the second mode, the total number of accidents is estimated directly, and average accident rates derived by dividing the resultant number of accidents by BGTM. These two modes are referred to later as the rate-based and the number-based accident equations, respectively.

Finally, the model obviously could be used for any individual or subgroup of railroads; in the latter case it is important to remember that weighted average data should be employed.

4.2.4 Forecast Data Scenarios

The next topic of discussion is the nature of the underlying scenarios used for the forecast period 1978-90. Two basic scenarios for the exogenous variables were employed, each with two identical variations, for a total of four unique scenarios.

The first scenario assumes that the 1977 Status Quo will be extended through 1990, except for two variations in funds available per BGTM. That is, the 1977 Status Quo Scenario assumes that the values of the independent variables such as loaded car weights, relative prices, rail weights, track miles, traffic levels and the like will remain fixed at the 1977 weighted average values throughout the 1978-90 time period The second major scenario assumes, essentially, a basic continuation of the trends evident in the 1967-77 time frame, but with slightly more rapid track abandonment and moderately increased traffic growth which may be possible via effective marketing and railroad operations believed readily achievable under deregulation. This latter scenario, referred to later as the Continue 1967-77 Trends Scenario, recognizes the massive inertia and basic conservatism of the railroad industry and its regulatory (including Congress, DOT, and state governments as well as the Interstate Commerce Commission (ICC) and operating environments, including intra and intermodel competition, slow technological change and the like. Hence, it is postulated that track abandonments and traffic growth will proceed gradually over the next decade or so rather than abruptly in two or three years.

Each of the major scenarios summarized above is subject to two variations in funds available per million gross ton-miles (defined as [Gross Operating Revenue - Operating Costs + MOW Spending]/Traffic). This variable, which could be considered as gross margin available for application to fixed costs (including track maintenance) and profits/taxes, on a per ton-mile basis, reflects both changes in transportation efficiency and rate regulation. Generally, available funds per gross ton-mile have been declining at least since 1967, despite improved transportation operating efficiencies, on a real basis (after adjustment for inflation). This squeeze on marginal profits, then, can be viewed as the result of a combination of ICC rate regulation coupled with strong truck and intra-industry competition plus operating inefficiencies such as excessive circuity and archaic work rules within the industry itself. The first variation on each major scenario assumes a continued gradual decline (deterioration) in the funds available variable, while the second variation assumes a gradual increase (improvement) in this variable. The latter variation is assumed to be principally the result of rate deregulation and gradual exploitation of rate setting freedom by the railroads rather than major improvements in technology or labor relations.

The weighted average data used in the calculation of weighted average results and the extrapolated trend data used in the forecast are portrayed graphically in Figures 4-3 to 4-8. Actual weighted average values are connected by solid line while the projected values are connected by dashed line. It is believed that the projected variables are reasonable in the absence of major technological, institutional or other significant sources of structural change.

4.2.5 Discussion of Results

In order to fully understand and evaluate the forecasted 1978-1990 results, it is useful to also present the 1967-77 predicted and actual values, developed on the basis of the weighted average data portrayed in Figures 4-3 through 4-8. Thus, in the discussion which follows, the results will be presented graphically over the entire 1967-90 time frame. It is noted, however, that only the 1978-90 results utilize the forecast model of Figure 4-2 and the extrapolated weighted average data; 1967-77 results use both the 1967-72 and the 1973-77 sub-period equations, together with the actual weighted average data.

Speed - The first result to be examined is average speed, for which results are plotted in Figure 4-9. For the 1967-77 time frames, the predicted values are consistently higher than the weighted average actual values, with both weighted average pre-

