

A SYSTEMS DYNAMICS MODEL OF THE
U.S. RAILROAD INDUSTRY

by

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S.B., Massachusetts Institute of Technology
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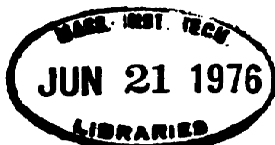
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ABSTRACTA SYSTEMS DYNAMICS MODEL OF THE
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Submitted to the Department of Civil Engineering on May 7, 1976 in partial fulfillment of the requirements for the degree of Master of Science in Civil Engineering.

The railroad industry is a vital part of America's freight transportation system. However, the financial performance of the industry has been rather dismal for the past several decades. This thesis is therefore centered around the development and use of a model which might aid in the investigation of the effectiveness of various alternatives aimed at improving the long-run financial performance of the railroad industry. This performance is determined by a myriad of dynamically interacting factors which can be conceptualized as forming a complex feedback system. Thus, Systems Dynamics, a modelling approach developed for the study of such systems, was used in this research.

The model developed focuses on an important subset of the system and problems of interest. Specifically, it addresses the "supply" side of the industry's financial system. It represents, and can be used to study, the dynamic interactions of maintenance of way policies, quality of the fixed facilities, operating costs, capital costs, labor and equipment productivities, profitability, solvency, and the ability to provide capacity for an assumed inelastically growing demand and fixed traffic mix.

The model is of a macroscopic nature, as it deals with the entire industry, and the factors affecting the profitability of the entire industry, at an aggregate level of detail. For this reason alone, the model should not be expected to be an accurate

predictor of the absolute numerical impacts of any one alternative tested. Furthermore, the model only deals with a subset of the total system which determines the railroad industry's profitability. Thus, the model is best used, and was used in this research, as a comparative tool. This is because its outputs indicate the approximate extent of the impacts of any alternative tested, given the model's scope. The model is therefore most useful as a tool for comparing the effectiveness of alternatives in light of its simplifications and scope, rather than as an absolute predictor of the impacts of each alternative tested.

The applications of the model in this study focused on the impacts of maintenance of way policies on the industry's long-run profitability, and on various means of financing and complementing a capital program aimed at eliminating the large backlog of deferred expenditures on way and structures which exists in the industry today. The model provided some quantitative evidence as to the detrimental effects of continued expenditure deferral, and indicated that improving the quality of the fixed facilities is very important to the long-run health of the industry. The relative effects of volume growth, labor productivity, and freight car utilization on the industry's ability to undertake such a massive program with minimal external aid were demonstrated, and the manner in which these factors interact with quality improvement to affect the long-run performance of the industry was seen.

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"FREE AT LAST, FREE AT LAST,
GREAT GOD ALMIGHTY,
I'M FREE AT LAST."

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Chapter 1

INTRODUCTION

The railroad industry represents a vital segment of America's transportation system.¹ With approximately 39 percent of all intercity freight traffic and 50 percent of all non-pipeline volume,² railroads are the nation's major supplier of freight transportation, and the demand for rail service continues to increase.³ As the nation's transportation requirements grow with the economy, the need for an efficient, high-quality rail systems capable of handling that portion of the traffic for which it is best suited will continue.

As a part of the private enterprise system, railroads must generate adequate profits if they are to continue as such, and must provide an acceptable return on investment if they are to successfully compete for expansion funds in capital markets. Even if the rail-

¹ This research is primarily concerned with railroads as transporters of freight. Since the formation of Amtrak in 1971, and even during the preceding decade, passenger operations have represented a minor portion of the industry's activities.

² Traffic volumes referred to in this study are measured in ton-miles (the movement of one ton one mile), a common measure of freight volume.

³ Excellent sources of statistical data may be found in [1] and [2].

roads were a public enterprise, it would be important for costs to be kept in line to ensure the efficient use of society's resources. However, the financial performance of the industry has been rather dismal for the past several decades, and there exists a strong need for improvement if the railroads are to efficiently serve the growing needs of the economy.

One of the underlying motivations for this research is the investigation of the effectiveness of various alternatives aimed at improving the long-run financial performance of the railroad industry. This performance is determined by a myriad of dynamically interacting factors which can be conceptualized as forming a "feedback" system as depicted in Figure 1-1. Of critical interest in this system is the positive feedback¹ which can aggravate already poor earnings into becoming worse. Specifically, a feedback "loop" exists which has produced earnings deterioration in the past and the loop operates as follows.

¹ Positive feedback is a process of amplification. For example, good earnings lead to better earnings if affected by positive feedback, and poor earnings lead to worse earnings. The reader is referred to [3] for a comprehensive discussion of positive, and other types of feedback in complex systems.

Poor earnings (partially the result of regulation and competition from the trucking industry¹) reduce the ability of the industry to maintain and invest in its physical plant by reducing the amounts of both internal and external funds available for these purposes. In turn, the quality of the physical plant deteriorates and causes operating costs to increase while at the same time causing the quality of service supplied to decline. Declines in service quality cause traffic, and hence revenues, to be diverted to competing modes of transportation (those segments of traffic that are service-sensitive are often the same ones that provide the highest unit revenues). These increased costs and decreased revenues further erode earnings, and the cycle is complete. Further aggravating the situation is the fact that decreased cash flow leads to more debt financing of equipment purchases.² This in turn raises the level of fixed charges (primarily the interest expense on out-

¹ Section 1.1 will give a brief review of the industry's financial condition and will discuss the roles that regulation and competition have played in promoting the railroad industry's current state. Also, much of the terminology used here will be explained at that point for readers unfamiliar with railroad finance.

² This will be further discussed in Section 1.1.

standing debt) while earnings deteriorate, making debt or equity for improvement of the physical plant more difficult to issue while at the same time reducing cash flow and the amount of internal funds available for this same purpose.

Thus, there is a vicious, self-feeding cycle of deterioration which currently threatens the economic survival of the industry. However, this feedback loop can operate in favor of the industry as well. The potential that this cycle has as a means of bolstering the long-run financial viability of the railroads begs investigation. A major task for the industry is to find the means by which to get this loop to act in their favor. Various operating, financial, and governmental policy changes can be helpful in causing the cycle to change its current direction. One aspect of this research is the investigation of alternative methods of aiding this reversal.

As is evident in the above discussion and in the structure of the system depicted in Figure 1-1, the overall financial performance of the railroad industry is affected by many interacting factors. The industry understands the major issue involved in affecting its profitability, but there is need for some method of

integrating these issues. Hence, this research centered around the construction and use of a model which would facilitate such an integration.

The construction of a model of a system such as this fosters a better understanding of the problem at hand by forcing the explicit identification and unambiguous specification of all the factors and interactions believed to be involved in causing the problem. Furthermore, such a model facilitates the testing of alternatives aimed at improving the status quo since it reduces the situation to an explicit set of equations that can be easily worked through (usually by a computer) to produce unambiguous, quantitative statements about the effects of these alternatives.

The interest in this study is in the long-run financial performance of the industry, and this performance is the result of dynamic (i.e., time-dependent) interactions. Thus simulation has been selected as the modelling approach since, by definition, it is the "stepping through time" of a problem, which allows the analysis of its dynamic behavior. A major portion of the research effort described here has been directed towards the construction of a simulation model of the railroad industry.

In problems of the type of interest here, "Systems Dynamics"¹ is a useful approach to the construction and use of simulation models in that it provides a framework that facilitates the conceptualization of feedback systems and a computer package [5] specially developed for the implementation of a model structured within this framework. Furthermore, systems dynamics provides a rational philosophy about the application of simulation models to the analysis of the dynamic behavior of complex feedback systems. This philosophy stresses the importance of system structure and behavior, and places less emphasis on the ability to predict actual system state. Hence, models are viewed as being more useful as prescriptive tools rather than predictive tools. The systems dynamics philosophy recognizes the fact that models are simplifications of reality aimed at the study of certain segments of reality. As such, they cannot be expected to accurately predict future system state due to the myriad of factors outside the scope of the model that also have an effect on system state, particularly in the case of

¹ Systems dynamics is a general name for an approach to the study of complex feedback systems by means of specially structured simulation models. Industrial dynamics is a name often given to the application of this approach to business problems. The reader is referred to [3] and [4] for detailed descriptions of the approach.

socio-economic systems. Thus, the emphasis in a systems dynamics study is on the functioning of the system of interest. The purpose of the model is to allow the study of total system behavior in response to system changes, with the ultimate objective of identifying promising areas of change by promoting a better understanding of the relative effects of the alternative system changes on all aspects of the system.

Because of the convenience of the systems dynamics method for model construction and the rational philosophy it provides for the use of models, it was selected as the overall approach in this research.

This chapter will give a brief review of the industry's financial condition and will introduce the reader to the terminology used in dealing with railroad finance. In addition, the objectives and conclusions of the study will be explicitly stated and the study approach and scope outlined.

1.1 REVIEW OF THE INDUSTRY'S FINANCIAL CONDITION.

Railroads are in the business of providing transportation services, and the profitability of these

services is usually measured by net railway operating income (NROI), an income statement construct that measures the difference between operating revenues and operating costs, total taxes, and net rental costs of facilities and equipment. Railroad companies also earn income from sources other than railroading (such as interest on short- and long-term investments and income provided by the diversification of railroad companies into other industries), and in the railroad's financial reports, this is referred to as other income. In arriving at the net income of the railroad companies, the interest expense and amortizations associated with borrowed capital (for use in both railroad and non-railroad investments), commonly referred to as fixed charges, are deducted from NROI and other income to arrive at ordinary income, which is adjusted for extraordinary and prior period items to arrive at net income.¹

A simplified aggregate income statement of the

¹ The process of arriving at NROI, ordinary income, and net income is somewhat more complex than that outlined here due to the presence of other factors involved and the charging of federal income tax against NROI, while this tax is based on overall income, the end result of the process described above.

Class I line-haul railroads¹ in the U.S. for the year 1973 is presented in Table 1-1 to indicate the relationships between the above-mentioned factors. This discussion, as well as the entirety of this research, is directed towards these railroads, as they represent practically the entire industry. Hence, whenever the "industry" is mentioned in this study, the reference is to Class I line-haul railroads.

NROI is the most common measure used in evaluating the performance of railroad operations. The major factors that determine NROI, and in most cases net income also, are operating revenues and operating expenses, both of which are primarily generated by freight operations. Operating expenses are traditionally reported as falling into six categories: maintenance of way and structures, maintenance of equipment, traffic, transportation, miscellaneous, and general expenses; and basically represent the labor, fuel, materials, depreciation, and overhead costs associated with maintaining and operating a railroad.

¹ Class I line-haul railroads are those railroads with annual operating revenues in excess of \$5 million. These companies currently represent about 99 percent of the industry in terms of traffic, operate 96 percent of rail mileage, and account for 93 percent of the workers employed by all railroad companies.

TABLE 1-1
SIMPLIFIED 1973 INDUSTRY INCOME STATEMENT*

	Total Operating Revenues		14,770
Less:	Total Operating Expenses	11,559	
	Railway Tax Accruals	1,348	
	Net Rental Expense	<u>1,014</u>	
		<u>13,921</u>	<u>(13,921)</u>
Equals:	NROI		849
Plus:	Other Income		468
Less:	Fixed Charges	626	
	Miscellaneous deductions	<u>132</u>	
		<u>758</u>	<u>(758)</u>
Equals:	Ordinary Income		559
Plus:**	Extraordinary and Prior Period Items		<u>50</u>
Equals:	Net Income		609

* All financial figures are in millions of dollars, and are taken from [2].

** These adjustments caused an addition to ordinary income in 1973, but they can also cause a reduction.

With the basic terminology of railroad income accounting having been presented, the relative magnitudes and recent trends of the various components of income will now be analyzed along with a discussion of some of the important factors contributing to the observed phenomena. The values of NROI, other income, fixed charges, and ordinary income for the period 1963-1973 are presented in Table 1-2.

As is evident from the data presented in Table 1-2, there has been a slight downward overall trend in NROI, in spite of the fact that the declining value of the dollar is not taken into account. Freight traffic, however, a prime determinant of NROI, was growing during this period at an average annual rate of 3 percent. This poor behavior of NROI is, of course, considerably affected by the poor performance of the railroads of the Northeast and somewhat by the inclusion of losses on passenger service, only recently relieved by the formation of Amtrak. However, there are other important factors contributing to this behavior of NROI, namely: regulation, changing traffic mix, cost inflation, and the declining quality of the physical plant.

Regulation of railroad freight rates by the Interstate Commerce Commission (I.C.C.) has been a major

TABLE 1-2FINANCIAL STATISTICS 1963-1973*

<u>Year</u>	<u>NROI</u>	<u>Other Income</u>	<u>Fixed Charges</u>	<u>Ordinary Income</u>
1963	806	330	368	652
1964	818	369	380	698
1965	962	365	401	815
1966	1046	399	426	904
1967	676	458	461	554
1968	678	500	484	569
1969	655	505	521	514
1970	486	482	589	227
1971	696	422	601	347
1972	828	395	606	492
1973	849	468	626	559

* All financial figures are in millions of current (non-deflated) dollars.

reason for these rates not keeping up with the rate of general economic inflation, which does affect railroad costs through its effect on the bargaining positions of the labor unions and the price of fuel, equipment, and materials that must be purchased by the railroads. Of course, not all railroads raise their rates when allowed by the I.C.C. However, the rates of the industry in general have been held down by regulation. Furthermore, I.C.C. regulation prevents the railroads from abandoning many services where the rates charged to the users do not cover the costs to the railroads providing them. Thus, regulation has played an important role in allowing unit costs to increase relative to unit revenues.

There has been another factor involved in causing this phenomenon. The railroads have been losing a significant portion of their high value (i.e., high unit revenue) traffic to the trucking industry [6] , causing the rail traffic mix to shift to more of lower value, bulk commodities that are on the low end of the regulated I.C.C. rate scale. The combination of all of these factors has led to an increase in average revenue per ton-mile of only 23% over the ten-year period, while unit labor and material costs rose by 117% and 34% respec-

tively.¹

Further aggravating the effects of cost inflation have been those of deferred maintenance of way and structures on operating costs. As was evident in the previous discussion of the earnings deterioration cycle inherent in the system of Figure 1-1, inadequate maintenance of way can be both a cause and an effect of insufficient earnings. This cyclical relationship between maintenance of way and earnings has existed in the past, as many railroads have been deferring maintenance.² both as a means of raising the current level of reported profits and as a result of the insufficiency of earnings to support increased expenditure levels. This in turn has had adverse effects on operating costs, and one example of these effects is given in [6] : "As an illustration of deferred maintenance, the total number of train derailments reported to the FRA Bureau of Railway Safety rose 110% between 1961 and 1970, while the number of those derailments attributed to . . . roadway alone

¹ These figures, and many others, are available in [1] and [2].

² It is estimated that the amount of deferred maintenance of way currently could be as high as \$10 billion. See [7].

rose 315% during this same nine-year period."

Thus, the feedback loop from earnings to quality of the facilities and back to earnings again has been acting against the industry in the past. As mentioned earlier, one of the aspects of this research is to investigate the dynamic impacts on earnings that the reversal of the cycle can have.

Along with the slightly downward trend in NROI, there has been a strong upward trend in fixed charges, leading to a more pronounced decline in ordinary income. This rise in fixed charges is due to both advancing interest rates and the increasing amount of debt relative to equity in the capital structure of the industry.¹ Due to the poor behavior of NROI with volume, and a policy of high dividends being prevalent in much of the industry,² cash flow has been insufficient to cover capital expenditures, thus promoting a growing reliance on debt financing. In spite of the poor earnings of the rail-

¹ Poor earnings have made equity very difficult to issue in the railroad industry [6] due to the seniority of the claims of creditors relative to those of stockholders on these poor earnings. However, debt has been less difficult to obtain, as will be discussed shortly.

² Dividends were typically above 50% of ordinary income over 1963-1973, and exceeded 100% on several occasions [6].

roads relative to their increasing contractual obligations (fixed charges), they have been able to issue debt, primarily in the form of "equipment debt". This form of debt financing of equipment purchases has been possible because of the excellent security which the equipment (used as collateral) provides to the creditor and because of the seniority of the claims on earnings of the creditors compared to the claims of bondholders and stockholders.¹

Many railroads have been unable to attract outside funds for other than equipment financing, due to their poor earnings record and already highly leveraged capital structures. This inability, together with the insufficient cash flow that promotes it, leads to further reductions in expenditures on way and structures, and aggravates the previously mentioned deterioration cycle.

It is also important to realize that the rather high levels of other income have been very important in aiding the railroads to cover their interest payments. This stream of income is largely attributable to the diversification of many railroads into other industries.

¹ For an excellent discussion of the industry's ability to attract external funds, the reader is referred to pp. 113-121 of [6], which has been the source of much of this discussion.

While it has been helpful in the past, other income does not represent a solution to the problem of interest here, which is the profitability of the railroad operations themselves.

As is evident in the above discussion of what has been occurring in the railroad industry, the feedback system depicted earlier in Figure 1-1 is representative of the many factors and interactions which have led to this past behavior. However, this same system is capable of producing behavior different than that observed in the past. Hence, this research has focused on modelling this system, so that its potential for producing other than poor financial performance may be investigated.

1.2 STUDY OBJECTIVES.

Thus far, the discussion has served to clarify some of the basic problems of the railroad industry and the motivation for constructing a simulation model of it. Given this general background, then, the specific objectives of this study are the following:

- 1) To gain a better understanding of the factors (policies and parameters) and interactions that affect

railroad profitability and financial performance. The construction of a mathematical model forces the explicit identification and specification of all the factors and interactions believed to be involved. The use of the model furthers an understanding of the dynamic nature of these interactions.

2) To establish a framework for the use of systems dynamics in studies of the rail industry's overall long-run financial performance. Inasmuch as this is the first time the approach has been applied to this particular problem (to the author's knowledge), it is hoped that the presentation of the model developed in this research effort will provide guidelines and incentives for further model developments and applications.

3) To demonstrate the relative effectiveness of various changes to the current system and to identify their financial implications. The model developed will be used to analyze the effects of changes in such factors as maintenance policies, labor productivity, and equipment productivity, and the implications of each for the financial performance of the railroad industry.

1.3 STUDY APPROACH AND SCOPE.

This study addresses the long-run financial performance of the railroad industry, which can be conceptualized on a macroscopic level as being generated by the system depicted previously in Figure 1-1. Underlying this macroscopic representation are the policies and decisions of individual railroads as well as the specific items which constitute such abstract macroscopic entities as service quality, quality of the facilities, investment levels, etc. Because of the magnitude and complexity of the true system which Figure 1-1 represents, it would be extremely difficult to account for its every detail. Hence the model developed for studying this system is of a macroscopic nature, with the level of detail applied to system components being generally not more than that indicated in Figure 1-1. In modelling at this aggregate level, therefore, many simplifications had to be made, and these are discussed at length in Chapter 3 and Appendix D.

The simplifications made necessarily detract from the model's ability to produce accurate numerical estimates of financial variables such as NROI, ordinary income, annual capital expenditures, etc. However, as

Chapter 3 will also show, the model is sufficiently detailed and structured so that it captures the important relationships between each of the macroscopic entities it deals with, and is capable of determining the proper direction and approximate extent of the reaction of any one of these entities to a change occurring in any other. Hence, while highly "simplified", the model is still extremely complex, and can provide valuable insight into the overall interconnected functioning of the system which determines the railroad industry's profitability.

In constructing a macroscopic model of this system, it was desirable for the model to be able to produce outputs that were both meaningful and useful, in spite of its aggregate level of detail. In order to achieve this objective, the production of a model with a minimal amount of structural and parametric uncertainty, but with a wide range of applicability was sought. Therefore it was decided to narrow the model's scope so as to focus on a more easily quantifiable, yet very important, subset of the total system (and problems) represented in Figure 1-1. The (sub) system of interest is depicted in Figure 1-2.

The major simplifications made in extracting this (sub) system from the total system depicted earlier in Figure 1-1 have to do with the treatment of operating policy, service quality, and demand. There has been a significant lack of previous research done on these components and their interactions with the rest of the system, particularly in a manner applicable at the macroscopic level necessitated by the scale of the problem being addressed here. Major uncertainties exist about demand elasticities (i.e., sensitivity to quality of service, freight rates, etc.) and reaction times (which are necessary in a dynamic model). Also, there is uncertainty about the macroscopic effects of changes in operating policy on costs, service, and demand. Thus, changes in operating policies are not explicitly dealt with in the model. Demand is assumed to be inelastic (i.e., insensitive to service quality, etc.) and growing at a specified rate, and the traffic mix is assumed to remain constant.¹ These demand assumptions, while simplistic, are more straightforward than a host of assumptions about demand elasticities and reaction times

¹ In spite of the past changes in the traffic mix caused by the loss of high value goods to the tracking industry, it is believed that this phenomenon has already pretty well run its course [6]. Thus, this assumption may not be that major.

(i.e., the amount of time required for a given change in service to fully manifest itself as a change in demand). Service quality, which is difficult to numerically represent at a macroscopic level, is therefore omitted, as demand is assumed to be insensitive to it. Another area of simplification has to do with the treatment of dividends and equity financing. There is further discussion of this in Chapter 3.

It must be noted that the above simplifications only represent those made in order to reduce the total system to the system of interest depicted in Figure 1-2. Because of the macroscopic nature of this system of interest, modelling it involves all the simplifications necessary to represent the underlying microscopic mechanisms at this aggregate level, as will be explained in Chapter 3. However, the components and interactions of the (sub) system are more readily quantifiable than those which have been omitted. Thus, while the simplifications made in extracting this system from the total overall system detract somewhat from the scope of the model's applicability, this is more than compensated for by the reduction of model complexity and internal uncertainty. By using a simple, more certain model to investigate the important subsystem depicted in Figure 1-2, it is possible to perform more meaningful and useful analyses of

its dynamic nature. Since the subsystem to be studied is in itself complex and representative of many of the major problems facing the industry, this approach should prove to be very worthwhile.

However, the simplifications made in constructing the model cannot be ignored, It is for this reason that the model should not be used as an absolute predictor of the financial impacts of any one alternative tested. Rather, the model is used in this study as a comparative tool. Inasmuch as the simplifications of the model affect the exact numerical values of the model's outputs, conclusions should not be based upon the numerical values of the outputs of any one case. Rather, given the model structure, conclusions are sought about the effectiveness of one alternative as compared to other possibilities. Hence, the use of the model as a comparative tool is emphasized.

The model developed to represent the system depicted in Figure 1-2 can be used in the comparative analysis of problems on the "supply" side of the financial picture. Specifically, it represents, and can be used to study, the dynamic interactions of maintenance of way policies, quality of the fixed facilities, operating costs, capital costs, labor and equipment productivities, profitability,

solvency, and the ability to provide capacity in the face of an assumed inelastically growing demand and fixed traffic mix.

In studying these interactions, the model allows the testing of a wide range of alternatives aimed at improving the financial performance they cause. Some options that can be tested (jointly) with the model are various changes in:

- i) maintenance policies;
- ii) volume-growth policies;
- iii) investment/financing/liquidity policies;
- iv) labor costs and productivities;
- v) debt availability/desirability and interest rate levels;
- vi) fuel costs;
- vii) freight rates; and,
- viii) inflation in general.

The above list is by no means exhaustive, but is meant to be indicative of the wide range of issues that can be investigated with the model. The flexibility of the model will become more apparent in Chapter 3, where its structure is discussed in detail. It should be noted that because of the omission of service quality, operating policy, and demand elasticity from the model,

options aimed at improving the financial performance of the industry through changes in, or dependent upon, these factors cannot be tested realistically. (In particular, the effects of changes in freight rates in the light of the assumed demand inelasticity must be interpreted carefully.) Rather, the model focuses on the financial policy and cost side of the system of interest, and is useful in studying changes in these areas, given an assumed growing demand for rail service.

A limited, yet important, subset of the many problems addressable have been analyzed as part of this research, and the conclusions of these analyses are presented in the next section of this chapter, while a detailed discussion of the model outputs that led to these conclusions is given in Chapter 5.

Prior to putting the model to use, it had to be constructed and validated. Construction of the model involved a preliminary specification of the model's structure, followed by the analysis of ten years of financial data¹ to allow the identification and initial specification of the policies, cost relationships, financial parameters, and interactions that have affected

¹ Principal sources of data were [1], [2], [6], and [8].

rail profitability in the past. Once these factors had all been identified, a final model structure was developed and the results of the data analyses were used in specifying the equations and parameters of the model itself. Validation runs were then performed for the purpose of checking the model's ability to approximate reality with minor modifications being made to equations and "noncalibratable" parameters¹ in order to achieve a fair degree of accuracy and an internal structure consistent with the observed facts. The final model structure is discussed at length in Chapter 3, followed by a presentation and discussion of validation results in Chapter 4.

1.4 CONCLUSIONS.

In forming conclusions from the analyses performed with the model in this study, several important facts must be kept in mind. First of all, the model deals

¹ Certain parameters, particularly those that appear in policy equations, cannot be determined by data analysis alone. The values of these parameters are set by running the model with trial values until the "decisions" they cause in the model, given the state of the system, are similar to those observed in the validation period.

with the industry in the aggregate, so the observations available in the model's outputs and the conclusions based upon these observations also apply to the industry in the aggregate. The degree to which these observations and conclusions apply to any one railroad therefore depends upon how similar it is to the industry in general in terms of policies, earnings, cost structure, etc. as represented in the model.

Second, because the model is a macroscopic representation of the industry in the aggregate, many simplifications were made in constructing it. Thus, conclusions about the specific numerical results of any one alternative tested with the model should not and will not be made here. Rather, the model is used in this study as a comparative tool. That is, it is applied to obtain approximate numerical statements of the relative effectiveness of various alternatives aimed at improving the long-run financial performance of the industry. Because of the complex, interactive nature of the system being dealt with, the alternatives tested can have many inter-related impacts throughout the system of interest. Thus, this seemingly "imprecise" method of applying the model is useful in that it allows the relative effectiveness of alternatives to be judged on the basis of the overall

impact they have, and the inter-related behavior of these impacts over time. In developing a model of such a broad perspective, therefore, accuracy had to be sacrificed somewhat. However, as will be apparent throughout this thesis, the simplifications made which detract from the model's precision do not detract from its ability to be effectively used as a comparative tool.

Third, the interest in comparing alternatives in this study is in their relative effectiveness in allowing the industry to meet an assumed growing demand for its service profitably and without excessive reliance on external funds to maintain solvency. Because the railroads have a role to fulfill in the economy and are regulated, this type of comparison was felt to be more meaningful than one which centered around a purely economical measure of the worth of the alternatives. Thus, such measures as net present value are not used here in the comparison of alternatives.

Fourth, while a wide range of issues is addressable with the model, this study focused on the issues of labor productivity, car utilization, and the quality of the fixed facilities. These problem areas have been the subjects of discussion and/or study for years, and the conclusions reached here represent commonly accepted

viewpoints. However, this study has provided some additional quantitative evidence upon which these conclusions may be based. Specifically, the outputs of the model indicate the approximate extent and timing of overall system responses which can occur under various assumed future conditions.

Fifth, the model has been calibrated and structured based upon observed data over a ten-year span, in which traffic volumes varied between 622 billion and 852 billion revenue ton-miles, while in this study the model is projected 35 years into the future and deals with volumes ranging from 300 billion to 1700 billion revenue ton-miles. Thus, these projected futures are not predictions of the future, as they represent how the industry, with the technology and financial environment of the recent past, would fare under a wide range of circumstances. That is, the system itself is assumed not to change, regardless of the situation. In reality, if the situation changed dramatically (i.e., widespread bankruptcy or excessive profitability), the system itself would change in response to the situation. These situation-induced system changes are completely unknown at the present time, and thus are not modelled. This further emphasizes that the model should be used as a comparative tool

(given the current system) rather than an absolute predictor. Any conclusions drawn here must therefore be based upon the model's use as a comparative tool, as it is assumed in all situations that the parameters, policies, and external factors affecting the industry are similar to those which led to the observed behavior over 1963-1973.