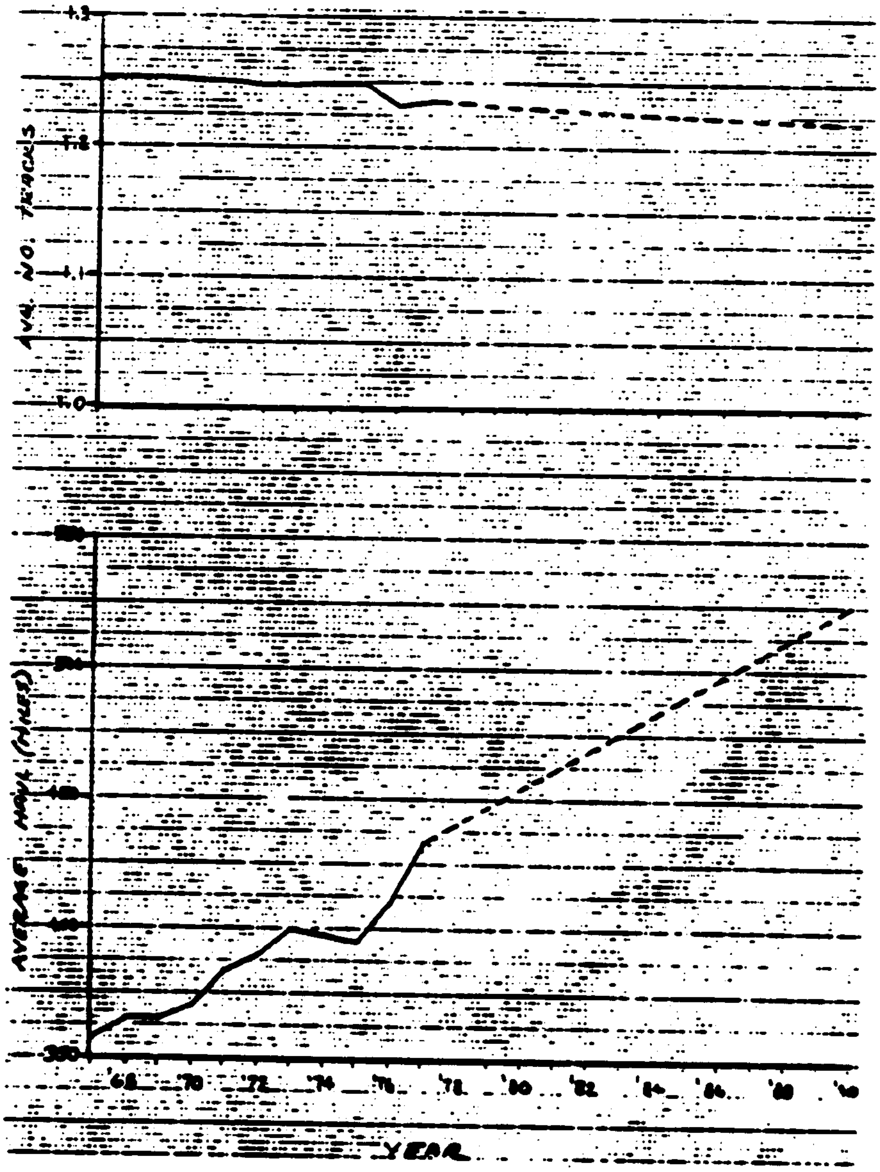


FIGURE 4-3. WEIGHTED AVERAGE NUMBER OF TRACK/ROUTE MILE AND AVERAGE HAUL OVER TIME, 1967-1990

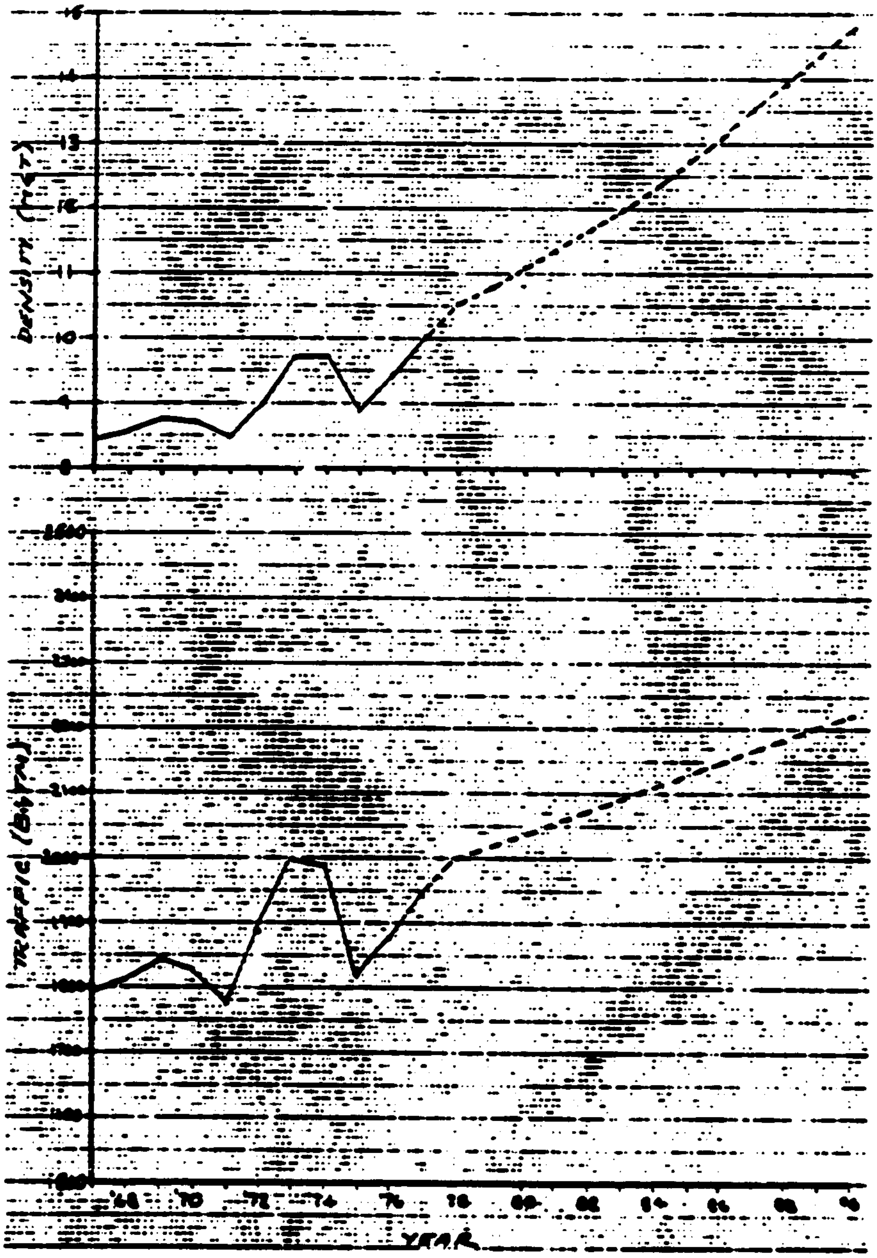


FIGURE 4-4. TOTAL TRAFFIC (BGTM) AND AVERAGE TRAFFIC DENSITY OVER TIME, 1967-1990

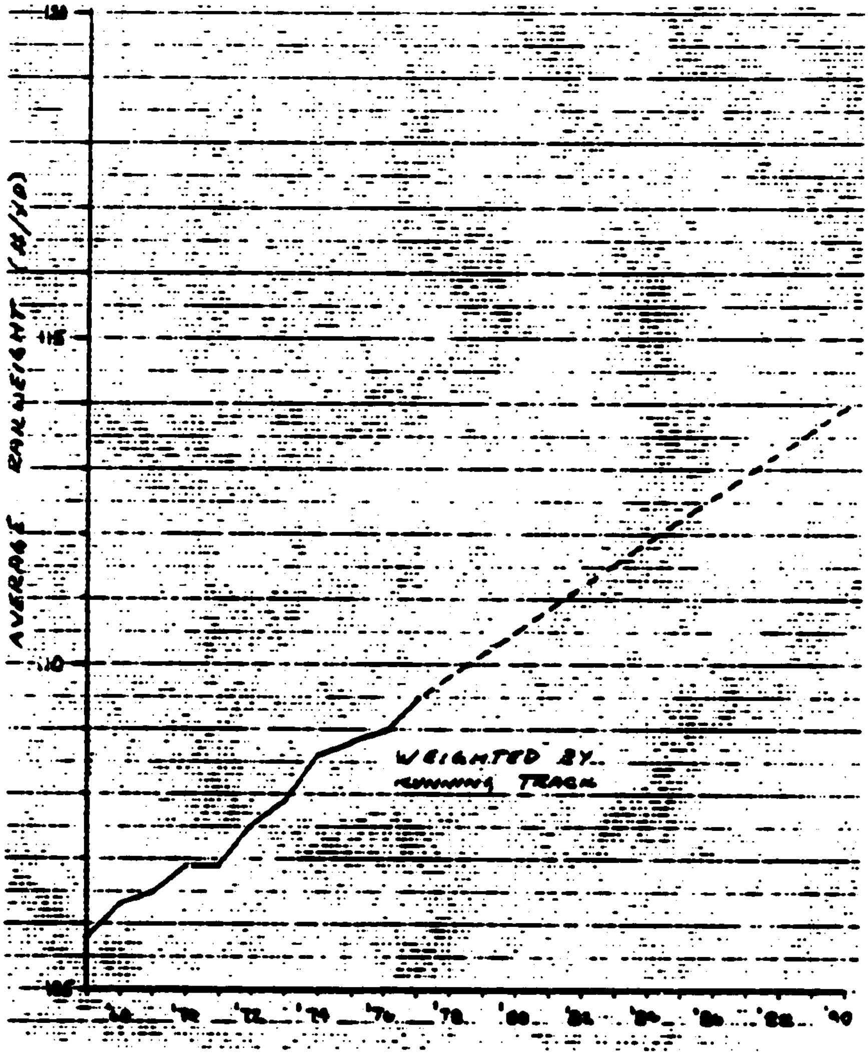


FIGURE 4-5. WEIGHTED AVERAGE RAIL WEIGHT OVER TIME, 1967-1990

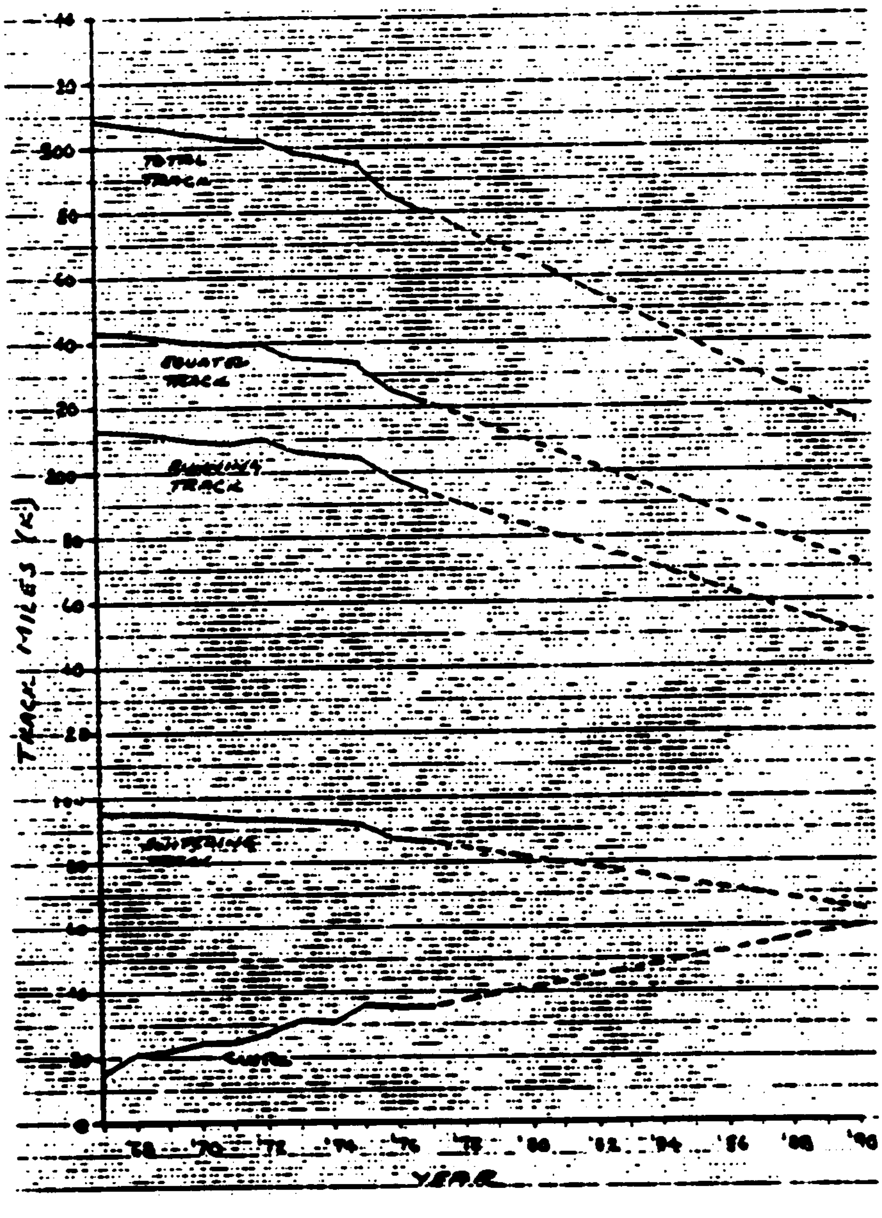


FIGURE 4-6. MILES OF TRACK AND CWR OVER TIME, 1967-1990

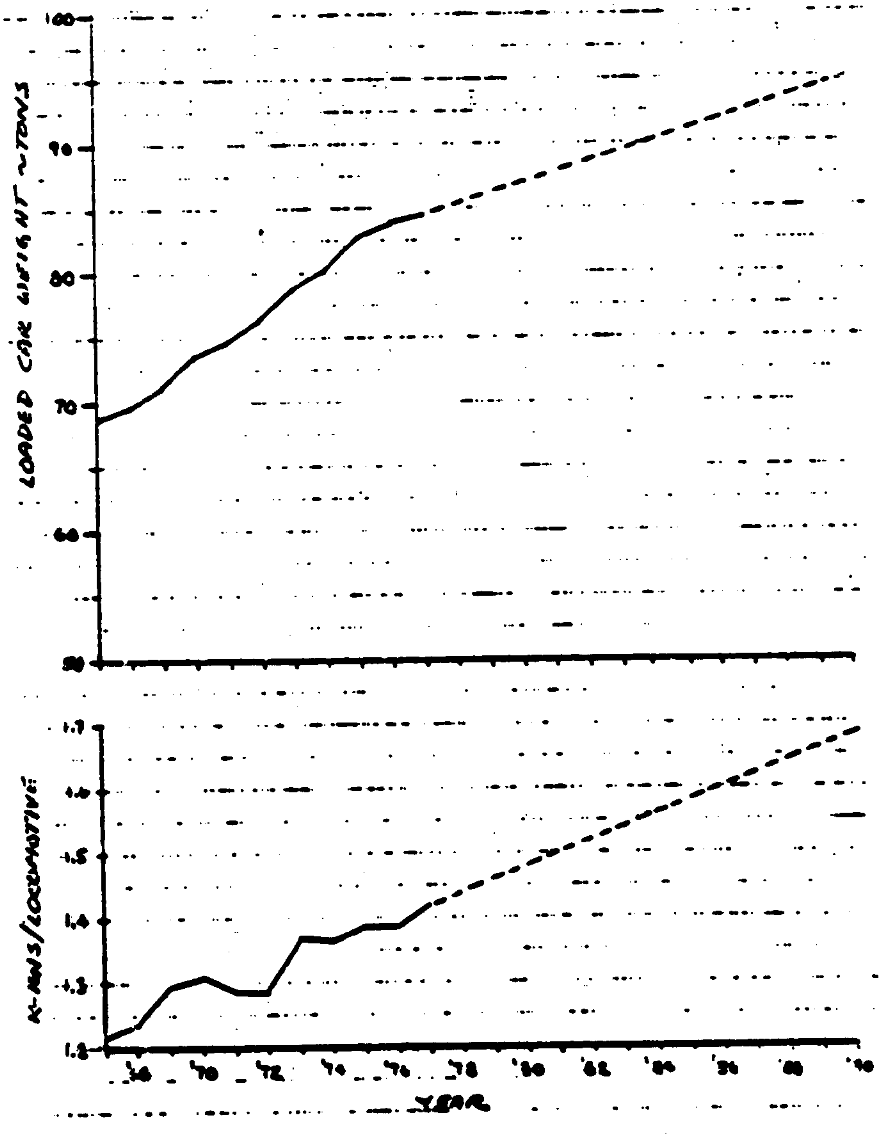


FIGURE 4-7. WEIGHTED AVERAGE LOADED CAR WEIGHTS AND TONS PULLED PER LOCOMOTIVE OVER TIME, 1967-1990

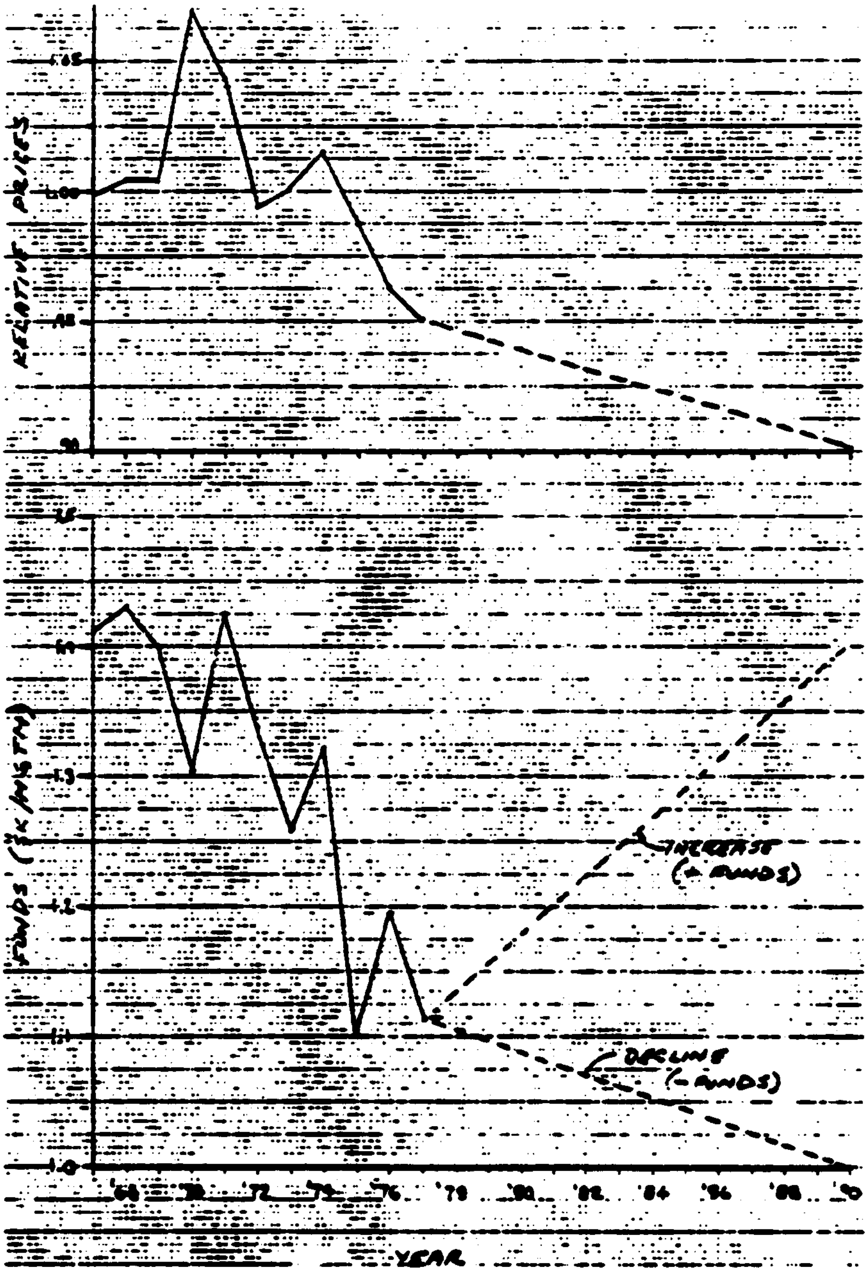


FIGURE 4-8. WEIGHT AVERAGE RELATIVE PRICES (COSTS) AND FUNDS (MARGIN) OVER TIME, 1967-1990

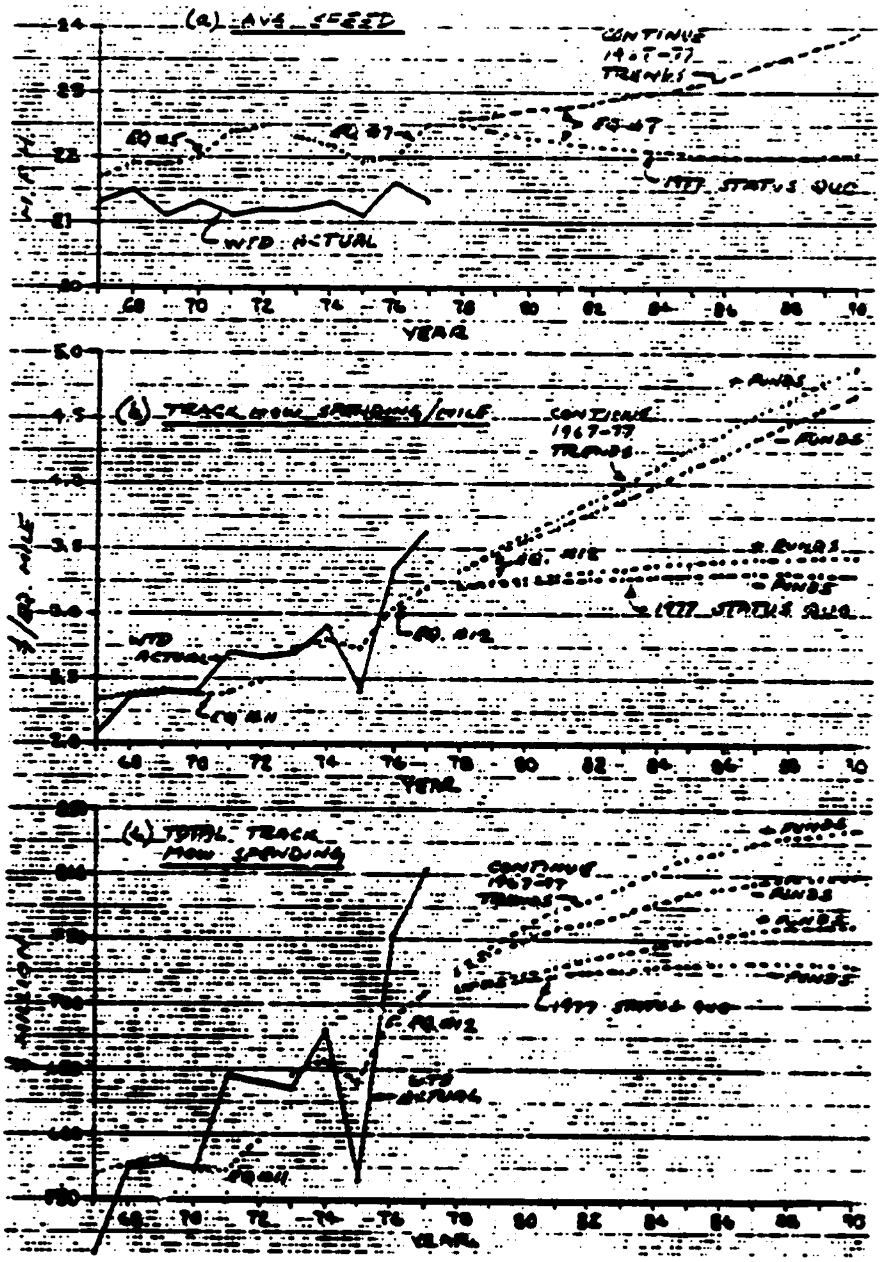


FIGURE 4-9. WEIGHTED AVERAGE SPEED AND MOW SPENDING, ACTUAL AND PREDICTED 1967-77 AND FORECAST 1978-90

dicted and actual values higher than the simple average actuals presented previously in Figure 4-1. This rsult obtains due to the major influence of the western roads, which tend to be large, higher density, longer haul operations and, as a consequence, better maintained (lower deferred rail per mile). The discrepancy between weighted average predicted and actual is generally less than 1.3 mpn (or 6 percent) and is a result of using normalized values to estimate the predictive equations and is not considered important.

The forecast values of weighted average speed for the 1978-90 time frame are divergent for the two major scenarios considered; the effcts of the available funds variations on the results for each scenario were essentially negligible.

The divergence in speed versus time trends evident for the two scenarios can be explained by the following rationale. In the 1977 Status Quo Scenario, the only variable in the speed equation which changes over time is deferred rail; all others are held constant via the input data reflecting the basic assumption of the scenario. However, the 1977 Status Quo Scenario results in only minimal increased MOW spending per mile (see Figure 4-9(b)), resulting in gradually increased deferred rail (declining track quality) until the late 1980's, when the small annual increase in MOW spending over time gradually stabilizes and then starts to improve track quality.

The increased average speeds resulting from the Continued 1967-77 Trends Scenario, on the other hand, is a consequence of the combination of several favorable factors, offset by one unfavorable factor. First, in this scenario, average haul continues to improve, contributing directly to improved average speed. Improved average haul also can have an indirect contribution to speed via reduced switching costs on a gross ton-mile basis and hence increasing funds available for MOW spending and consequent small improvements in track quality; this indirect effect, however, was not considered in these results. Perhaps more important than improved average haul is the increased traffic density resulting from the traffic growth and track mileage reduction postulated in this scenario; the increased density results in increased MOW spending because more total dollars are available, leading to improved track quality despite the greater wear rate induced by the higher tonnage. That is, the increased MOW spending resulting from increased traffic density improves track quality to a greater degree than the decline in track quality generated by the wear induced by the higher density. Also contributing to higher MOW spending in this scenario is the further growth in loaded car weights. Unfortunately, however, it was not possible to include the effect of loaded car weight on track quality (deferred rail) directly; only by inclusion as a major factor in the accident equations is there indication of an effective reduction in track quality vis a vis the demands placed on track by heavier cars. However, it is now becoming quite evident that 100 ton capacity loaded crs have substantial deleterious effects on the short and long run quality of the existing track structure. The gains in speed obtained via the improved average haul and track quality obtained by traffic density is offset somewhat by countervailing trend, that of increasing tons pulled per locomotive.