Lastly, the sensitivity of the conclusions reached here to the simplifications and assumptions of the model has not been tested. Due to the large number of assumptions and simplifications, it was impossible to test their effect on the model's outputs, and hence on the conclusions reached in this study. However, it is the author's belief that the conclusions reached here are insensitive to the assumptions made.

With these qualifications having been made, the study conclusions may be presented. These conclusions, and their implications are discussed in detail in Chapter 6, and the model outputs which led to these conclusions are presented and discussed in Chapter 5. The conclusions will be briefly presented here, with the reader being urged to read the rest of this thesis in order to understand the bases upon which they are made. In summary, therefore, the major conclusions of this study are as

follows:

1) Continued deferral of expenditures on way and structures on the part of the industry can have serious impacts on its long-run profitability and growth potential. By raising unit costs relative to unit revenues, continued quality degradation can cause a continual decline in earnings. Furthermore, by reducing the NROI possible from a given volume of traffic, poorer system quality results in a lower return being generated from a given level of investment in rolling stock. This latter phenomenon can lead to the undesirability or inability of the industry to acquire expansion funds, or can lead to insolvency if investments are continually made while the return on these investments is diminishing.

2) Improvement of the quality of the fixed facilities is very important, if not necessary, to the long-run health of the industry. Even with rather minor payoffs to quality improvement, the characteristics of growth and long-run financial health were evident in the cases analyzed. By reversing the positive feedback loop which is currently causing earnings deterioration, a good basis for long-run growth and profitability is provided. Thus, various methods of financing and complementing a quality improvement program were tested in this study. The

results of these investigations form the bases for the following conclusions.

3) Without changes to its cost/rate structure other than those eventually accruing from improved system quality, the industry can internally finance a major portion of a quality improvement program aimed at eliminating its current backlog of deferred expenditures on way and structures if it is willing/allowed to forego growth in the near future. Extensive external aid (probably supplied by the government) would be required if the industry were to improve quality while maintaining growth. However, an important issue here is whether the industry, as common carriers, can legally forego the growth demanded by shippers. This issue, and others, are discussed at length in Chapter 6.

4) Significantly increased transportation labor productivity is an extremely effective method of improving the long-run financial condition of the industry, but labor savings alone might not be enough to ensure continued profitable growth. Specifically, major labor productivity improvements can provide a valuable source of internal financing for a quality improvement program, and can also provide a valuable complement to the pay-offs of such a program. The important issue here, which

is discussed in Chapter 6, is the magnitude, timing, and implementation of the productivity improvements. That is, dramatic savings can be realized immediately if the work force is significantly reduced at no cost to the industry. However, union pressure would likely prevent such a reduction, and labor agreements would probably cause the industry to compensate the displaced employees.

5) Major improvements in car utilization can have significant impacts on the industry's long-run profitability if achieved in conjunction with increased labor productivity and the performance of a quality improvement program. The increase in freight car productivity considered was of identical magnitude (25%) as that considered for transportation labor productivity. When viewed alone, increased car productivity was therefore less effective than the labor alternative as a means of lowering costs, due to the relative magnitudes of labor and equipment costs. However, the magnitude of the increase in car productivity considered is more feasible than a similar increase in transportation labor productivity, due to union concerns constraining the latter, and due to the potential which exists for the former through reduced yard-times.

6) As is apparent in all the above conclusions,

there seems to be no one alternative that can cure the industry's problems. This is because the effectiveness of each alternative is constrained, either for technological reasons (i.e., the maximum cost reductions accruing from fixed plant improvement, or the maximum feasible increase in car utilization possible) or for socio-economic reasons (i.e., the legality of the industry to forego the growth demanded by shippers, or the possibility of union opposition to labor force reductions and the compensation required for displaced employees). While little can be done about the technological constraints, the socio-economic constraints can be "relaxed" through government aid. Thus, it seems that a combination of technologically feasible changes within the industry coupled with the "relaxation" of its socio-economic constraints through government involvement, can lead to long-term growth and profitability.

7) Model construction and use provided valuable insight into the overall structure of the system which determines railroad profitability and financial performance. Constructing the model forced the explicit identification of all the factors (policies and parameters) and interactions which comprise this system. It also required the specification of the individual factors, so that the

behavior caused by their interactions could be addressed through model use. However, even if the system components had not been specified for implementation on a computer, the insight gained into the roles and interactions of these various system components was useful in and of itself.

1.5 SUMMARY AND OVERVIEW.

In Chapter 1, the motivation for and general approach followed in this research were outlined, and the reader was introduced to the basic terminology used in discussing the financial performance of the railroad industry. Chapter 2 will give some insight into the systems dynamics modelling approach, discussing both the framework that the approach gives to the modelling of systems and the philosophy it proposes about the usefulness of simulation models in the study of complex systems. The applicability of the framework provided by systems dynamics to the problem of interest here will be presented in Chapter 3, where a comprehensive verbal exposition will be given on the structure of the model developed in this study. (A detailed listing of the model's equations

is available in Appendix A.) The role of model validation in this research, and a discussion of validation results will be the focus of Chapter 4. Chapter 5 gives the outputs and analyses of fifteen cases run with the model as the basis for the conclusions presented earlier in this chapter. Finally, Chapter 6 summarizes the research effort and recapitulates the conclusions that may be drawn from it, and suggests some directions for further research, with emphasis on alternative problem areas to which the model could be applied and on the possibility of extending the model to deal with the entire system depicted in Figure 1-1.

1.6 NOTES ON CHAPTER 1.

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- [6] Task Force on Railroad Productivity; "Improving Railroad Productivity, A Report To The National Commission On Productivity And The Council Of Economic Advisors"; Washington, D.C.; November 1973.

- [7] A.A.R. Staff Studies Group; "Returns On Investments In Fixed Plant Rehabilitation"; Staff Memorandum 75-18; September 1975.
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Chapter 2

THE SYSTEMS DYNAMICS MODELLING APPROACH

Chapter 1 has explained the usefulness of mathematical modelling as an approach to the analysis of complex feedback systems, and briefly discussed the role of simulation, and in particular, systems dynamics, in the study of the dynamic behavior of such systems. It is the purpose of this chapter to expand upon this, presenting systems dynamics as a means of logically conceptualizing the structure of a complex feedback system, as a method of implementing this structure in a computer model, and as a philosophy about the role of simulation modelling in the analysis of these systems.

Systems dynamics has been applied to the study of a wide range of problems, such as: the growth and stagnation characteristics of urban areas [1]; corporate policy [2]; the dynamics of commodity markets [3]; the behavior of research and development organizations [4]; the dynamics of stagnation in industrial economies [5]; and even to the behavior of the world's ecological system [6]. Chapter 3 will discuss how the approach is applied to the analysis of the railroad industry in this study. This chapter will provide the reader with a general description of the method and its associated philosophy so that the presentation in

Chapter 3 will be more easily understood.

2.1 THE SYSTEMS DYNAMICS PHILOSOPHY.¹

Together with the development of systems dynamics as a method, there has evolved a philosophy about the usefulness and purpose of the application of simulation in the study of complex feedback systems. This philosophy stresses that the ultimate purpose of modelling is to aid in the improvement of the performance of the system of interest, and that the major role of models in achieving this goal is the promotion of a better understanding of the complicated functioning of the system being dealt with. This understanding is a prerequisite to our being able to suggest effective changes to the real system.

Modelling a complex system necessarily entails making simplifications. Recognizing this fact, the systems dynamics philosophy questions the ability of a system model to predict the precise state of the system resulting from any given stimulus with a great degree of accuracy. It therefore views models as best being used as comparative tools.

¹For an in-depth exposition of this philosophy, the reader is referred to [7].

That is, as long as the model captures the important features of the complex system of interest, it may be effectively used as a guide to improvement by enabling us to see and compare the direction and approximate extent of all the changes in system behavior caused by various alternatives. Furthermore, because model construction and use allows us to understand why these behavior patterns occur, models can be useful in identifying those factors that are important and/or effective in system improvement and in providing a better understanding of the relative importance and/or effectiveness of these factors.

Because of the role that this philosophy sees models as fulfilling, it emphasizes that the details of system structure are the most important aspect of model development, with the derivation of exact parametric values being of secondary importance. Of course, it must be recognized that grossly incorrect parameter values would render a model useless, regardless of how well its structure represents the true system. What this philosophy proposes, therefore, is that fairly accurate (as opposed to painstakingly accurate) parameters are sufficient for use in a comparative tool as long as the model is structured correctly.

This philosophy, while basically sound, can sometimes be followed in such a manner that little or not enough

effort is made in the calibration and validation of a model. Indeed, this has been one of the major causes of criticism of systems dynamics in the past. In this study, it is recognized that the complexity and abstraction involved in modelling a system as immense as the railroad industry make the accurate prediction of system state an unobtainable goal, and that the major usefulness of the model developed lies in its employment as a comparative, and not an absolute, predictor of system performance. However, in this research rather extensive efforts were made in the calibration and validation of the model, as well as in the detailed specification of the model structure, with the objective being the enhancement of its usefulness as such a comparative tool.

2.2 THE SYSTEMS DYNAMICS FRAMEWORK.¹

Systems dynamics, in its approach to systems modelling, provides a general framework that serves as a logical means of conceptualizing the structure of a system, and which greatly facilitates the representation of an actual system

¹This discussion of the basic concepts of the systems dynamics framework will be fairly brief and general. For a detailed presentation, the reader is referred to [7].

in a model. It does this by presenting a system (or model) as being composed of two basic types of structural elements, which are referred to as "levels" and "rates" for reasons that will soon become quite obvious. Interconnecting the levels and rates is an information network, and it is through this network that feedback plays an important role in determining system behavior.

Levels are the net accumulations over time which occur in any system, and are representative of such diverse items as inventories, populations, accounts receivable, etc., depending on what type of system is being dealt with. The name given to these types of system components is indicative of the fact that they represent "accumulation levels" which exist at any given point in time, and levels of one sort or another exist in any dynamic system.

Rates, on the other hand, are the instantaneous "flow rates" or activities that affect the accumulations occurring in the levels. As such, they are the time derivatives of the levels, and the levels are the time integrals of the net flow rates. Rates are thus measured in terms of "level units" per unit time. With respect to the examples of levels given above, some associated rates might be :
amounts of goods received and shipped per month (affecting the level of inventory); numbers of births and deaths per year (affecting the level of population); and dollar values

of credit sales and collections per quarter (affecting the level of accounts receivable). Thus rates can be thought of as activity rates, while levels measure the resulting state to which the system has been brought at a specific point in time by these activities.

In modelling a system of accumulations and activities, it is necessary to specify equations that represent the levels and rates.¹ Levels, by their very nature, can be represented by equations which merely integrate the rates, and this is done on a computer by means of difference equations. The determination of a rate or activity, however, is more complex, both in a real system and in the equations used to model a system. This complexity arises from the fact that an activity or rate must be determined within the system of interest and is generally a function of the current state of the system, where the current state also includes all current knowledge about the past and all current expectations as to the future.

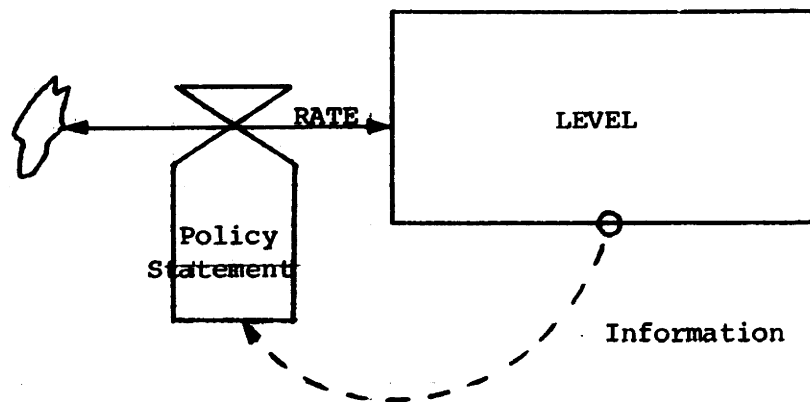
In many situations, activity rates are often the result of managerial decisions. Thus, rates can often be thought of as being controlled by decision functions which are policy statements that specify how the available infor-

¹The reader is referred to [7] or [8] for a detailed discussion of the forms of equations used in systems dynamics models to represent levels and rates.

mation about the state of the system (provided by levels) leads to decisions and rates of activity. For example, a company's inventory policy could determine the amount of goods ordered at the start of a month as a function of the current level of inventory and the expected usage of an item in the upcoming month.

In a non-managerial context, rates are the result of a "rule" or "policy statement" of the system itself. For example, the birth rate in a population is some function of the current population. Again, some explicit statements about the current state of the system control the rates which alter this state. The equations which determine the rates in a system, whether it be managerially-oriented or not, therefore represent some "rules" which act upon the information provided by the levels as to the current state of the system.

In the symbol diagrams typically constructed for systems to be modelled in the systems dynamics framework, the relationship between levels as accumulations of flows and as providers of information about the current state of the system to the policy statements (rate equations) determining the flows (rates) is quite evident. A highly simplified system, consisting of only one level and one rate, is depicted in Figure 2-1. The information provided by the level (the dashed line) is seen feeding a valve (policy

FIGURE 2-1RELATIONSHIP OF LEVELS AND RATES

statement) that controls the rate of flow (solid line) that affects the level.

This "cycling" from level to rate and back again to level is indicative of the notion of feedback which makes the system dynamics modelling approach useful in this study of the railroad industry. In Figure 2-1, the level, which represents the current state of the system as the accumulation of all previous decisions by the policy statement as to rates of flow, "feeds back" to help determine what the current rates of flow will be. This same type of feedback exists in the railroad industry, except that it occurs in a wide variety of ways and in much more complicated manners. This will be evident in the discussion in Chapter 3. Briefly, however, previous decisions as to flows (of money) have determined what the current state of the industry is, and this state has an important impact on what the current flows (of money) will be.