In summary, the increased speeds indicated by the Continue 1967-77 Trends Scenario are principally the result of improved average haul and increased MOW spending induced by higher traffic densities and loaded car weights, offset somewhat by increased tons pulled/locomotive. The magnitude of the speed increase is likely somewhat overstated, however, since the effects of loaded car weights on long term track quality (via deferred rail) are not included in the model.

MOW Spending - Turning now to MOW spending, on both a per equated track mile and total (constant) dollar basis, the actual and predicted weighted average values will be compared first. Figure 4-9(b) shows the trends over time on a per mile basis, while the total MOW spending situation is presented in Figure 4-9(c). For the 1967-77 time frame, and particularly for the 1972-77 sub-period, the weighted average predicted and actual values are in reasonably good agreement, without consistent bias. In the 1973-77 time frame, the predicted values tend to be more stable (i.e., less dramatic swings up or down) than the actual, but this behavior is generally the case with regression analysis of this kind. The smaller response of the predicted value to the 1975 traffic decline caused by the recession, compared with the actual, may be the consequence of the normalizing process or possibly inadequate sensity (coefficient to small) for the density variable in the predictive equation. The relatively large errors in 1976 and 1977 may also be a consequence of the normalizing process or lack of adequate sensitivity to the density variable; however, the underestimation of MOW spending in those years are more likely the consequence of federal cash infusions to CONRAIL and preference share/loan guarantee financing for a few other roads provided under the 4R Act passed into law in early 1976.

The MOW spending forecast throught 1990 exhibits divergent trends between the two principal scenarios. Under the 1977 Status Quo Scenario, annual MOW spending would increase very gradually; since all variables except deferred rail are held constant in this scenario, the increase in MOW spending is in response to continued deterioration of track quality. The leveling off which occurs in the late 1980's indicates attainment of an equilibrium point achieved by balancing the deferred maintenance subsequent to 1950 or so with expenditures perhaps in excess of long term requirements in the late 1970's and throughout the 1980's.

The continued substantial increase in MOW spending/equated track mile projected under the alternative Continue 1967-77 Trends Scenario is driven principally by the postulated increase in traffic density and loaded car weights, which are offset somewhat by reduced deferred rail demands. As previously indicated, however, deferred rail calculations do not include the deterious effects of high loaded car weights, such that deferred rail in the later years is likely understated, leading to a probable understatement of the projected MOW spending for this scenario. In 1990, the difference in annual MOW spending/mile between the two alternatives would be about 40 percent.

For total MOW spending, the 1977 Status Quo results are a direct one-for-one consequence of the increase in spending/mile, because track miles are held constant under this scenario. The total MOW spending under the alternate scenario exhibits a tendency to level off, i.e., the annual rate of increase declines over time. This behavior is due to the assumed continuing decline in track miles, a decline which though less rapid than the increase in per mile spending has cumulative effects because the percentage reduction in track miles increases with time when the absolute reduction in miles/year is held constant. The difference in annual total spending projected by this model in 1990 for the two alternative scenarios amount to about $75 million (in 1967 dollars) or about 10 percent annually; the cumulative effect of the spending difference would be more substantial.

The effects of the two funds availability variations on the basic scenarios is also quite evident and significant. Clearly, as would be expected, higher gross margins via improved rates and transportation efficiency would lead to greater MOW spending. The funding variations have a greater effect, in absolute terms, on the results based on the Continue 1967-77 Trends Scenario, but in relative (percentage) terms the effects are slightly greater in the 1977 Status Quo Scenario, a result which should be expectd since there is no other source of additional funding under this scenario, whereas in the alternative, higher density provides more dollars directly.

Probably the most important consequence of the two scenarios effects on MOW spending is the impact on track quality, for which the 30 year sum of deferred rail serves as a surrogate in this analysis. Under the 1977 Status Quo Scenario, deferred rail continues to increase, indicating a decline in track quality, until a sort of equilibrium occurs in the late 1980's. The alternate scenario, however, implies a gradual but accelerating improvement in track quality (decline in deferred rail), absent effects on continued increases of loaded car weights on track quality not included in this model. This implications of the MOW spending consequences of the two alternative scenarios on average speed (via deferred rail as a surrogate for track quality) have already been discussed. The further implications of MOW spending on accident rates and number will be addressed next.

Accidents - The explanatory power of the accident rate equations is considerably less than that for the speed and MOW spending equations, due to several factors. First, accidents occur on a random basis and seem to be related to very local track conditions. The data available for this research provides only an implied general track quality based on system-wide aggregate data, principally rail (and tie) installations. Due to multicollinearity problems, whereby rail and tie installations tend to move together both in time and cross-sectionally, the separate effects of each could not be determined by the statistical techniques currently available. As will be shown in the discussion which follows, the weighted average accident results are somewhat less accurate and credible, in absolute terms, than the speed and MOW spending results. However, the forecast results do provide at least a better understanding of the interplay of a few of the factors associated with accidents on an overall system basis.

As indicated previously, there are two methods employed in the model prediction and forecast of the accident rates and number of accidents for running track and all track. These two methods have been identified previously as the rate-based mode and the number based mode. The relative efficacy of the two methods for application to weighted average industry predictions and forecasts will be evident in the following.

Running Track Accidents - Figure 4-10(a) shows the results of the two approaches to accident rate (per BGTM) estimation for running track, while Figure 4-10(b) shows the results in terms of estimating the total number of running track accidents. In terms of comparing predicted versus actual accident rates over the 1967-77 time frame, the number-based mode is clearly superior in terms of overall accuracy (difference between actual and predicted). For the 1967-72 sub-period, the accident rate derived from direct estimation of the number of accidents consistently underestimates the actual values, while for the 1973-77 sub-period, the predicted values run through the middle of the actual values. In the latter sub-period, the maximum error in accident rate using the number-based method is - 0.6 accidents/BGTM, or about - 8.6 percent. On the other hand, the rate-based equations yield estimates which are substantially higher than the actual values, generally about 0.2 accidents/BGTM in the early sub-period and 0.27 or so in the later (1973-77) sub-period. However, the rate-based equations seem to correspond better in shape to the actual number of accidents; that is the rate based equations are more sensitive to variations in traffic level. The difference in results is due to the use of normalized data for the rate-based equations and non-normalized data for the number-based equations, in the latter

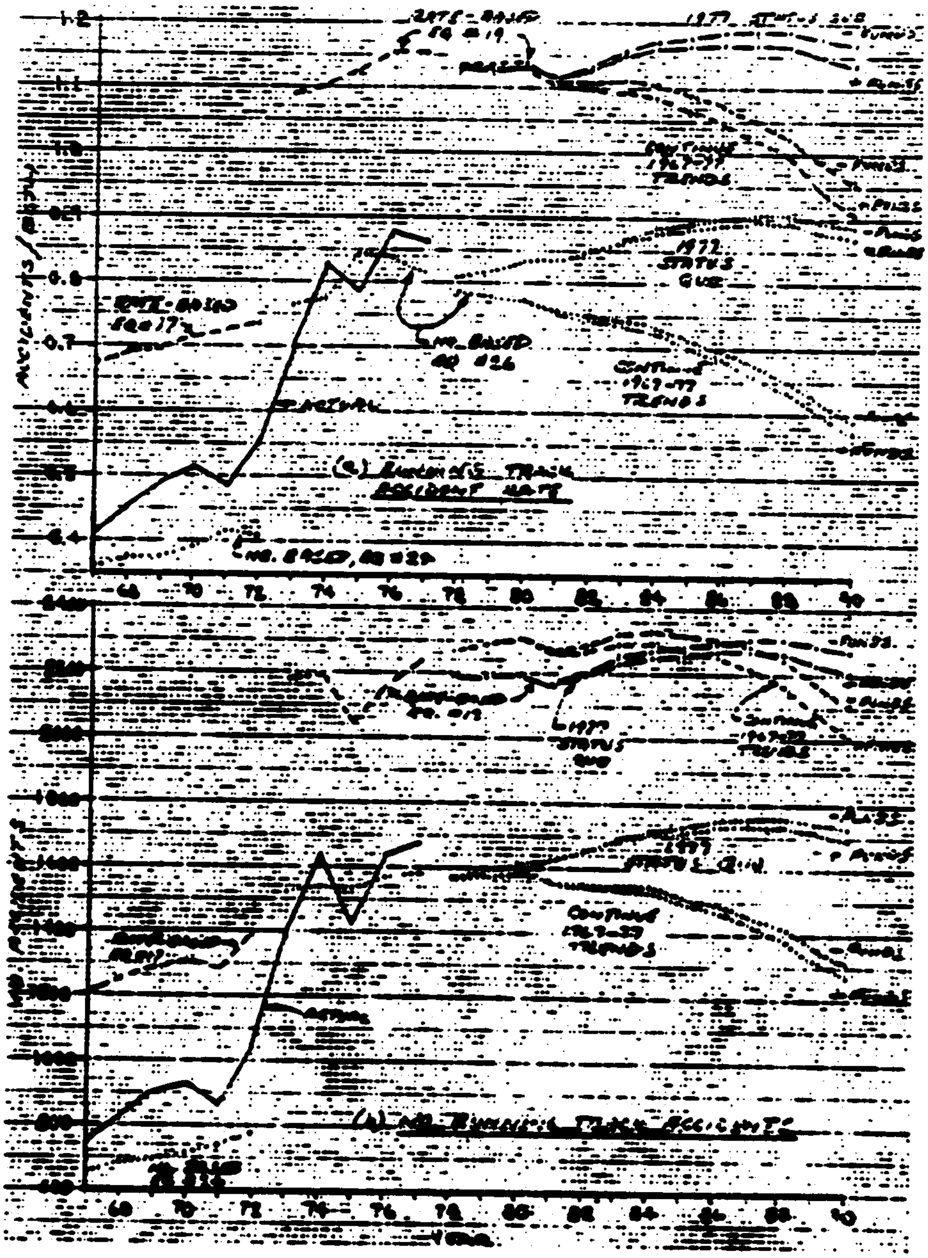


FIGURE 4-10. WEIGHTED AVERAGE RUNNING TRACK ACCIDENT RATES AND NUMBERS, ACTUAL AND PREDICTED, 1967-77, AND FORECAST 1978-90

case the effects of size are explicitly taken into account, although the change in variance (squared error) with size has been essentially eliminated by the GLS procedure.

Turning to the forecasted results, continuation of the 1977 Status Quo would be expected to yield increasing accident rates and number of running track accidents until the later 1980's. Since track miles, loaded car weights, and traffic are held constant, the only variables which change over time in this scenario are the 5-year average MOW spending and its effect on deferred rail. As previously discussed, annual MOW spending only increased very gradually over this time frame, and thus MOW spending will also increase only slowly. (Incidentally, the dip in the rates-based results which occurs in 1981 is due to the elimination of the dip in MOW spending which occurred in the 1975 recession from the 5-year average.) Thus the gradual increase in MOW spending is insufficient to halt the upward climb of deferred rail until the mid-to-late 1980's, and the effects of deferred rail are greater than the short-term effects of increased MOW spending. The rate-based equations suggest that running track accident rates will peak in 1987-88 at a level 3-4 percent higher than those predicted for 1977, under the 1977 Status Quo Scenario. By contrast, the number-based rate results suggest a peak at about the same time but 12-14 percent higher than that predicted for 1977. The corresponding number of accidents for the 1977 Status Quo Scenario are similar since traffic is held constant.

For the alternative scenario, continued 1967-77 trends, both equations suggest a strong downward trend in accident rates. This occurs because of the increased MOW spending which results from this scenario, as previously discussed. The effects of the dramatic increase in MOW spending on accident rates are two-fold. First, the long term effects on track quality, for which deferred rail is a surrogate, is driven down through increased installation of new rail. Second, and complementing the reduction in long-term deferred rail, the short term beneficial effects of 5-year average MOW spending are increased. Taken together, the combination of the short and long term effects of increased MOW spending per mile result in a continuing improvement in track quality which accelerates with time, leading to continually improving rate of decrease in the accident rates. The decline in accident rates for this scenario may, however, be overstated since the effects of increasing loaded car weights on track quality (deferred rail) are not captured by this model, as previously discussed. On the other hand, the direct adverse effects of the increased loaded car weights are included in the model, and offset some of the benefits of the reduced rail deferrals and short-term MOW spending.

Another factor in the favorable consequences of the continued trends scenario is the assumed continued gradual increase in average rail weight, both via installation of heavier rail on mainline track and abandonment of low density branch line and switching track, both of which usually have light rail installed. Although rail weight is not used directly in calculation of the end results, it is used in the calculation of deferred rail. However, since average rail weight is assumed to increase less than one half pound/yd per year (on a base of 109.8 lbs/yd in 1978), the annual contribution of increased rail weight in reducing deferred rail is small, but cumulative over the full period).

The effects of the variations in available funds (gross margin) on accident rates and numbers is relatively small but significant. Generally, the absolute effects of the variations in funds is greater for the rate-based equation results. In 1990, the difference in the rate-based results for accident rates is about 0.04 accidents/BGTM or about 4 percent. For the number-based accident rates, the difference in results, on an absolute basis, is about 0.02 accidents BGTM, but the relative difference is about the same (4%).

With respect to the number of running track accidents, the results for 1977 Status Quo Scenario directly reflect the corresponding results previously discussed for accident rates because traffic level is held constant at the 1977 level. The effects of the Continue 1967-77 Trends scenario are slightly different for the number of accidents as compared with accident rates, due to the more rapid percentage increase in traffic compared with the slower decrease in accident rates in the early 1980's. The rate-based forecast for accident rates yields essentially constant values of the accident rate for the 1981-83 time frame; since traffic levels are increasing during this period, the number of accidents also increases, peaking in 1984 and declining thereafter, somewhat slower than accident rates due to the offsetting influence of increased traffic levels. The predictions using the number-based mode exhibit a continuing and accelerating decline commencing in 1981, again with the effects of the more rapid decline in accident rate offset somewhat by increasing traffic levels.

Total Track Accidents - The last items to be discussed are the actual and estimated values, predicted (1967-77) and forecast 1978-90), for accident rates and number of accidents for both running and switching track combined (total track). These results are presented in Figure 4-11.