Besides levels and rates, there are two other constructs used in systems dynamics modelling that are worthy of mention here: auxiliaries and delays.

Auxiliaries are used to simplify modelling the processes by which rates are determined. That is, except in the simplest of models, it would be very difficult (but still possible) to formulate one equation representing the rule or policy statement which determines a rate from the

current values of the levels in a system. In Figure 2-1, for instance, several computations might be required by the "policy statement" before it determined the rate based upon the information passed to it from the level. Thus, besides the one equation which specifies what a rate will be at any point in time, there are typically additional equations which aid (hence the name "auxiliary") in determining the rate. These auxiliary equations perform intermediate computations on the information supplied by the levels before the rate equation finally specifies what the rate will be. In so doing, auxiliaries can represent intermediate concepts about the state of the system which are important in their own right and which have a bearing on the determination of rates. They can also be used to represent a complex decision function (policy statement or rule) by means of a series of simple equations that are easier for the modeller to conceptualize. In this instance policies may be imbedded in the auxiliary equations, which represent "subdivisions" of a rate equation.

Delays are a means of retarding the flow of physical or informational quantities, thus aiding in the formation of levels of delayed items or in the delayed recognition of the state of the system in the process that is determining a rate. The use of levels, rates, auxiliaries, and delays in modelling the system of interest in this study is dis-

cussed in Chapter 3, and the roles that these constructs play in the formulation of the model should become very clear at that point.

A special computer package, known as DYNAMO [8], has been developed for the implementation of a system model described in terms of levels, rates, auxiliaries, and delays. This package has been designed in such a manner as to free the user from most of the burdens of programming a simulation model. All that is required is the specification of an equation for each level, rate, and auxiliary (delays are built-in functions that can be invoked) and the initial values of the levels. The user does not have to be concerned about the order of the equations, as DYNAMO takes care of the solution sequence at each step in time. DYNAMO also has tremendous output capabilities, and can produce neatly scaled and formatted plots or prints of the values of system variables over time with negligible effort on the part of the user. Thus, the modeller can concentrate more on the structure of the system and less on the details of programming, which leads to a more efficient use of the human resources involved in a simulation study.¹ Inasmuch

¹The details of DYNAMO, such as the manner of specifying equations, and the means by which it steps the model through time, will not be discussed here. The reader is referred to [7] and [8].

as DYNAMO was developed specifically for the implementation of systems dynamics models, it was used as the programming tool in this research. A complete listing of the DYNAMO code for the model developed in this study is available in Appendix A.

2.3 SUMMARY OF CHAPTER 2.

In this chapter, a philosophy about the use of simulation models in the study of complex feedback systems was presented. The basic premise of this philosophy is that models of complex systems, as simplifications of reality, are best used as comparative tools which allow us to see the relative overall implications of various alternatives aimed at improving a system's behavior. Also, the basic concepts of the systems dynamics modelling framework were introduced, and the DYNAMO computer package was discussed.

Chapter 3 will give a fairly detailed explanation of the model developed in this study, indicating the application of the various systems dynamics modelling constructs in this instance, and the results of using the model as a comparative tool will be presented and discussed in Chapter 5.

- [1] Forrester, J.W.; "Urban Dynamics"; M.I.T. Press; 1969.

- [2] Forrester, J.W.; "Market Growth As Influenced By Capital Investment"; Industrial Management Review, Vol. IX, No. 2; Winter 1968; pp. 83 - 105.

- [3] Meadows, D.L.; "Dynamics Of Commodity Production Cycles"; Wright-Allen Press; Cambridge, MA; 1970.

- [4] Roberts, E.B.; "The Dynamics Of Research and Development"; Harper & Row; New York, N.Y.; 1969.

- [5] Forrester, N.B.; "The Life Cycle Of Economic Development"; Wright-Allen Press; Cambridge, MA; 1973.

- [6] Forrester, J.W.; "World Dynamics"; Wright-Allen Press; Cambridge, MA; 1971.

- [7] Forrester, J.W.; "Industrial Dynamics"; M.I.T. Press; 1961.

- [8] Pugh, A.L., III; "Dynamo II User's Manual"; M.I.T. Press.

Chapter 3

MODEL STRUCTURE

The preceding chapter introduced the concepts of levels, rates, auxiliaries, and delays, and explained the role of these constructs in the formulation of a systems dynamics model. Levels were seen to represent the net accumulations over time which occur in a system, while rates are the "flow rates" or activities that affect the accumulations occurring in the levels. Rates are determined within a system (or model) by policy statements or rules which act upon the information provided by the levels as to the current state of the system. Auxiliaries are used to simplify modelling the processes by which rates are determined. Auxiliary equations perform intermediate computations on the information supplied by the levels before a rate is determined. In so doing, auxiliaries can represent intermediate concepts about the state of the system which are important in their own right and which have a bearing on the determination of rates. They can also be used to represent a complex decision function (policy statement or rule) by means of a series of simple equations. In this instance, policies may be imbedded in

the auxiliary equations, which represent "subdivisions" of a rate equation. Lastly, delays were seen as means of retarding the flow of physical or informational quantities, thus aiding in the formation of levels of delayed items or in the delayed recognition of the state of the system in the process that is determining a rate.

This chapter gives a description of the model developed to represent the financial system of the U.S. railroad industry depicted earlier in Figure 1-2, and will indicate the roles of levels, rates, auxiliaries, and delays in this particular application of system dynamics. The model is very large and complex, containing approximately 350 equations, of which 16 define levels and 31 describe rates. The remainder of the equations are auxiliary equations, and their large number is indicative of the complexity of the processes by which the rates are determined, both in the model and in the real world.

The levels and associated rates used in the model are listed in Table 3-1. As is evident by the list of items in the table, the model, as well as the system of interest, is financially oriented, with most of the levels and rates representing monetary/accounting entities.

Twelve of the sixteen levels represent balance sheet or income statement items. These levels provide

TABLE 3-1LEVELS AND RATES OF THE MODEL

<u>LEVEL (units)</u>	<u>ASSOCIATED RATES (units)</u>
1. Retained Earnings (\$)	1.1 Ordinary Income (\$/yr.) 1.2 Dividends (\$/yr.)
2. Net Working Capital (\$)	2.1 Sources of Funds (\$/yr.) 2.2 Uses of Funds (\$/yr.)
3. Long-Term Debt (\$)	3.1 Debt Issuance (\$/yr.) 3.2 Debt Repayment (\$/yr.)
4. Fixed Charges (\$/yr.)	4.1 Interest Added Due To Debt Issuance (\$/yr./yr.) 4.2 Interest Removed Due To Debt Repayment (\$/yr./yr.)
5. Gross Book Value of Cars (\$)	5.1 Capital Expenditures On Cars (\$/yr.) 5.2 Car Write-Offs (\$/yr.)
6. Accumulated Depreciation on Cars (\$)	6.1 Depreciation Expense On Cars (\$/yr.) 6.2 Depreciation Write-Offs On Cars (\$/yr.)
7. Gross Book Value of Locomotives (\$)	7.1 Capital Expenditures On Locomotives (\$/yr.) 7.2 Locomotive Write-Offs (\$/yr.)
8. Accumulated Depreciation on Locomotives (\$)	8.1 Depreciation Expense On Locomotives (\$/yr.) 8.2 Depreciation Write-Offs On Locomotives (\$/yr.)
9. Gross Book Value of Other Equipment (\$)	9.1 Capital Expenditures On Other Equipment (\$/yr.) 9.2 Other Equipment Write-Offs (\$/yr.)
10. Accumulated Depreciation on Other Equipment (\$)	10.1 Depreciation Expense On Other Equipment (\$/yr.) 10.2 Depreciation Write-Offs On Other Equipment (\$/yr.)

TABLE 3-1 (continued)

<u>LEVELS (units)</u>	<u>ASSOCIATED RATES (units)</u>
11. Gross Book Value of Way And Structures (\$)	11.1 Capital Expenditures On Way And Structures (\$/yr.) 11.2 Way And Structures Write-Offs (\$/yr.)
12. Accumulated Depreciation On Way And Structures (\$)	12.1 Depreciation Expense On Way And Structures (\$/yr.) 12.2 Depreciation Write-Offs On Way And Structures (\$/yr.)
13. Freight Cars Owned (cars)	13.1 Owned Cars Purchased Or Rebuilt (cars/yr.) 13.2 Owned Cars Retired Or Rebuilt (cars/yr.)
14. Freight Service Locomotives Owned (locomotives)	14.1 Owned Locomotives Purchased Or Rebuilt (locomotives/yr.) 14.2 Owned Locomotives Retired Or Rebuilt (locomotives/yr.)
15. Quality Of The Fixed Facilities (constant \$)	15.1 Maintenance And Investment In Way (constant \$/yr.) 15.2 Wear And Tear On The Facilities (constant \$/yr.)
16. Demand For Rail Service (revenue ton-miles/yr.)	16.1 Rate Of Demand Growth (revenue ton-miles/yr./yr.)

valuable information about the financial state of the system at any point in time, and this information is useful as output from the model (enabling us to observe the results of decisions made within the model) and as dynamic feedback to the model (enabling it to make further decisions conditional upon the state of the system that these levels, which are the result of all previous decisions, describe).

The other four levels also play an important role in determining the financial performance of the railroads. The major driving force in the model is the volume of traffic carried, which is a function of the demand for rail service (one of these levels) and the capacity of the rolling stock (which depends in part on two more of these levels: the numbers of owned freight cars and freight service locomotives). Also, the level that measures the quality of the fixed facilities has an effect on operating costs, and therefore it too is important in affecting financial performance.

In examining the list of rates given in Table 3-1, it can be seen that some rather complex "decisions" must be made in the model, such as: the number of cars and locomotives to purchase each year, the financing mix to be used for these purchases, the amounts to spend on way and structures each year, and the financing mix for these

expenditures, to name a few. Also, many calculations must be made to relate traffic volume to income, book values to depreciation expense, etc. This is where the auxiliaries fit in, relating all these items in such a manner as to arrive at the decisions that determine the rates. Delays are used principally as a means of relating write-off rates to capital expenditures, retirements of equipment to installations, and in determining debt repayments as a function of debt issuance.

Due to the size and complexity of the model, a symbol diagram of its entirety in the format of Figure 2-1 will not be presented, as it would be too complicated to be readily intelligible to the reader. Rather, symbol diagrams of portions of the model will be presented to clarify the roles of levels and rates in this application of systems dynamics,¹ and to indicate the interrelationships between the various levels and rates throughout the model. Furthermore, this chapter will not give a detailed explanation of each of the model's equations.¹ Rather, the discussion here will be of a qualitative nature and will describe the general aspects of the model's structure and the manner in which rates are determined. By their very nature, auxiliaries play an

¹ A complete listing of the model's equations and the definitions of the variables used in these equations is available in Appendix A.

important role in the rate determination process, so most of the factors mentioned in the discussion are represented in the model by its many auxiliary equations.

In modelling the human decision processes and other "rules" that determine rates, simplifications must be made in order to represent these processes by equations. In this particular case, industry "decisions", which are the aggregated result of the decisions of individual railroads, are the ones being dealt with. Since the industry in total is not a true decision-making unit (whereas each individual railroad is), further simplifications are required. Thus, the industry is treated as one large railroad, with the decision rules implemented in the model being based upon the general nature of those that would be followed by an individual railroad, and being calibrated (parameterized) so as to conform with observed industry behavior in the past.¹ This chapter explains how the decision processes of the industry, treated as one large railroad, are represented in the model, and the simplifications that have been made in this representation. All simplifications and assumptions made throughout this study are indexed in Appendix

¹ By treating the industry as one large railroad, it is being assumed that aggregate industry conditions are representative of the average conditions of the railroads comprising the industry.

D so that they may be easily located in the text. Appendix D will also give a brief discussion of the relative importance of these assumptions in affecting the model's outputs.

The model may be conceptualized as having six major modules, as depicted in Figure 3-1. Each module performs certain functions that require information from, and supply information to, other modules. The main items of information (coming directly from levels or by means of auxiliaries) flowing between the modules are shown in Figure 3-1, and will be discussed along with the general functions performed in each module in the ensuing sections of this chapter.