In terms of the ability to replicate actual results during the 1967-77 base periods, the rate-based predictive equations for total track accidents and accident rates are relatively poor, both in terms of bias and in inability to capture the steep increase which occured in the 1973-77 period. The number-based equations, on the other hand, provide unbiased results, but do

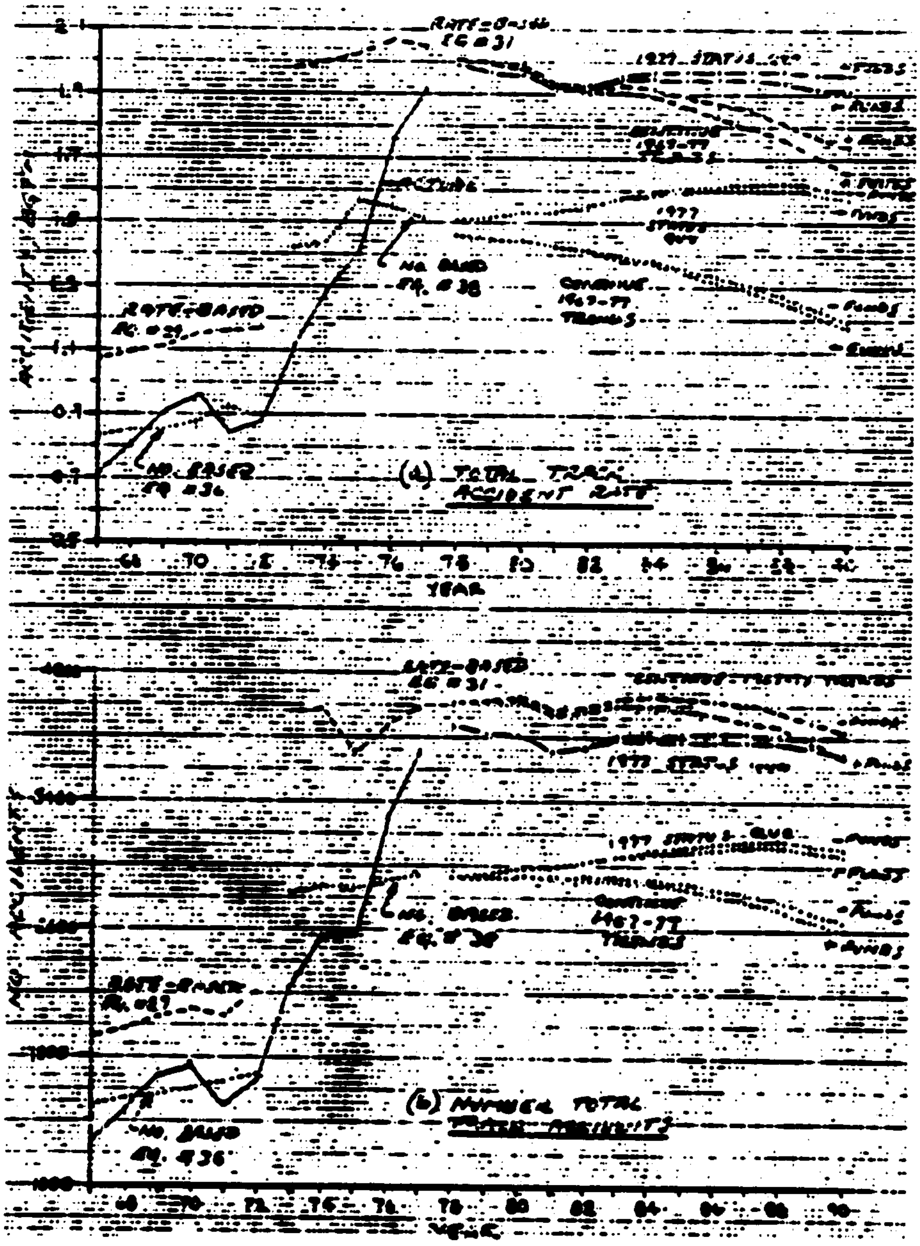


FIGURE 4-11. WEIGHTED AVERAGE TOTAL TRACK ACCIDENTS, ACTUAL AND PREDICTED, 1967-77 AND FORECAST, 1978-90

not capture the steep slope exhibited in the actual values. The relatively poor performance of the predictive model during the 1973-77 period strongly suggests that the absolute values of the forecast total accident rates and numbers of total track-caused accidents be treated with a high degree of caution. The trends (rather than magnitudes) evident in the forecast values may have somewhat greater credibility, but only marginally so and should also be used with caution.

The results for total track accident rates and numbers are portrayed in Figure 4-11(a) for rates and 4-11(b) for number of accidents. For accident rates during the 1967-77 base period, the rate based equations yield results that are consistently overestimated compared with actuals, while the number-based predictions do not exhibit consistent bias. While the slopes of the predicted values correspond roughly with the slope for the actual values in the 1967-72 sub-period, the slopes for the predicted values in the 1973-77 period are much flatter than the steep slope for the actual values. It is noted that the steep slope in the running track accident situation occurs principally between the years 1972 and 1973, and, in reality reflects a structural shift in the intercept value rather than a continuing trend; hence, the trends evident in the running track accident forecasts, if not the absolute magnitude of the forecast values themselves, can be considered as reasonably reliable.

In the total track case, however, the steep slope of the actual accident rate values is nearly linear throughout the entire 1973-77 period. Since the accident rate for running track is much flatter during this period (evident in the previous Figure 4-10 despite a 2X difference in scale), the steep slope of the total accident rate in the 1973-77 period is due mostly to a dramatic increase in switching track accidents, particularly in yards. It is noted that the deferred rail variable used in the predictive equations for both running track and total track accidents is the same, i.e., for running track only. Use of only running track deferred rail for all track accidents was based on the consideration that about half of the total accidents occurred on running track and on the rationale that railroads with high values of deferred rail on running track would also have high deferred rail on switching track due to the rail cascading process commonly practiced by all railroads. Apparently, the total track regression results were dominated by the running track situation, even though the proportion of running track accidents to total track accidents declined from 63 percent in 1973 to about 45 percent in 1977. Clearly, either a major explanatory variable has been omitted from the total accident predictive equations or the results are overly influenced by running track accidents. In retrospect, better results, in terms of a closer match between actual and predicted values and at least reasonable agreement on the slope characteristics, may have been obtained if the analysis focussed directly on switching track accidents per se rather than on total track accidents.

Given the poor predictive power of the total accident equations, further detailed discussion is not warranted. Of the two basic approaches, the number-based forecast results would appear to be more credible, at least in relative trend terms, although the absolute magnitude of the predicted values are likely substantially underestimated. The initial decline and subsequent leveling off of the rate-based results are simply not believable given the actual value trend for the 1973-77 time frame, although the rate based equations seem to yield better results with respect to the level of the absolute values.

Finally, the divergent characteristics of the two alternative scenarios and their funding variations are similar in behavior to those obtained for running track, and can be evaluated in the same fashion; it is likely, however, that the peak in total accident rates and numbers would occur later than those for running track alone since railroads give priority in track maintenance resource allocations to mainline and important branchlines compared with switching track, with the possible exception of key yards whose deterioration could have substantial impact on operations in a major fraction of the system.

4.3 SUMMARY

Based on the results and assessments presented above, it is apparent that reasonably accurate estimates for speed, MOW spending and running track accidents - rate and number - can be derived using the equations developed as described in the previous section. The results are quite accurate when simple average data are used for the exogenous variables, with good agreement obtained between predicted and actual values when both are based on simple average data. Thus the equations comprising the model would likely provide reasonably accurate results for individual railroads.

When weighted average data are used, reasonably good agreement is still obtained between predicted and actual values for speed, MOW spending and running track accidents. For the 25 railroad "industry", however, predicted speed is slightly biased toward overestimation compared with weighted average actual values. Estimates of MOW spending are unbiased, however. Of the two approaches to running track accident prediction, for the 25 railroad "industry", the use of the number-based equations would appear to be preferable to the rate-based equations.

The predictive equations, for total track accidents are relatively poor, using both simple average and weighted average data, since they fail to capture the steep climb in switching track accidents evident commencing in 1973.

The forecast model, for which a simple computer model was developed and used to perform all calculations for the 1978-1990 forecast period, seems to provide a useful tool for overall policy evaluation at an industry level using weighted average input data. The potential application of the forecast model to individual railroads or groups of railroads was also identified but not explicitly evaluated.

The computerized forecast model was used to evaluate two principal alternative scenarios; the first assumed extension of conditions extant in 1977 unchanged throughout the 1978-90 time period, while the second asssumed, essentially, a continuation of the trends evident in the 1967-77 time frame but with slightly increased rates of track abandonment and traffic growth which could reasonably be expected under deregulation. In both scenarios, the effects of variation in available funds (gross margin) per gross ton-mile were examined; the first variation assumed a continuation of the decline in unit gross margin or profit squeeze (in real terms) which occurred in the 1967-77 period (but which began earlier) while the second variation assumes a gradual improvement in unit gross margin, principally through exploitation of deregulation and continued small improvements in transportation operating efficiency.

The results of the application of the two major scenario alternatives and the two variations in funds available/gross ton-mile are summarized below:

<u>1977 Status Quo Scenario</u>

- <u>Track MOW Spending</u> per mile and total increases gradually, driven only by a continued long term deterioration of track quality, for which deferred rail is a surrogate. Spending levels off in the late 1980's as the cumulative effects of gradually increasing MOW spending result in stabilized track quality.

- Average Speed deteriorates gradually over time due to continued growth in deferred rail (deterioration in track quality). However, the total decline in speed from 1978 to 1990 is only 0.5 mph, or less than 2.25 percent in 12 years.

- Running Track Accidents, in terms of both rate and number, continue to increase until a peak is reached in the late 1980's. The increase is attributable to the effects of the long-term (30-year sum of deferred rail) track quality, which is only slightly offset by the short term 5-year average MOW spending.

Continue 1967-77 Trends Scenario

- Track MOW Spending, on a per mile basis, grows dramatically, increasing by about half over the 1977 predicted value or one third over the 1977 actual value. Total track MOW spending also grows substantially, but at a diminishing rate due to the decline in track miles. The increase in spending is driven principally by increased traffic density, resulting from a combination of overall traffic growth and the declining track mileage, and from continued moderate growth in average loaded car weights.

- Average Speed improves at a small but accelerating rate due to a continued increase in average haul and improved track condition (reduced deferred rail); these increases are somewhat offset, however, by gradual increases in tons pulled/locomotive (heavier if not longer trains).

- Running Track Accidents rates decline immediately at a slow rate of decrease, which accelerates with time. The number of running track accidents increases slightly until a peak is reached in 1980, due to traffic growth which exceeds the decline in accident rate. After 1980, the number of accidents declines, at an accelerating rate after 1984, as the combined effects of reductions in long term deferred rail and short-term average MOW spending have increasing beneficial effect on accident rates which more than offset further traffic growth.

Funding Variations

- A gradual increase as compared with a continued decline results in a four percent difference (about $40 million) in annual MOW spending in 1990. The percentage is about the same for both major scenarios.

- The effect of improved unit gross margins (funds available) on average speed is negligible due to the small effect on MOW spending.

- The effect on running track accidents is about the same, 4 percent or so, as that observed for track MOW spending.

There are a few effects which have not been explicitly considered in the above. Perhaps of greatest impact is the inability to include the long term impact of growth in loaded car weights on deferred rail (track condition). Omission of this effect suggests that, for the continued trends scenario, speed and accident improvements may be overstated and MOW spending understated, because deferred rail computed by the forecast model would be underestimated.

The other factor worth mentioning is that the effects of increase in average locomotive horsepower and tractive effort being gained by new technology to improve wheel-rail adhesion are likely to mitigate some, but not necessarily all of the adverse effects of increased tons pulled/locomotive on average speed. Hence, from consideration of this factor alone, the forecast speed is likely understated. The combination of the loaded car weight effects on deferred rail and this locomotive loading factor would be mutually offsetting to some degree, such that the predicted speed trend is likely reasonable.

Other scenarios could be explored using the model. These include, for example, a more rapid increase in available funds/ton-mile, slower traffic growth and track abandonment, holding car weights and tons pulled/locomotive constant while continuing other trends, and others of equal or greater interest from a policy evaluation point of view. The overall model, though quite simple in nature, has been demonstrated to be capable of providing a reasonably powerful tool to explore the effects of a variety of policy issues related to track maintenance, for the industry as a whole or for individual railroads.

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APPENDIX A

MOW BEHAVIORAL MODEL DATA BASE DESCRIPTION*

Contract DOT-TSC-1679 had as its principal purpose the development of an econometric model for the prediction of railroad maintenance of way (MOW) spending, average speeds, and track caused accidents (rates and numbers). In support of that objective, DYNATREND was required to develop a data base for use in performing statistical (regression) analyses and providing forecasts of potential industry results through the year 1990. In addition to reports describing the results of the research efforts, the contract also required the delivery of the data base used in the study. This appendix provides an overview of the data base acquisition efforts, the transformations made in the original source data, and the detailed arrangement (in terms of tape parameters, file content and record layout) of the data base delivered to the Transportation Systems Center (TSC).

Original Data Sources

Much of the original data was provided by TSC in the form of computer tapes, as indicated below:

(1) Financial and Operating Data, 1962-67, extracted from Interstate Commerce Commission (ICC) R-1 Reports filed by Class I railroads.

(2) Accident Data, 1967-74 and 1975-77, complete FRA RAIRS Data Base, all railroads.

(3) Gross Track Miles and Traffic, and Detailed Rail and Tie Installation and Status Data, 1934-77, extracted from ICC R-1 Reports for Class I Railroads.

For conduct of the research study, selected data elements or summaries were extracted from the original data sources identified

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*Prepared by Dynatrend, Incorporated, for Department of Transportation, Transportation Systems Center, under Contract DOT-TSC-1679, Dec. 1980.

above and consolidated into a single data base for the 52 Class I railroads existing in 1977.

Certain data items were not contained in any of the original computer tapes provided by TSC. DYNATREND acquired some of the additional data from Transportation Statistics published by the ICC, fine and inspection data from the Federal Railroad Administration (FRA), and miscellaneous data from a variety of sources. This additional data was also entered into the consolidated data base.

Railroads Included in the Data Base

The data base includes 47 Class I line haul railroads, whose business in 1977 was principally freight. AMTRAK, the Long Island Railroad (LIRR), and Auto-Train, although also Class I line haul operations, are not included, either because they are principally passenger (AMTRAK and LIRR) or own no mainline track (Auto-Train).

Data for independent railroads which no longer existed in 1977 because of mergers was consolidated into the data for the surviving railroad for the appropriate years of the study. For example, data for the formerly independent railroads merged to become CONRAIL in 1976 were consolidated for all prior years (1974-75), in order to maintain continuity of the railroad as a system. In addition, certain subsidiary railroads of the Southern Railway were consolidated into the parent, since the subsidiaries did not report separately on all items in the data base.

Table A-1 provides a list of the 47 railroads included in the data base, together with their code identifiers used in the data base. The table also identifies the subsidiary or previously independent railroads whose data was consolidated into the 47 prime railroads; these subsidiaries/former independents are indentured beneath the prime and do not have code identifiers.

TABLE A-1. RAILROADS IN DATA BASE

CODE	RAILROAD
ATSF (*)	Atchison, Topika, and Santa Fe
BAR	Bangor and Aroostook
BLE	Bessimer and Lake Erie
BM (*)	Boston and Maine
BN (*)	Burlington Northern
	Northern Pacific
	Chicago, Burlington, and Quincy
	Great Northern
	Spokane, Portland, and Seattle
BO (*)	Baltimore and Ohio
CNWR (*)	Chicago and North Western
CO (*)	Chessapeake and Ohio
CONR (*)	CONRAIL
	Ann Arbor
	Central of New Jersey
	Lehigh Valley
	Penn Central
	Pennsylvannia
	Penn Reading Seashore
	New York Central
	New York, New Haven, and Hartford
	Reading
CP	Canadian Pacific Lines (in Maine)
CRR	Clinchfield
CS	Colorado and Southern
CV	Central Vermont
DH	Delaware and Hudson

TABLE A-1. RAILROADS IN DATA BASE (CONTINUED)

CODE	RAILROAD
DMIR	Duluth, Missabe and Iron Range
DRGW (*)	Denver and Rio Grande Western
DTIR	Detroit, Toledo, and Ironton
DTSL	Detroit and Toledo Shore Line
DWP	Duluth, Winnepeg and Pacific
EJE	Elgin, Joliet and Eastern
FEC	Florida East Coast
FWD (*)	Fort Worth and Denver
GLO	Georgia (Leasing Organization)
GTW	Grand Trunk Western
ICG (*)	Illinois Central Gulf
	Illinois Central
	Gulf, Mobile, and Ohio
ITRR (*)	Illinois Terminal
KCS (*)	Kansas City Southern
	Kansas City Southern
	Louisiana and Arkansas
LN (*)	Louisville and Nashville
	Monon
MEC	Maine Central
MILW (*)	Chicago, Milwaukee, St. Paul, and Pacific
MKT (*)	Missouri, Kansas, and Texas
MP (*)	Missouri Pacific
	Chicago and Eastern Illinois
	Texas Pacific
	Kansas, Oklahoma and Gulf
	Missouri Pacific
NW (*)	Norfolk and Western
	Akron, Canton and Youngstown
	Wabash
	New York, Chicago and St. Louis

TABLE A-1. RAILROADS IN DATA BASE (CONTINUED)

CODE	RAILROAD
NWP	Northwestern Pacific
PLE	Pittsburgh and Lake Erie
RFP	Richmond, Fredericksburg, and Potomac
RI (*)	Chicago, Rock Island, and Pacific
SCL (*)	Seaboard Coast Lines
	Seabrook Airline
	Atlantic Coast Line
SLSF (*)	St. Louis and San Francisco
SOO (*)	SOO Line
SOU (*)	Southern Railway System
	Alabama Great Southern
	New Orleans and Northwestern
	Central of Georgia
	Savannah and Atlanta
	Cincinnati, New Orleans, and Texas Pacific
	Georgia Southern Florida
	Southern
	Norfolk Southern
	Carolina and Northwestern
	Georgia and Florida
SPT (*)	Southern Pacific Transportation
TM	Texas Mexican
TPW	Toledo, Peoria and Western
UP (*)	Union Pacific
WM	Western Maryland
WP (*)	Western Pacific

(*) Indicates that the primary railroad data was used in development of the predictive equations.

Only railroads having greater than 1000 miles of track were specifically included in the sample used to support the model development efforts of the contract. Twenty five of the forty seven primary roads included in the data base met this criteria. The railroads included in the sample are indicated by an asterisk at the right of the identifier code.

Data Validity

The original data tapes contained random errors, either missing data in specific elements for specific railroad - year combinations, improper order of magnitude (decimal point location), or erroneous values. Correction of errors was focused on the 25 railroads included in the study sample and on the variables of particular relevance to the model development efforts. The data base, however, contains data for all 47 railroads and a number of variables which were not used in the study. Caution, therefore, should be exercised in using the data base for other applications.

Missing or erroneous data was corrected in a number of ways. First, other sources such as American Association of Railroads (AAR) and ICC publications and Moody's Transportation Manual were consulted. If these sources did not provide the correct values, the missing or erroneous data were corrected by estimating values based on corresponding values for prior and successive years, that is, by interpolation. Since the variables used in the study were, typically, ratios such as speed (train-miles/train hour), the corrections were made to the ratios themselves rather than the individual components of the ratio; in some instances, however, the constituent elements of the ratios were corrected directly.

On the whole, the data base for the 25 railroads and the variables used in the study are free of error. The data for the remaining 22 railroads and variables not used in the study likely have a few random errors. The accident data for all railroads should be free of error; however, accident rates (per billion gross ton miles (BGTM)) for the 22 railroads not included in the study may be wrong due to missing traffic (gross ton-mile) values.

Inflation Adjustments

Most of the financial data used in the study was adjusted for inflation, using AAR deflator indices, to provide values in 1967 equivalent dollars. Seven deflator indices were applied selectively to the current dollar values provided in the original source data; these deflator indices are provided in Table A-2. Except as indicated below, the values in column A (Combined Material Prices and Wage Rates) were the principal deflator used to adjust financial data for inflation.

The six components of MOW spending were adjusted using the deflators included in columns B and C, as indicated below:

Deflator	Item
B	Ties Expense and Betterments
B	Rail Expense and Betterments
B	Other Track Material (OTM) Expense
B	Ballast Expense
C	Roadway Maintenance Expense
C	Track Laying and Surfacing Expense

A relative price (cost) index comprised of weighted MOW and transportation price indices was used as an explanatory variable in the prediction equation for track MOW spending (per equated track mile). In developing this relative price ratio, the deflators defined in columns D to G were used, as indicated below.

$$\text{Relative Price} = \frac{\text{MOW Index}}{\text{Transportation Index}}$$

$$\text{MOW Index} = \frac{X_R}{X_{TOT}} P_R + \frac{X_T}{X_{TOT}} P_T + \frac{X_L}{X_{TOT}} P_L$$

where: X_R = \$ Rail, Deflated using Column B
X_T = \$ Ties, Deflated using Column B
X_L = \$ Surfacing and Laying, Deflated using Column C
$X_{TOT} = X_R + X_T + X_L$
P_R = Iron and Steel Price Index, Column D
P_T = Forest Products Price Index, Column E
P_L = Labor Price Index, Column C

$$\text{Transportation Index} = \frac{Y_F}{Y_{TOT}} P_F + \frac{Y_{TL}}{Y_{TOT}} P_{TL}$$

where: Y_F = Sum of \$ Train Fuel plus \$ Yard Switching Fuel, Each Deflated using Column F
Y_{TL} = Sum of \$ Train Enginemen plus \$ Trainmen plus \$ Yard Conductors and Brakemen plus \$ Yard Switch and Signal Tenders plus \$ Yard Enginemen, Each Deflated using Column G.
$Y_{TOT} = Y_F + Y_{TL}$
P_F = Fuel Price Index, Column F
P_{TL} = Transportation Labor Index, Column G.

The tables containing the identification and record layouts for each file indicates the deflation schedule used.

Number of Accidents and Associated Damages

The number of accidents and associated damages for each railroad each year have been adjusted for inflation and changes in the reporting threshold. This was accomplished by deflating the damage value for each accident in the Railroad Accident Incident Reporting System (RAIRS) data base using the combined wage and material index, Column A in Table A-2, and eliminating those accidents falling below the 1977 threshold ($2300 in 1977 dollars, deflated for preceding years) before summing to obtain system totals for each railroad for each year.