In developing the model, the following steps were performed. First, a preliminary model structure was specified in terms of the major modules required, the levels and rates necessary within each module, and the important intra- and inter-module flows of information that would have a bearing on the determination of the rates. The next step was the identification of necessary parameters and policy statements that would determine the values of the flows of information and how the model would react to these values. Thirdly, data for the period 1963-1973 [1], [2], [3], [4] was investigated to obtain the values of the parameters and to discern

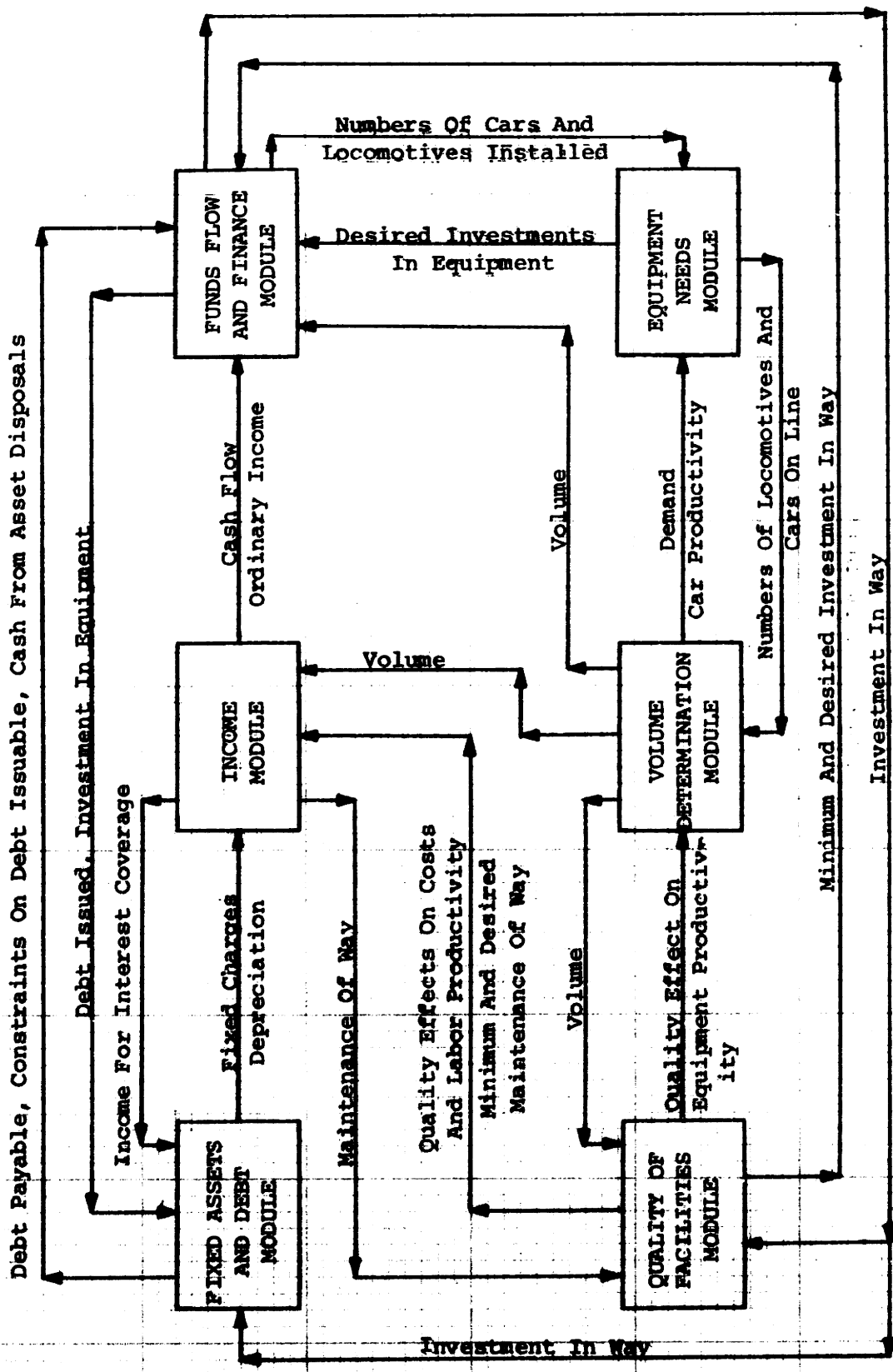


FIGURE 3-1
GENERAL MODEL STRUCTURE

the apparent industry "policies" causing the observed behavior. A final model form was then specified and calibrated based upon these empirical findings. This final model form was subsequently "checked out" or validated by comparing its outputs to actual data over the calibration period, with adjustments being made to parameter values or model specification in order to better match reality. This validation process is the topic of Chapter 4, whereas this chapter is concerned with the model specification, the nature of which is described in the ensuing sections which deal with each of the modules depicted in Figure 3-1.

3.1 INCOME MODULE.

The major function of the Income Module is the determination of revenues and expenses, and hence income¹ and cash flow. The module consists entirely of auxiliary equations, as its outputs are used to determine rates in the other modules. Therefore, unless otherwise stated, all the items discussed in this section are determined within the model by means of auxiliary equations.

The most complex task performed by the Income Module is the calculation of expenses. It does this in a manner which is necessarily a simplification of reality, but which attempts to capture the general nature of industry costs, as will now be described.

¹ The model deals with ordinary income, rather than net income, because it is more representative of the earnings generated in any year through the normal course of business operations which are of interest here. Furthermore, the extraordinary items and prior period expenses that are used to adjust ordinary income to obtain net income often represent "pseudo" transactions that do not affect cash flow, which is an important element of the system of interest. Thus, for the purposes of this study, ordinary income and net income are assumed to be the same, and the two names are used interchangeably.

3.1.1 GENERAL DISCUSSION OF APPROACH TAKEN IN MODELLING EXPENSES.

3.1.1.1 Expenses Determined By The Income Module.

Railroad expenses are typically categorized as operating expenses, taxes, net rental expenses for facilities and equipment, and fixed charges. Operating expenses are reported for both freight and passenger operations, and are sub-divided into six categories for each service: maintenance of way (which includes depreciation expense for certain road assets), maintenance of equipment (which includes equipment depreciation), traffic, transportation, general, and miscellaneous expenses. These expenses represent the labor, fuel, material, and overhead costs (as well as depreciation expense) associated with operating and maintaining a railroad. Furthermore, additional labor costs show up as payroll taxes, which represent such items as Medicare, unemployment insurance, and pension fund contributions made by the railroad companies for their employees. In the model, payroll taxes are combined with the labor costs usually categorized as operating expenses (i.e., health and welfare benefits, salaries, and wages). Hence whenever operating expenses are referred to in this discussion, payroll taxes are also implied even though they are not categorized as operating expenses in the industry.

The Income Module computes all expenses except depreciation and fixed charges, which it accepts from other modules for use in its determination of income. Most of the Income Module's equations deal with operating expenses (other than depreciation), which represent the majority of industry expenses [3]. Therefore, the following section deals with the general approach taken to modelling operating expenses (other than depreciation).

3.1.1.2 General Approach Taken In Modelling Operating Expenses - Degree Of Disaggregation To Account For Inflation, And Choice Of Volumetric Basis For Variable Costs.

Operating expenses by definition are those expenses associated with operating and maintaining a railroad. As such, they contain significant variable costs which are affected by the amount of business done. Operating expenses are also affected by inflation. Thus, in modelling these expenses, it was desirable to account for their dependence on both time (i.e., inflation in unit resource costs) and volume (i.e., the variable amounts of resources consumed). Operating policies also play an important role in determining operating costs, as do maintenance policies. As mentioned in Chapter 1, operating policies are not explicitly considered in this study.

Rather, it is assumed that they will generally remain the same as they were over 1963-1973, the data period used for the derivation of the cost functions to be described here. The effect of maintenance policies in affecting costs is one of the major issues addressed by this research, and is discussed at length in Section 3.4. This discussion therefore centers around how the model's operating cost functions account for inflation and changes in volume.

Since time series data was used for the calibration of the model, it was important to separate the time-dependent aspects of costs from those that depend upon the amount of business done. Thus it was desirable to disaggregate the reported cost data so that changes in the unit costs of the individual factor inputs could be taken into account in relating total costs to volume. This would also make the model a more flexible tool, as changes to particular cost categories could be studied if costing was done on a disaggregate basis. For the sake of model simplicity, however, and due to data limitations, a substantial amount of disaggregation was not possible. Thus, costs were disaggregated so as to be represented by four major categories: labor, fuel, and material and "other", as will be explained below.

In selecting a basis for representing the amount of

business done,¹ it was recognized that there were many possibilities, and that various categories of cost depend on various cost bases (i.e., carloadings, tons originated, gross ton-miles, net ton-miles, revenue ton-miles, etc.). Due to the fact that revenue ton-miles is a common measure of annual freight volume and since many cost categories are affected by this measure,² it was selected as the primary cost basis for freight operations. Furthermore, if traffic patterns, car sizes, and operating policies do not change much in the future, as is assumed in this study, all other cost bases will vary linearly in revenue ton-miles.³ Thus, its use as a simplified measure of freight volume seems justified.

¹ Concern here is for freight operations, as passenger operations are almost negligible in comparison, and are treated separately by the model.

² Actually, costs are often dependent upon net ton-miles, which includes non-revenue traffic. However, non-revenue traffic makes up a very small portion of the total, so that the two measures are almost identical. This is evident in the statistics available in [3].

³ For example, over 1963-1973, based upon the data in [3], gross ton-miles were found to be approximately equal to 2.4 times revenue ton-miles, in spite of the changing traffic patterns, etc., over this period.

3.1.1.3 Overview Of Income Module Costing Procedures.

The Income Module accepts fixed charges (which are computed by means of a level) and depreciation expense from the Fixed Assets And Debt Module, while it internally calculates operating expenses (other than depreciation), taxes, and net rental expense. With the above explanation having been given for the degree of disaggregation in the model's costing process and the cost basis used, the manner in which the model computes costs can now be discussed.

This module's internal costing procedures determine four major areas of expense (besides income taxes):

- i) traffic, transportation, general, and miscellaneous expenses, inclusive of associated payroll taxes, for freight service (hereafter usually referred to by the acronym TTGM);
- ii) maintenance of equipment expense net of depreciation and inclusive of associated payroll taxes, for freight service (hereafter usually referred to by the acronym ME);
- iii) maintenance of way and structures expense net of depreciation and inclusive of associ-

ated payroll taxes, for freight service (hereafter usually referred to by the acronym MW); and,

- iv) all other expenses - state and local taxes, net rents for equipment and facilities, and all passenger-related expenses not accounted for elsewhere.

The first three areas of expense are modelled in some detail, while the fourth is treated very simply. Each of these cost categories will be dealt with in turn, followed by a discussion of the computation of revenue and income. It should be noted that many areas of operating expense are affected by the quality of the fixed facilities. Those expenses which are affected, and the nature of their relationship with system quality, are discussed at length in Section 3.4.2. Thus, the cost functions presented here represent costs before quality effects are taken into account, and represent the bases against which the quality cost "multipliers" of Section 3.4.2 are applied.

3.1.2 TTGM EXPENSE.

TTGM represents the costs incurred in operating (as opposed to maintaining) the railroads. It is the biggest "single" category of expense,¹ and is broken down into three sub-categories: labor, fuel, and "other" (basically representing loss and damage to lading, materials used, and overhead incurred by the TTGM accounts).

3.1.2.1 TTGM Labor Cost.

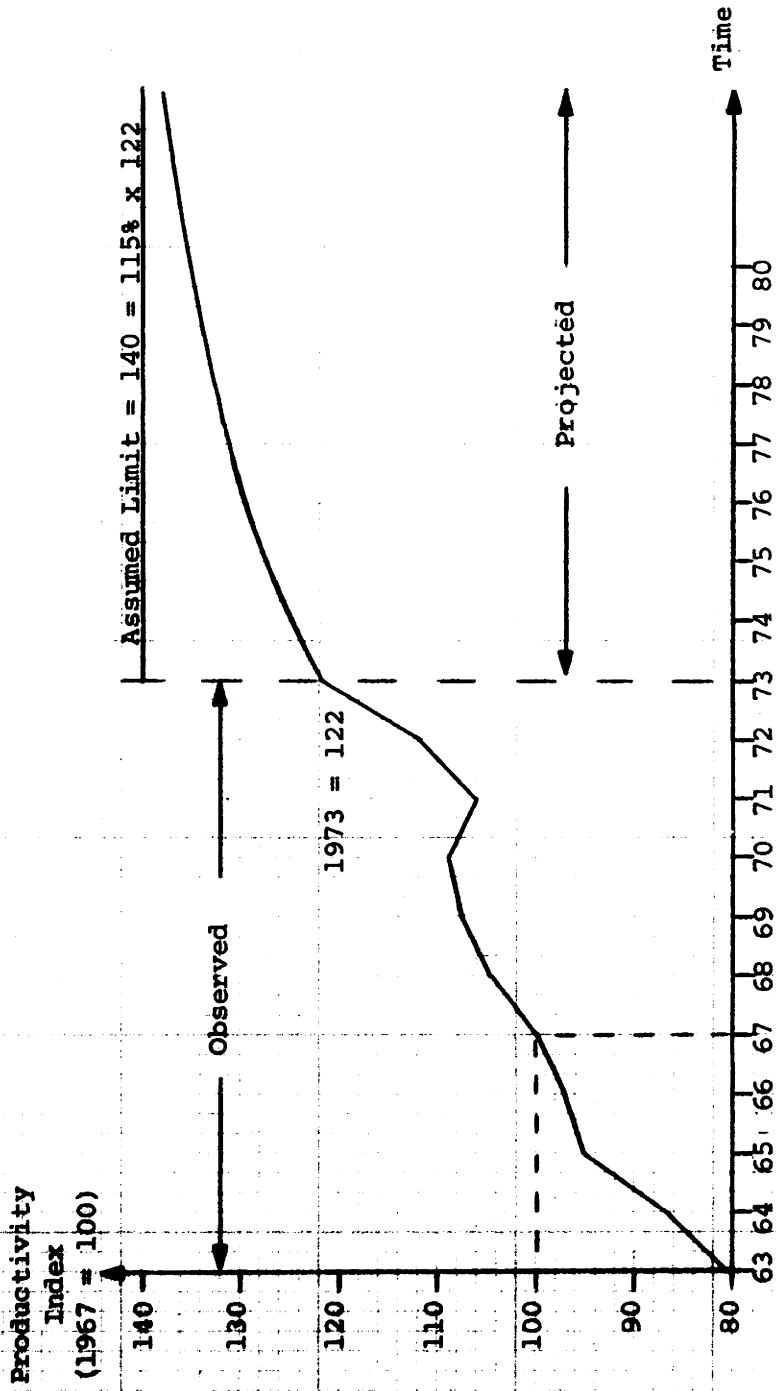
These labor costs represent the wages, salaries, health and welfare benefits, and payroll taxes associated with TTGM employees. In order to compute these costs, the model first determines the number of man-years required to serve the current level of volume (revenue ton-miles/yr) by means of the TTGM labor productivity function² depicted in Figure 3-2, which shows that labor

¹ In 1973, traffic, transportation, general, and miscellaneous expenses represented 60% of total freight operating expenses (as typically defined) [3].

² This function, and all other cost-related factors discussed in this chapter, is derived in Appendix B. As will be explained there, all productivity and cost functions presented are approximations to those which actually existed over 1963-1973, as the data used in their derivation was somewhat insufficient to allow a completely accurate assignment of employees to the various categories of expense. However, the assignments made should be close to those which actually existed, as is explained in the Appendix.