File Composition

The entire data base is subdivided into five separate files. A separate table has been prepared for each file, with each table identifying the record layout, contents of each field by name and units ($K, miles, etc.), deflator index used (if applicable), the record number, column positions, the format used for each data element, and the data source. The contents of each file, the associated time span, and the corresponding file description table are identified below:

File 1 - Selected Balance Sheet Items, 1962-77, Table A-3

File 2 - Selected Income/Expense and Transportation Items, 1962-77, Table A-4

File 3 - Gross Ton-Miles, Track Miles Operated, and Rail and Tie Installation and Status Data, 1934-77, Table A-5

File 4 - Track Caused Accidents and Associated Damages, Total and by Track Type (Running, Switching), and Cause Code Groups (Roadbed, Geometry, Rail, Other), 1967-77, Table A-6

TABLE A-2. PRICE DEFLATORS FOR FINANCIAL VARIABLES (1967 = 1.00)

Year	(A) Combined Material and Wage Rates	(B) Materials Other Than Fuel	(C) Wage Rates	(D) Iron & Steel	(E) Forest Products	(F) Fuel	(G) Transport Labor
1962	0.819	0.936	0.833	0.959	0.875	0.996	-
1963	0.826	0.934	0.842	0.958	0.884	0.991	-
1964	0.846	0.942	0.863	0.963	0.897	0.933	0.888
1965	0.899	0.949	0.909	0.963	0.913	0.956	0.935
1966	0.935	0.965	0.939	0.976	0.967	0.972	0.950
1967	1.000	1.000	1.000	0.997	0.998	1.000	1.000
1968	1.057	1.026	1.051	1.019	1.035	1.035	1.038
1969	1.123	1.055	1.122	1.046	1.133	1.067	1.115
1970	1.230	1.094	1.227	1.091	1.206	1.105	1.129
1971	1.337	1.135	1.368	1.168	1.253	1.146	1.270
1972	1.456	1.187	1.495	1.238	1.301	1.171	1.450
1973	1.635	1.229	1.694	1.291	1.470	1.365	1.577
1974	1.868	1.421	1.734	1.629	1.929	2.272	1.665
1975	2.126	1.902	1.908	2.076	2.147	3.219	1.866
1976	2.354	2.032	2.107	2.159	2.160	3.501	2.033
1977	2.554	2.172	2.273	2.277	2.264	3.896	2.172

TABLE A-3. FILE 1 - SELECTED BALANCE SHEET ITEMS, 1962-77

Description	Units	Record No.	Columns	Format	Sources
RR	Code *	1	1-4	A4	R1-ICC
YR	Year	1	5-6	A2	R1-ICC
Total Assets	$ M	1	7-14	F8.1	R1-ICC
Total Transportation Property Less Recorded Depreciation and Amortization	$ M	1	15-22	F8.1	R1-ICC
Recorded Depreciation and Amortization	$ M	1	23-30	F8.1	R1-ICC
Equipment Obligations (long term debt due within 1 year)	$ M	1	31-38	F8.1	R1-ICC
Total Long Term Debt Due After 1 Year	$ M	1	39-46	F8.1	R1-ICC
Total Shareholders Equity	$ M	1	47-54	F8.1	R1-ICC
Rate of Return on Net Transportation Property	decimal	1	55-60	F6.3	R1-ICC

* See Table A-1

TABLE A-4. FILE 2 - SELECTED INCOME/EXPENSE AND TRANSPORTATION ITEMS, 1962-77

Description	Units	Deflator	Record #	Columns	Format	Sources
RR	Code *	-	1	1-4	A4	R1-ICC
YR	Year	-	1	5-6	A2	R1-ICC
Railway Operating Expenses	$ K	A	1	7-14	F8.1	R1-ICC
Railway Operating Revenues	$ K	A	1	15-22	F8.1	R1-ICC
Net Revenue From Railway Operations	$ K	A	1	23-30	F8.1	R1-ICC
Railway Operating Income	$ K	A	1	31-38	F8.1	R1-ICC
Net Railway Operating Income	$ K	A	1	39-46	F8.1	R1-ICC
Total Other Income	$ K	A	1	47-54	F8.1	R1-ICC
Total Income	$ K	A	1	55-62	F8.1	R1-ICC
Income Available for Fixed Charges	$ K	A	1	63-70	F8.1	R1-ICC
Income After Fixed Charges	$ K	A	1	71-78	F8.1	R1-ICC
Ordinary Income	$ K	A	1	79-86	F8.1	R1-ICC
Net Income Transferred to Retained Income	$ K	A	1	87-94	F8.1	R1-ICC
Dividends	$ K	A	1	95-102	F8.1	R1-ICC

* See Table A-1

TABLE A-4. FILE 2 - SELECTED INCOME/EXPENSE AND TRANSPORTATION ITEMS, 1962-77 (CONTINUED)

Description	Units	Deflator	Record #	Columns	Format	Sources
Total Maintenance of Way and Structures	$ K	A	1	103-110	F8.1	R1-ICC
Road Property Depreciation	$ K	A	1	111-118	F8.1	R1-ICC
Total Track Maintenance of Way, Including Betterments	$ M	A	1	119-126	F8.1	Derived
Track MOW Per Equated Track Mile (All Track)	$ K/mile	A	1	127-132	F6.3	Derived
Total Track MOW, Running Track	$ K	A	1	133-140	F8.1	Derived
Roadway Maintenance, Running Track	$ K	A	1	141-148	F8.1	R1-ICC
Ties, Running Track	$ K	A	1	149-156	F8.1	R1-ICC
Rail, Running Track	$ K	A	1	157-164	F8.1	R1-ICC
Other Track Material, Running Track	$ K	A	1	165-172	F8.1	R1-ICC
Ballast, Running Track	$ K	A	1	173-180	F8.1	R1-ICC
Track Laying and Surfacing, Running Track	$ K	A	1	181-188	F8.1	R1-ICC
Salvage Value of Rails, Total Track	$ K	A	1	189-196	F8.1	R1-DYN
Salvage Value of Ties, Total Track	$ K	A	1	197-204	F8.1	R1-DYN

TABLE A-4. FILE 2 - SELECTED INCOME/EXPENSE AND TRANSPORTATION ITEMS, 1962-77 (CONTINUED)

Description	Units	Deflator	Record #	Columns	Format	Sources
Betterments - Rail, Total Track	$ K	A	2	1-8	F8.1	R1-TSC
Betterments - Ties, Total Track	$ K	A	2	9-16	F8.1	R1-TSC
Total Maintenance of Equipment	$ K	A	2	17-24	F8.1	R1-ICC
Total Equipment Depreciation	$ K	A	2	25-32	F8.1	R1-ICC
Total Transportation Expenses	$ K	A	2	33-40	F8.1	R1-ICC
Train Enginemen	$ K	G	2	41-48	F8.1	R1-ICC
Trainmen	$ K	G	2	49-56	F8.1	R1-ICC
Train Fuel	$ K	F	2	57-64	F8.1	R1-ICC
Clearing Wrecks	$ K	A	2	65-72	F8.1	R1-ICC
Damage to Property	$ K	A	2	73-80	F8.1	R1-ICC
Loss and Damage to Freight	$ K	A	2	81-88	F8.1	R1-ICC
Wreck Clearing Costs and Damage to Property per million GTM	$K/MGTM	A	2	89-95	F7.2	R1-ICC
Total Track Miles Owned	miles	-	2	96-103	F8.1	R1-ICC
Miles of Road Owned	miles	-	2	104-111	F8.1	R1-ICC

TABLE A-4. FILE 2 - SELECTED INCOME/EXPENSE AND TRANSPORTATION ITEMS, 1962-77 (CONTINUED)

Description	Units	Deflator	Record #	Columns	Format	Sources
Miles of Second Main Owned	miles	-	2	112-119	F8.1	R1-ICC
Miles of All Other Main Tracks Owned	miles	-	2	120-127	F3.1	R1-ICC
Miles of Passing Tracks, Crossovers and Turnouts Owned	miles	-	2	128-135	F8.1	R1-ICC
Average Route Miles Operated	miles		2	136-143	F8.1	R1-ICC
Ratio of All Running Tracks Owned to miles of Road Owned	miles/mile	-	2	144-151	F8.1	Derived
Freight Train Miles	K-miles	-	2	152-159	F8.1	R1-ICC
Freight Train Hours	K-hours	-	2	160-167	F8.1	R1-ICC
Average Freight Train Speed	MPH	-	2	168-173	F6.2	Derived
Total Freight Car Miles	M-miles	-	2	174-181	F8.1	R1-ICC
Loaded Freight Car Miles	M-miles	-	2	182-189	F8.1	R1-ICC
Average Freight Train Length	cars/train	-	2	190-195	F6.1	Derived
Total Gross Ton-Miles	MGTM	-	3	1-8	F8.1	R1-ICC
GTM of Locomotives and Tenders in Road Service	MGTM	-	3	9-16	F8.1	R1-ICC
GTM of Freight Train Cars, Contents, Cabooses in Road Service	MGTM	-	3	17-24	F8.1	R1-ICC

TABLE A-4. FILE 2 - SELECTED INCOME/EXPENSE AND TRANSPORTATION ITEMS, 1962-77 (CONTINUED)

Description	Units	Deflator	Record #	Columns	Format	Sources
Revenue Tons	K-tons	-	3	25-32	F8.1	RI-ICC
Revenue Ton - Miles	MRTM	-	3	33-40	F8.1	RI-ICC
Net Ton - Miles	MNTM	-	3	41-48	F8.1	RI-ICC
Average Haul	miles	-	3	49-54	F6.1	Derived
Average Loaded Freight Car Weight	Tons	-	3	55-60	F6.1	Derived
Average Density, Running Track	MGT	-	3	61-66	F6.2	Derived
Average Number of Trains Per Route	trains/route	-	3	67-74	F8.1	Derived
Net Revenue Before MOW Per MGTM	$/MGTM	A	3	75-82	F8.1	Derived
Average Number of Tons Pulled Per Locomotive	K-tons	-	3	83-90	F8.1	Derived
Locomotive Miles in Service	K-miles	-	3	91-98	F8.1	RI-ICCRoad
Ratio of Price of MOW Index to Price of Transportation Index	None	See Text	3	99-104	F6.3	Derived
Fuel Price Index	None	(F)*	3	105-110	F6.3	AAR
Other Materials and Supplies Price Index	None	(B)*	3	111-116	F6.3	AAR

* See Note, Bottom of Next Page

TABLE A-4. FILE 2 - SELECTED INCOME/EXPENSE AND TRANSPORTATON ITEMS, 1962-77 (CONTINUED)

Description	Units	Deflator	Record #	Columns	Format	Sources
Wages Excluding Supplements Labor Price Index	None	(C)*	3	117-122	F6.3	AAR
Wages Excluding Supplements, Transportation Price Index	None	(G)*	3	123-128	F6.3	AAR
Forest Products Price Index	None	(E)*	3	129-134	F6.3	AAR
Iron & Steel Price Index	None	(D)*	3	135-140	F6.3	AAR
Material and Wages Price Index	None	(A)*	3	141-146	F6.3	AAR
Total Track MOW, Way-Switching Track (WST)	$ K	A	3	147-154	F8.1	Derived
Roadway Maintenance, WST	$ K	A	3	155-162	F8.1	R1-ICC
Ties, WST	$ K	A	3	163-170	F8.1	R1-ICC
Rail, WST	$ K	A	3	171-178	F8.1	R1-ICC
Other Track Materials, WST	$ K	A	3	179-186	F8.1	R1-ICC
Ballast, WST	$ K	A	3	187-194	F8.1	R1-ICC
Track Laying and Surfacing, WST	$ K	A	3	195-202	F8.1	R1-ICC
Way-Switch Track Miles Owned	miles	-	4	1-8	F8.1	R1-ICC
Train Switching Locomotive Miles	K-miles	-	4	9-16	F8.1	R1-ICC

*Contains value of deflator for year, for each RR.

TABLE A-4. FILE 2 - SELECTED INCOME/EXPENSE AND TRANSPORTATION ITEMS, 1962-77 (CONTINUED)

Description	Units	Deflator	Record #	Columns	Format	Sources
Total Track MOW, Yards	$ K	A	4	17-24	F8.1	Derived
Roadway Maintenance, Yards	$ K	A	4	25-32	F8.1	R1-ICC
Ties, Yards	$ K	A	4	33-40	F8.1	R1-ICC
Rail, Yards	$ K	A	4	41-48	F8.1	R1-ICC
Other Track Material, Yards	$ K	A	4	49-56	F8.1	R1-ICC
Ballast, Yards	$ K	A	4	57-64	F8.1	R1-ICC
Track Laying and Surfacing, Yards	$ K	A	4	65-72	F8.1	R1-ICC
Yard Conductors and Brakemen	$ K	G	4	73-80	F8.1	R1-ICC
Yard Switch and Signal Tenders	$ K	G	4	81-88	F8.1	R1-ICC
Yard Enginemen	$ K	G	4	89-96	F8.1	R1-ICC
Yard Switching Fuel	$ K	F	4	97-104	F8.1	R1-ICC
Yard Track Miles Owned	miles	-	4	105-112	F8.1	R1-ICC
Yard Switching Locomotive Miles	K-miles	-	4	113-120	F8.1	R1-ICC
Ratio of Thousands of Yard and Way Switching Locomotive Miles to Millions of Total Freight Car Miles (Switch Index)	miles/ mile	-	4	121-126	F6.3	Derived

TABLE A-5. FILE 3 - GROSS TON-MILES, TRACK MILES OPERATED, AND RAIL AND TIE INSTALLATIONS AND STATUS, 1934-77

Description	Units	Record #	Columns	Format	Sources
RR	Code *	1	1-4	A4	R1-ICC
YR	Year	1	5-6	A2	R1-ICC
Gross Ton - Miles	MGTM	1	7-14	F8.0	R1-Dyer
Main Track Miles Operated Including Trackage Rights	miles	1	15-22	F8.0	R1-Dyer
Total Track Miles Operated Excluding Trackage Rights	miles	1	23-30	F8.0	R1 Dyer
Main Track Miles Excluding Trackage Rights	miles	1	31-38	F8.0	R1-Dyer
Switching Track Miles Operated Excluding Trackage Rights	miles	1	39-46	F8.0	R1-Dyer
Miles of CWR	miles	1	47-54	F8.0	R1-Dyer
Total Cross Ties in Track	No.	1	55-62	F8.0	R1-Dyer
Ties Installed in Replacement	No.	1	63-70	F8.0	R1-Dyer
Average Tie Life in Running Track (Dyer Formula)	years	1	71-76	F6.2	Derived
Average Tie Life in Switching Track (Dyer Formula)	years	1	77-82	F6.2	Derived
Average Rainfall	inches/year	1	83-88	F6.2	Dyer
Average Temperature	degrees	1	89-94	F6.2	Dyer

*See Table A-1.

TABLE A-5. FILE 3 - GROSS TON-MILES, TRACK MILES OPERATED, AND RAIL AND TIE INSTALLATIONS AND STATUS, 1934-77 (CONTINUED)

Description	Units	Record #	Columns	Format	Sources
Average Track Curve Factor	See Note, Next Page	1	95-100	F6.2	Dyer
Average Rail Weight	lbs/yard	1	101-106	F6.2	Derived
Tons of New Rail Installed in Running Tracks	tons	1	107-114	F8.0	RI-Dyer
Tons of Relay Rail Installed in Running Tracks	tons	1	115-122	F8.0	RI-Dyer
Tons of New Rail Installed in Replacement in Switching Tracks	tons	1	123-130	F8.0	RI-Dyer
Tons of Relay Rail Installed in Replacement in Switching Tracks	tons	1	131-138	F8.0	RI-Dyer
Average Weight of New Rail Installed in Replacement in Running Track	lbs/yard	1	139-144	F6.2	Derived
Average Weight of Relay Rail Installed in Replacement in Running Track	lbs/yard	1	145-150	F6.2	Derived
Average Weight of New Rail Installed in Replacement in Switching Tracks	lbs/yard	1	151-156	F6.2	Derived
Average Weight of Relay Rail Installed in Replacement in Switching Track	lbs/yard	1	157-162	F6.2	Derived
Average Rail Life, Running Track (Dyer Formula)	years	1	163-168	F6.2	Derived

Note: The following table defines the meaning and values of the system curve and GTM factors used in the Dyer deferred rail formula.

System Curvature	E (for Curvature)*	C (for GTM)**
Heavily Curved	.53	1.13
Moderately Curved	.55	1.15
Lightly Curved	.58	1.17

*Value Included in Data Base
**Not Included in Data Base

TABLE A-6. FILE 4 - TRACK-CAUSED ACCIDENTS AND ASSOCIATED DAMAGES, TOTAL AND BY TRACK TYPE (RUNNING, SWITCHING), AND CAUSE CODE GROUPS (ROADBED, GEOMETRY, RAIL, OTHER), 1967-77

Description	Units	Deflator	Record #	Columns	Format	Sources
RR	Code *	-	1	1-4	A4	R1-ICC
YR	Year	-	1	5-6	A2	R1-ICC
Total Number of Track Related Accidents	No.	-	1	7-14	F8.0	FRA-RAIRS
Total Damage from Track Related Accidents	$	A	1	15-22	F8.0	FRA-RAIRS
Total Running Track Related Accidents	No.	-	1	23-30	F8.0	FRA-RAIRS
Total Damage From Running Track Related Accidents	$	A	1	31-38	F8.0	FRA-RAIRS
Number of Running Track Accidents Caused by Roadbed Defects	No.	-	1	39-46	F8.0	FRA-RAIRS
Damage From Running Track Accidents Caused by Roadbed Defects	$	A	1	47-54	F8.0	FRA-RAIRS
Number of Running Track Accidents Caused by Geometry Defects	No.	-	1	55-62	F8.0	FRA-RAIRS
Damage From Running Track Accidents Caused by Geometry Defects	$	A	1	63-70	F8.0	FRA-RAIRS
Number of Running Track Accidents Caused by Rail Defects	No.	-	1	71-78	F8.0	FRA-RAIRS

*See Table A-1.

TABLE A-6. FILE 4 - TRACK-CAUSED ACCIDENTS AND ASSOCIATED DAMAGES, TOTAL AND BY TRACK TYPE (RUNNING, SWITCHING), AND CAUSE CODE GROUPS (ROADBED, GEOMETRY, RAIL, OTHER), 1967-77 (CONTINUED)

Description	Units	Deflator	Record #	Columns	Format	Sources
Damage From Running Track Accidents Caused by Rail Defects	$	A	1	79-86	F8.0	FRA-RAIRS
Number of Running Track Accidents Caused by Defects in Frogs, Switches and Track Appliances	No.	-	1	87-94	F8.0	FRA-RAIRS
Damage From Running Track Accidents Caused by Defects in Frogs, Switches and Track Appliances	$	A	1	95-102	F8.0	FRA-RAIRS
Total Number of Switching Track Related Accidents	No.	-	1	103-110	F8.0	FRA-RAIRS
Total Damage From Switching Track Related Accidents	$	A	1	111-118	F8.0	FRA-RAIRS
Number of Switching Track Related Accidents Caused by Roadbed Defects	No.	-	1	119-126	F8.0	FRA-RAIRS
Damage from Switching Track Related Accidents Caused by Roadbed Defects	$	A	1	127-134	F8.0	FRA-RAIRS
Number of Switching Track Related Accident Caused by Geometry Defects	No.	-	1	135-142	F8.0	FRA-RAIRS
Damage from Switching Track Related Accidents Caused by Geometry Defects	$	A	1	143-150	F8.0	FRA-RAIRS

TABLE A-6. FILE 4 - TRACK-CAUSED ACCIDENTS AND ASSOCIATED DAMAGES, TOTAL AND BY TRACK TYPE (RUNNING, SWITCHING), AND CAUSE CODE GROUPS (ROADBED, GEOMETRY, RAIL, OTHER), 1967-77 (CONTINUED)

Description	Units	Deflator	Record #	Columns	Format	Sources
Number of Switching Track Related Accidents Caused by Rail Defects	No.	-	1	151-158	F8.0	FRA-RAIRS
Damage from Switching Track Related Accidents Caused by Rail Defects	$	A	1	159-166	F8.0	FRA-RAIRS
Number of Switching Track Related Accidents Caused by Defects in Frogs, Switches and Track Appliances	No.	-	1	167-174	F8.0	FRA-RAIRS
Damage From Switching Track Related Accidents Caused by Defects in Frogs, Switches and Track Appliances	$	A	1	175-182	F8.0	FRA-RAIRS
Number of Track Related Accidents Per Billion Gross Ton - Miles (all Track)	No.	-	1	183-188	F6.3	Derived
Number of Running Track Related Accidents Per Billion Gross Ton Miles	No.	-	1	189-194	F6.3	Derived
Thirty-year Sum of Rail Deferrals	tons/mile	-	1	195-202	F8.1	Derived
Thirty-year Sum of Tie Deferrals	ties/mile	-	1	203-210	F8.0	Derived
Five-year Average Maintenance-of-Way Spending	$K/Equated Track Mile	A	1	211-216	F6.3	Derived

File 5 - Federal Inspection and Fines, Claims, 1974-77, Table A-7

(Note: The tables indicated above are located at the end of this text.) The variables in each file are listed in order of their position, by record and field within record, for each case. Each file is sorted by railroad identifier code (alphabetically) and by year for each railroad.

The data base was created using SPSS and its associated FORTRAN format conventions. All numeric data is right-justified. It is noted that the implied decimal point positions (between actual characters) convention is used. Therefore, if the file is read using FORTRAN, the precise format designators must be used to assure proper location of decimal points.

Tape Arrangement

The entire data base is contained on a single 9-track tape. Data is recorded at 1600 bpi, ASCII characters. The pertinent tape reading details for each file are identified below:

File No.	Bytes/Record	Bytes/Block
1	60	3960
2	204	3876
3	168	3864
4	216	3888
5	78	3970

TABLE A-7. FILE 5 - FEDERAL FINE AND INSPECTION DATA, 1974-77

Description	Units	Deflator	Record #	Columns	Format	Sources
RR	Code *	-	1	1-4	A4	RI-ICC
YR	Year	-	1	5-6	A2	RI-ICC
Number of Federal Inspections	No.	-	1	7-14	F8.0	FRA
Number of Track Miles Inspected	miles	-	1	15-22	F8.0	FRA
Number of Defects Encountered	No.	-	1	23-30	F8.0	FRA
Number of Claims Opened	No.	-	1	31-38	F8.0	FRA
Amount of Claims Opened	$	A	1	39-46	F8.0	FRA
Number of Claims Closed	No.	-	1	47-54	F8.0	FRA
Amount of Claims Closed	$	A	1	55-62	F8.0	FRA
Ratio of Track Miles Inspected to Total Miles Operated	miles/mile	-	1	63-70	F8.3	FRA
Amount of Claims Opened Per Mile of track Operated	$/mile	A	1	71-78	F8.1	FRA

* See Table A-1.

APPENDIX B

REPORT OF NEW TECHNOLOGY

This report contains a statistical analysis of historical railroad expenditures on maintenance of way. As such, it contains no references to new technology.

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