FIGURE 3-2
TTGM LABOR PRODUCTIVITY FUNCTION

Productivity Measured In Revenue Ton-Miles Per Man-Year
1967 Productivity = $2,408 \times 10^6$



productivity has been generally increasing over the past. This trend has occurred for several reasons, as explained in detail in [4], the primary ones being the increasing capacity of cars and locomotives, the growth in average length of haul, and the substitution of capital inputs for labor due to the increasing relative cost of labor. Examples of this latter phenomenon are more automated yards and operating policies that lower labor costs while raising equipment needs (such as longer, less frequent trains). For the future cases analyzed in Chapter 5, it is assumed that these trends will continue, but in a decreasing manner so that TTGM productivity will approach 115% of its 1973 value in an exponentially decaying fashion over time, as depicted in Figure 3-2. (This 115% limit was "arbitrarily" chosen based upon the trend in the past observed values. However, its magnitude is fairly consistent with that of the assumed limit on rolling stock productivities, which are discussed in Section 3.6. This similarity was desirable because labor and rolling stock productivities are both affected by increasing car sizes, lengths of haul, etc.) In determining labor requirements by means of their productivity, it is being assumed that the work force can be adjusted quickly to the level required, and that labor requirements

are completely variable with respect to traffic.¹

Once the number of man-years required to serve the current volume is determined, it is multiplied by the cost per man-year to arrive at the total labor cost. Actual productivities and labor costs were used for the period 1963-1973 in the validation process described in Chapter 4, while the function depicted in Figure 3-2 and 1974² unit labor costs (adjusted for inflation) were used for the future cases analyzed in Chapter 5. Any other assumptions about costs and productivities could of course be used to test their impact on the overall system.

3.1.2.2 TTGM Fuel Cost.

Fuel costs are determined by multiplying the amount of fuel consumed at the current level of volume by the unit cost of fuel. Fuel consumption is related to volume

¹ Neither of these assumptions is completely realistic of course, as can be seen by the dip in productivity in Figure 3-2 that accompanied the significant drop in demand during 1971. However, as an approximation to long-run conditions, these assumptions are not too unreasonable. The implications of these assumptions, along with the others made in modelling costs, are discussed in Section 3.4.5.

² As will be explained in Chapter 5, later in this research, data became available that allowed the updating of certain factor prices, notably fuel, through 1974.

by the function shown in Figure 3-3, which is derived in Appendix B. Since most of the industry's freight locomotives are diesel-powered, the fuel consumption function is based upon the number of gallons of diesel oil that would have given rise to the total (diesel and other) fuel costs observed over the calibration period, given the cost per gallon of diesel oil. This fuel consumption function was used both in the validation runs and in the future cases analyzed, while actual unit fuel costs were used for the purpose of validation, and 1974 unit fuel costs (adjusted for inflation) were used for the future cases.

3.1.2.3 "Other" TTGM Costs.

"Other" TTGM costs are determined in the model by means of the function depicted in Figure 3-4, which relates their deflated value, in terms of 1967 dollars, to volume. (The material cost deflator available in [2] was used for deflating actual costs, as is explained in Appendix B.) The value obtained is then multiplied by an inflation factor to give the current cost.

FIGURE 3-3
FUEL CONSUMPTION FUNCTION

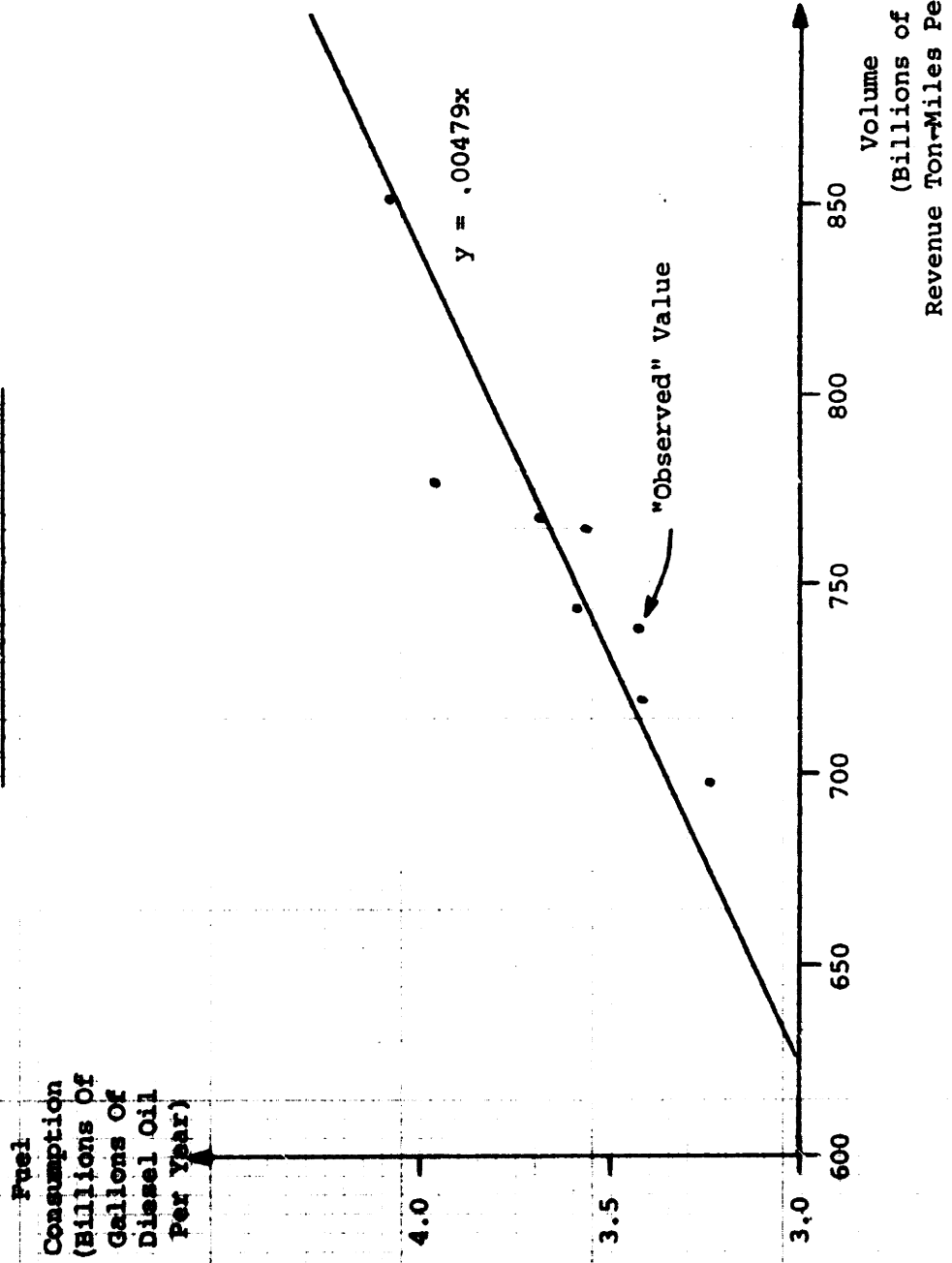
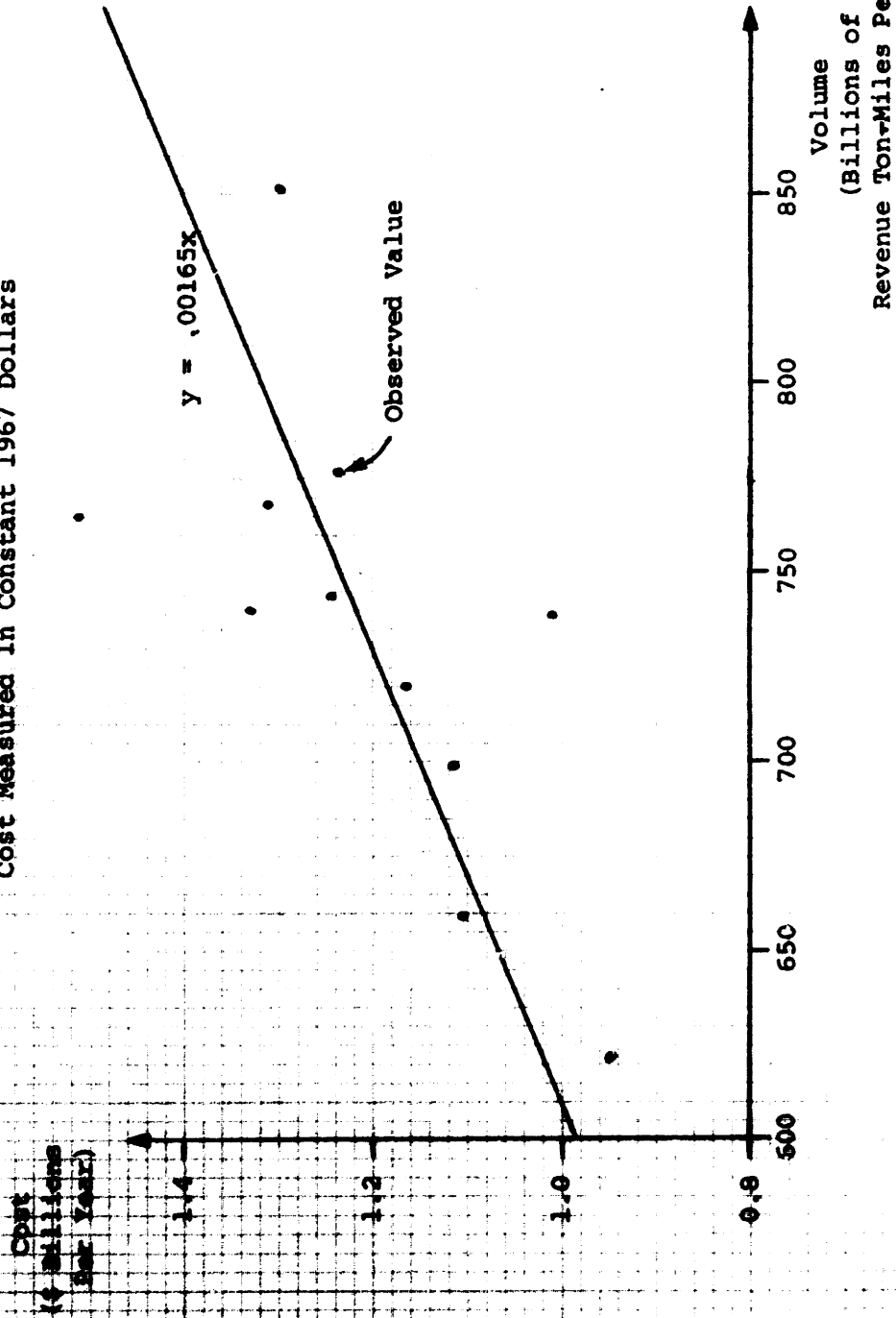


FIGURE 3-4
OTHER TRUCK COSTS

Cost Measured In Constant 1967 Dollars



3.1.3 ME EXPENSE.

ME expense is modelled by two sub-categories: labor and materials (which include all non-labor expenses except depreciation). The model does not deal with the deferral of maintenance of equipment. Even though this problem does exist in the industry, it is not as serious as the deferrals that have occurred in maintenance of way,¹ which are dealt with in the model. Thus, the (somewhat inadequate) observed expenses over the calibration period (1963-1973) were used as the basis for the cost functions described in this section.

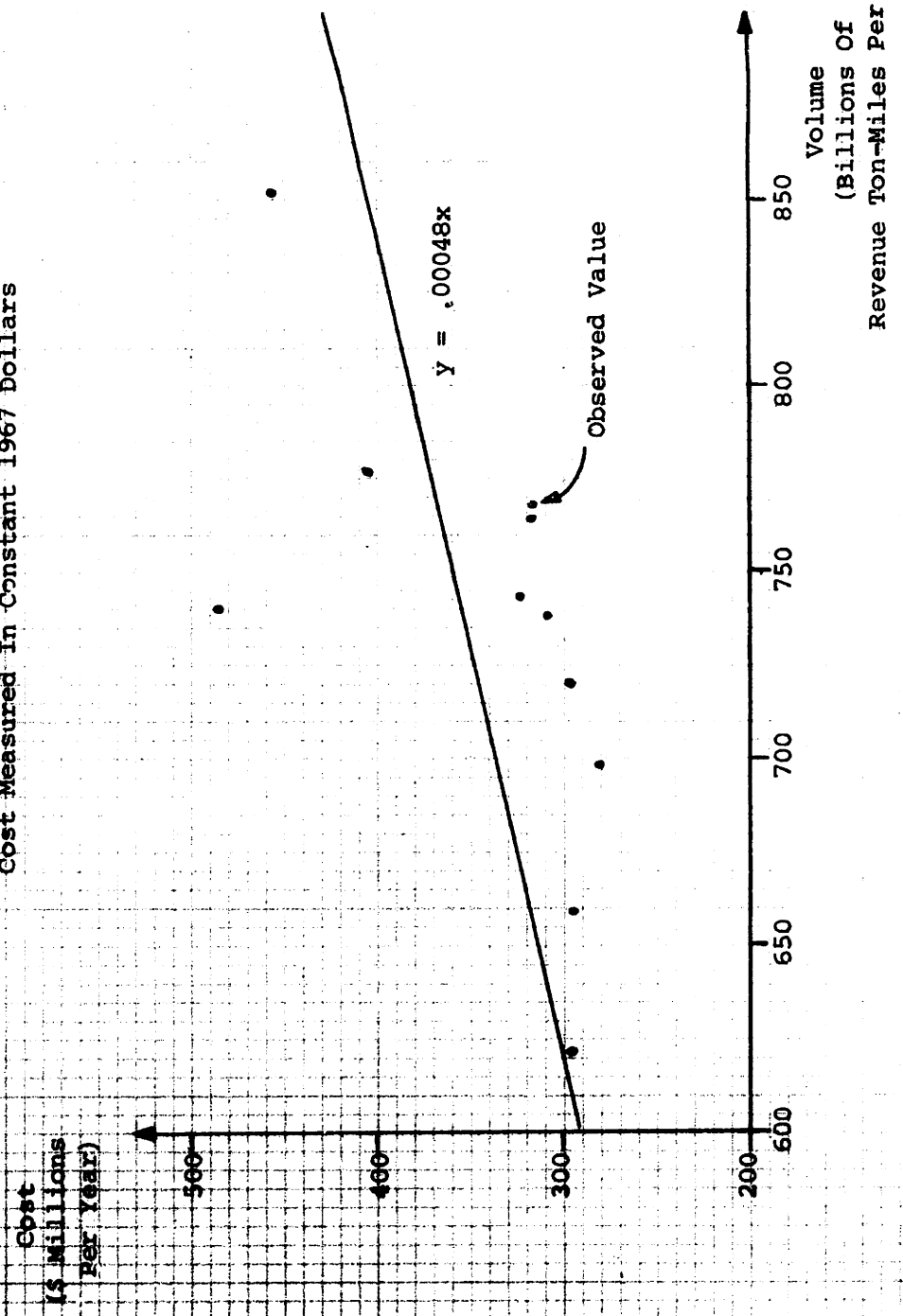
3.1.3.1 ME Material Cost - "Amount" Of ME Required.

The "amount" of maintenance of equipment necessary for a given volume of traffic is determined through the function depicted in Figure 3-5, which relates constant 1967 dollar material costs to volume. "Material" costs represent more than the costs of direct materials actually used to repair equipment, as this function was derived from all the non-labor expenses charged to maintenance of equipment (except for depreciation). Thus, cer-

¹ The interested reader is referred to [5] for estimates of the relative amounts of deferred maintenance and capital expenditures on way and on equipment.

FIGURE 3-5
MATERIAL COST

Cost Measured in Constant 1967 Dollars



tain items of repair shop overhead (such as heating and lighting) are included in these costs, but it was impossible to discern the extent of these factors, given the available data. It is likely, however, that direct materials comprise most of the reported costs, so that the constant dollar value of these costs is indicative of the "amount" of maintenance to be performed. The model computes the constant 1967 dollar amount of material cost necessary for a given volume via the function depicted in Figure 3-5, and then inflates the value obtained to give the current cost.

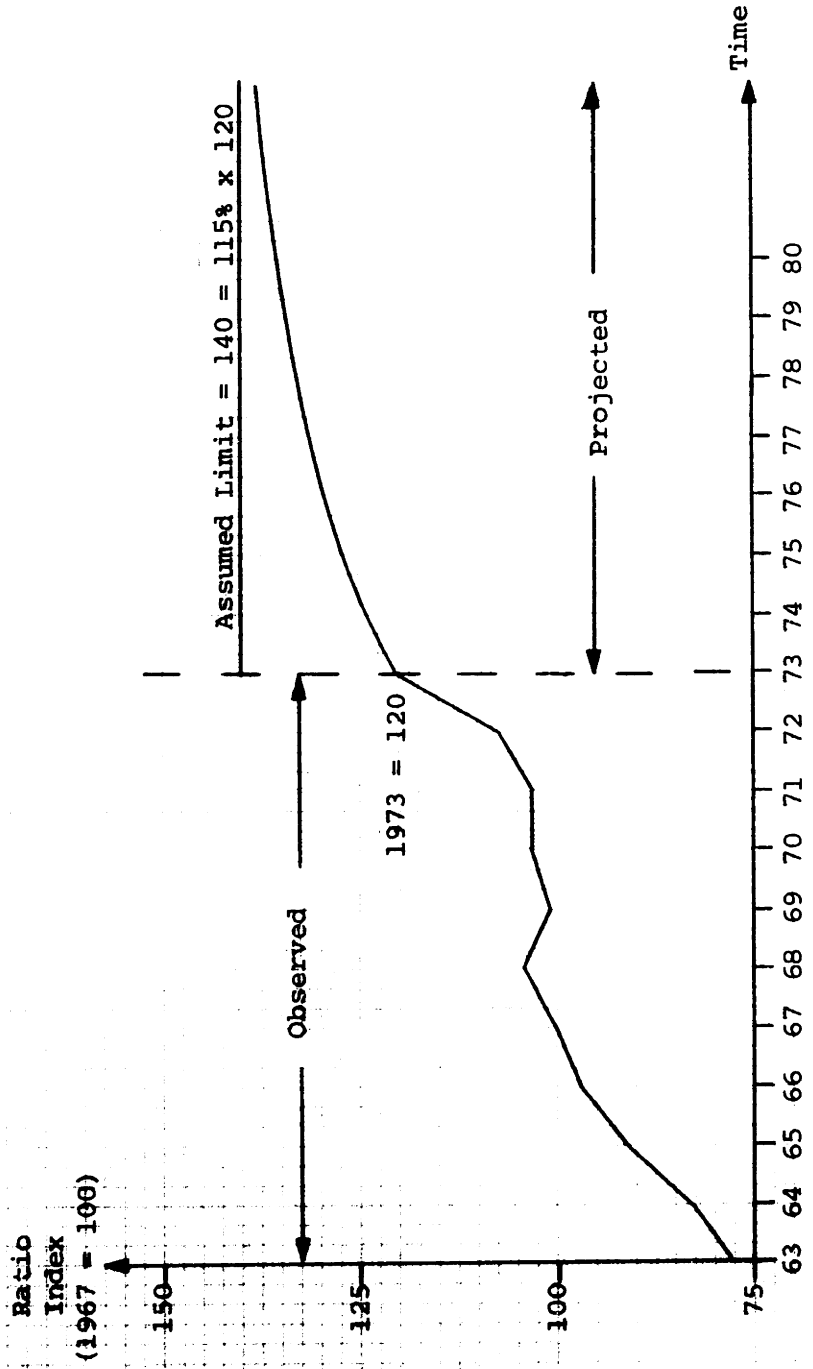
3.1.3.2 ME Labor Cost.

In order to obtain ME labor costs, the model first determines the amount of labor required, and then multiplies this by the unit ME labor cost (cost per man-year), which includes fringe benefits as it did for TTGM labor. To determine the amount of labor required, the amount of maintenance necessary (obtained through the function in Figure 3-5) is divided by the material/labor ratio presented in Figure 3-6.¹ This ratio measures the annual

¹ The function depicted in Figure 3-6 represents the ratio of material cost as would be computed by the model to actual man-years of labor estimated over the data period. These "productivities" rather than the actual

FIGURE 3-6
ME MATERIAL/LABOR RATIO

Constant 1967 Dollar Material Cost Per Man-Year
1967 Ratio = 3538



constant dollar material cost per man-year, and thus can be thought of as a measure of maintenance "productivity". As is evident in Figure 3-6, this ratio was increasing over 1963-1973, as was TTGM labor productivity (Figure 3-2). Although the cause of this increase is not clear, it too was probably the result of labor cutbacks occasioned by the rapidly rising labor costs over that period. As was the case with TTGM labor productivity, the actual values of this "productivity" were used for the purpose of validation, while for future cases it is assumed to exponentially decay up to 115% of its 1973 value, as indicated in Figure 3-6. (This 115% value was chosen based upon the observed past trends in the data, and to be identical in magnitude with that used for TTGM labor productivity. This consistency with TTGM productivity was not necessary, but was desirable for the sake of uniformity in assumptions.) Also, actual unit labor costs were used for validation, while in future cases the 1974 unit labor cost (adjusted for inflation) was used. Both the maintenance "productivity" and unit labor costs are parameters that could be altered as part

ones (which behaved similarly over 1963-1973) were used in model validation to avoid unnecessary error caused by combining model-computed material costs with actual material/labor ratios.

of an alternative to be tested with the model.

It should be noted that the method by which ME labor costs are computed inherently assumes that the work force can be adjusted quickly to the level dictated by the current volume, and that labor requirements are completely variable in volume. The implications of these and other cost assumptions are discussed in Section 3.4.5.

3.1.4 MW EXPENSE.

One of the focal points of this research is the relationship between quality of the fixed facilities and railroad costs. Since this quality depends upon the long-run effects of maintenance and investment in way policies, the model must be able to vary these expenditures in accordance with the specific type of policy being considered. Thus, MW is not determined solely through volume-based functions as are TTGM and ME expenses. Rather, the model "plans" MW expense through the maintenance policy described in the equations of the MW budgeting section of the Income Module. This planned amount then becomes part of the Maintenance and Investment (In Way) Rate that "supplies" quality to the Quality of Facilities Level in the Quality of Facilities Module.

The MW budgeting section of the Income Module is structured such that three factors are taken into consideration in planning MW: a maximum affordable amount of MW based upon income statement considerations; a minimum feasible amount that depends upon the current quality of the system and the volume passing over it; and lastly, a desired amount that would be undertaken in the absence of financial constraints. In order to understand how the latter two factors are determined in the model, it is necessary to understand how quality is modelled. Therefore, a detailed explanation of them is delayed until Section 3.4, which describes the Quality of Facilities Module. As will be explained at that point, in this study, the minimum feasible amount represents the continuation of past observed (inadequate) practices, while the desired amount represents the expense necessary to eliminate most of the current backlog of deferred MW over a period of about 25 years. The maximum affordable amount, as is explained below, represents a rather loose constraint which can limit MW expense for the sake of current reported earnings. As such, it is useful in the study of short-term versus long-term profitability, as affected by maintenance policy.

The Income Module accepts the minimum feasible and desired amounts of MW from the Quality of Facilities

Module, while it internally calculates the maximum affordable amount. It then uses these three factors to determine how much maintenance to perform, and hence the amount charged against income and the amount of quality supplied by maintenance. The general nature of this process is depicted in Figure 3-7(a), while Figure 3-7(b) shows how the budgeting process determines the appropriate amount to spend on MW. It should be noted that the desired amount is always at least as large as the minimum feasible amount in the model. Hence, only the three situations depicted in Figure 3-7(b) can occur.

As Figure 3-7(b) shows, the model is structured so that it will always perform at least the minimum feasible amount, which is based upon the observed (inadequate) relationship between MW and volume over 1963-1973. If there is sufficient "slack" in NROI to allow additional expense, MW will be increased, but only up to the lesser of the desired or maximum affordable amounts. This latter figure, which is computed within the Income Module, represents the amount of MW that can be performed while still achieving a minimum desirable return on investment (NROI divided by net investment) in the current year's financial statements. It thus stresses short-term profitability in the MW planning process. This minimum desirable return may be assigned various values as part of

FIGURE 3-7(a)
DETERMINATION OF MW EXPENSE

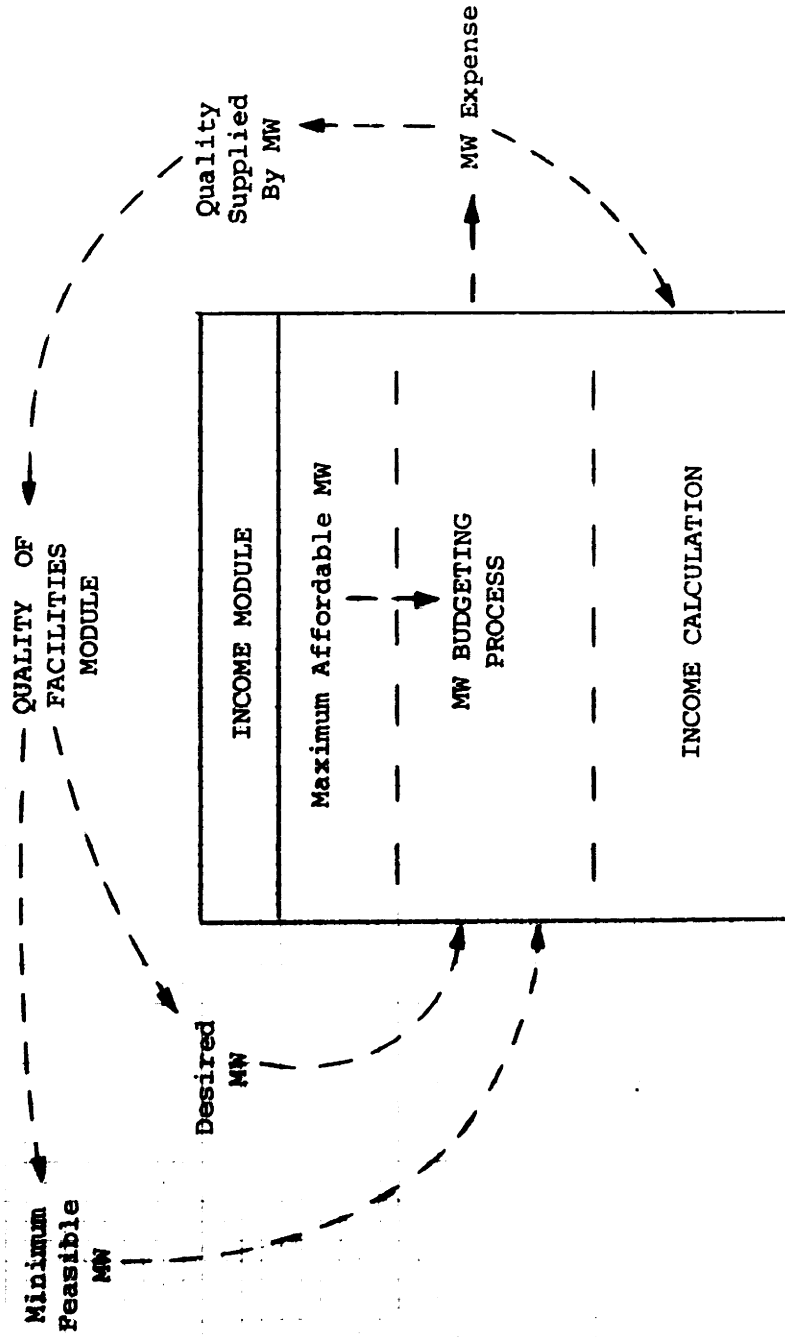
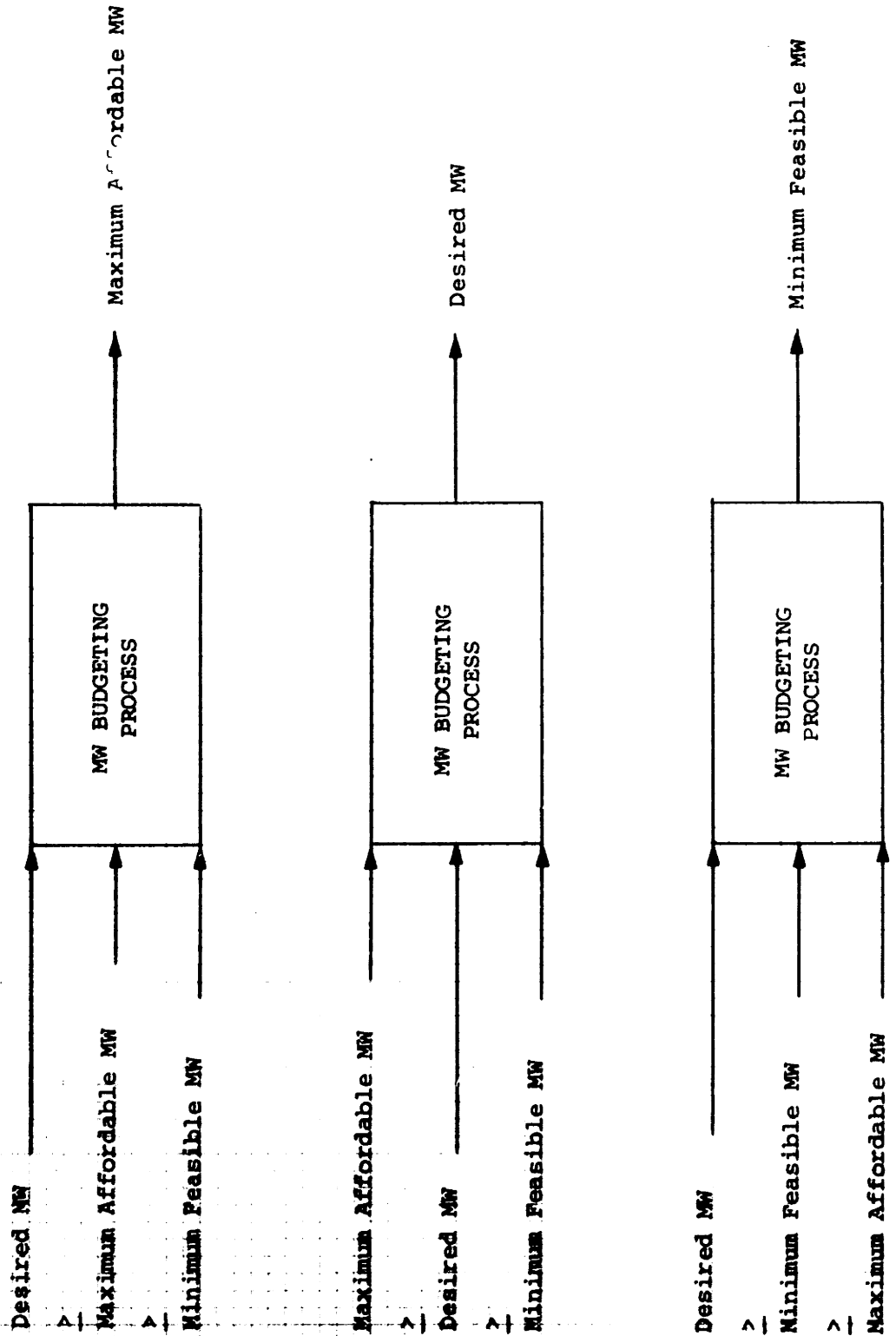


FIGURE 3-7 (b)
DETERMINATION OF MW EXPENSE



alternative policy options, but for the purposes of this study, it was assumed to be equal to the average interest rate on outstanding long-term debt, a proxy for the industry's cost of capital.

Because the average interest rate on outstanding debt is currently higher than the rate of return being achieved in the industry, the maximum affordable amount of MW turns out to be less than the actual MW being performed, which is assumed to be the minimum feasible amount (and hence is always done) in the model. Thus, the maximum affordable MW is "ignored" by the model unless a significant change in NROI occurs, in which case it can take over from the minimum feasible amount as the constraining maintenance factor. This phenomenon is discussed in Section 5.2.5. Furthermore, because the maximum affordable amount is typically less than the minimum feasible amount in the study, the desired amount would never be performed if the model were left to decide on its own. Hence, in the cases analyzed in Chapter 5 where the desired amount is spent, the model was forced to do so.

The above discussion points out how MW expense is determined in the Income Module, given the inputs it receives from the Quality of Facilities Module and the maintenance of way policy to be followed. In Chapter 5,

interesting results caused by varying this policy are discussed, whereas in Chapter 4, which deals with model validation, the policy in effect was designed to lead to the "minimum feasible" amounts of MW observed over 1963-1973.

3.1.5 ALL OTHER EXPENSES.

Besides computing TTGM, ME, and MW expenses, the Income Module must "determine" state and local taxes, net rental expense for equipment and facilities, and all passenger related expenses that have not been accounted for elsewhere.¹ The model does not explicitly deal with the mechanisms that give rise to these costs. Rather, it treats them as exogenously determined variables. For all future cases analyzed, these costs are assumed to stay at their 1973 value (adjusted for inflation) and for the purpose of model validation their actual values over 1963-1973 were used.

¹ Certain passenger service expenses are accounted for by the model in other cost categories. For example: state and local taxes include those of freight and passenger service; net rentals also include those associated with passenger service; and, book values and hence depreciation charges include those of passenger

This approach to dealing with these costs was taken to simplify the model, as the prime interest here is in the costs previously discussed as well as in total equipment-related costs (i.e., depreciation, fixed charges, and rental expense). These simplifications might detract from the model's usefulness as an absolute predictor, but should not affect its usefulness in comparing alternatives aimed at changing the costs of interest, as is done in this study. This is because these assumptions are invariant across alternatives, and thus affect all alternatives tested. Given that they are understood, their impacts on the model's outputs can be taken into account in comparing cases.

The rationale behind these simplifications is as follows. First of all, the industry is primarily freight-oriented, so it is beyond the scope of this study to deal with all the attributes of the negligible passenger operations. Therefore, these operations and their associated costs are assumed to stay at a constant level (adjusted for inflation) in the future, representing one of many expenses that the industry has to put up with.

service. Thus, the passenger expenses "not accounted for elsewhere" represent total passenger expense, inclusive of all associated taxes, less the state and local taxes, rental expense, and depreciation charges for passenger service.

State and local taxes, which were practically constant over the past twenty years [2], are assumed to continue this behavior and are adjusted for inflation to represent the fact that they too are affected by this economic ill. As will be explained in Section 3.2, it is assumed that the size of the industry's network is relatively fixed in the future cases analyzed. Thus property taxes, which are included in state and local taxes and most likely make up the majority of these taxes, would behave in the manner described here under this assumption about network size.

Net rents for equipment and facilities, which are almost entirely due to equipment [3], are also treated in this simple fashion. It is beyond the scope of the model to try to make the decision to lease or rent rolling stock instead of buying it. Rather, in all future cases analyzed, it is assumed that the numbers of leased or rented cars and locomotives stay the same as they were in 1973, with all additional equipment required after 1973 being purchased. This is a simplification, as poor earnings have led to an increasing reliance on leased or rented equipment in the past,¹ for two reasons. First, poor earnings make it difficult for a railroad to

¹ This is discussed in detail in Chapter 4.

finance the purchase of equipment, either by cash or debt financing. Secondly, railroads with no taxable income cannot use the investment tax credit or the additional depreciation charges associated with the purchase of new equipment as means of reducing their federal income taxes, so it is sometimes more economical for them to use lease financing or rented equipment.

In spite of these observed past phenomena, it is assumed that all additional rolling stock is purchased in the future cases analyzed, for the sake of model simplicity. This simplification should not detract from the model's usefulness as a long-run comparative tool, as it will purchase all equipment in each case analyzed. Furthermore, in the long run, the costs and cash flows associated with either method of equipment acquisition are not that different, as rental expense is replaced by fixed charges plus depreciation in the income statement, and by fixed charges plus the debt repayments and cash outlays for equipment in the flows of funds.¹

However, for the purpose of model validation over 1963-1973, it was recognized that if all equipment was purchased in the model over this period, the differences

¹ Of course, there is the tax shield provided by depreciation, but this is rather minor compared to the other flows of funds considered.

that would result between model and actual fixed charges, depreciation, and debt issuance/repayment could make it difficult to validate the other components of the model, as many of the model components interact. Therefore, over 1963-1973, the model was allowed to account for changes in the numbers of rented or leased cars and locomotives before it planned its capital expenditures on equipment. The amount of such equipment, and the associated net rental costs were therefore treated as exogenous variables which took on their actual values over 1963-1973 in the model's validation runs.

3.1.6 REVENUES AND OTHER INCOME.

Besides determining costs, the income module must also determine revenues and other income before ordinary income and NROI can be computed. The majority of industry revenues, and the ones of interest in this study, are those accruing from freight operations. Therefore, items such as other income, and passenger, mail, express, and miscellaneous revenues are treated as exogenously determined variables. That is, actual values were used for the purpose of validation, and future values are assumed to be inflation-adjusted constants, based on the

1973 actual values.¹

In dealing with freight revenues, the measure of unit revenue used is average revenue per (revenue) ton-mile, as this measure is in accord with the model's treatment of volume: revenue ton-miles per year. Freight revenue is therefore simply calculated as volume times average revenue. It should be noted that no consideration is given to the traffic mix and relevant freight rates for each class of traffic. Traffic mix is assumed to remain unchanged in future cases, and for the cases analyzed in this study, average revenue per ton-mile was assumed to inflate with general economic conditions after 1974, representative of across-the-board inflationary rate increases. For the purpose of model validation, actual values for average revenue per ton-mile over 1963-1973 were used.

3.1.7 INCOME MODULE SUMMARY.

The Income Module is responsible for determining

¹ Other income is treated as a constant, but is adjusted for interest earned/paid on deviations of net working capital about its 1973 year-end level, as other income includes the interest earned/paid on current assets/liabilities. This is further discussed in Section 3.2.

income. To do this, it accepts three sets of inputs: fixed charges and depreciation expense from the Fixed Assets And Debt Module, volume from the Volume Determination Module, and the minimum feasible and desired amounts of MW, as well as the effects of system quality on costs, from the Quality of Facilities Module. The first set of inputs are pre-determined expenses (i.e., short-run fixed costs), and no calculations have to be performed in the Income Module to obtain their values. Volume is used to determine revenues and all volume-dependent costs such as TTGM labor cost, fuel consumption, TTGM other costs, ME material costs, and ME labor costs through empirically derived functions and assumptions about the future courses of labor productivities, factor unit costs, and unit revenues. Many of these cost categories are affected by the quality of the fixed facilities, as will be explained in Section 3.4.2, so the Income Module adjusts its computed costs to account for these effects. The Income Module also has a maintenance of way budgeting section that determines the amount to be spent on MW, given the maintenance policy described in its equations. The amount that is decided upon is passed to the Quality of Facilities Module to form part of the Maintenance and Investment Rate that "supplies" quality to the Quality of Facilities Level.

Once all the expenses and revenues have been determined, income and cash flow are calculated¹ and passed to the Funds Flow And Finance Module for use in the rates that determine the levels of retained earnings and net working capital. Federal income tax must be computed before ordinary income and cash flow can be determined, and this is done by multiplying (ordinary) net income before tax (NIBT) by the effective tax rate. This tax rate was found to average 20% of NIBT,² with little variance, over 1963-1973, and this is the value used in the model. The tax rate could of course be varied as part of an alternative to be tested.

The Income Module also provides an input to the Fixed Assets And Debt Module in the form of income before (income) tax and fixed charges, which is used to measure the amount of interest coverage that exists in order to determine constraints on debt availability.

¹ The equations which perform these calculations are given in Appendix A.

² This is discussed further in Chapter 5. As is explained there, this seeming low tax rate is due to the use of accelerated depreciation, the investment tax credit, and in part due to some railroads operating at a loss. However, because railroads operating at a loss reduce aggregate net income before tax without reducing taxes paid by the profitable roads, it is possible that the effective tax rate would be lower if all railroads were profitable.

3.2 FUNDS FLOW AND FINANCE MODULE.

The major function of this module is the determination of sources and uses of funds, given policies regarding dividends, liquidity, investment, and financing described by its auxiliary equations, and subject to the availability of funds (both internally and externally generated) as computed by other modules. In so doing, the Retained Earnings Level and the Net Working Capital Level are computed, the equations for which are in this module, as are the equations for their associated rates: the Ordinary Income Rate, the Dividend Rate, the Sources of Funds Rate, and the Uses of Funds Rate. Before describing how the module actually operates in determining the sources and uses of funds, the treatment of these sources and uses by the model will be explained.

3.2.1 SOURCES OF FUNDS.

Sources of funds available to the industry are modelled as:

- i) cash flow (ordinary income plus depreciation);
- ii) cash supplied through the disposal of assets;
- iii) decreases in net working capital;

- iv) equipment debt; and,
- v) unsecured debt.

3.2.1.1 Equipment Debt And Unsecured Debt.

As is evident in the above list, external sources of funds have been aggregated into two categories: equipment and unsecured debt. For the sake of model simplicity there is only one type of equipment debt and one type of unsecured debt, and both these financial instruments are assumed to have the same maturity, yield, and payment schedule (although the model structure could be easily altered so that these two types of debt would not be similar in terms). The major difference between them is that equipment debt may only be used for investment in equipment and is more easily obtained than is unsecured debt, but unsecured debt may be used for any purpose. It should be noted that equipment debt is constrained in availability, only less so than unsecured debt. This is explained in Section 3.3.4, and is indicative of the fact that even this easily obtained source of funds has been becoming harder to obtain recently due to overall poor earnings in the industry.

New equity is not explicitly treated as a source of external funds. Rather, it may be conceptualized as be-

ing a part of unsecured debt, since it would not be available to the industry unless profits were high enough relative to debt obligations (the same consideration which constrains unsecured debt availability), and since it would have to offer an expected return at least as high as that on unsecured debt (ignoring tax considerations) to be attractive to investors, because it is a higher-risk security from an investor's standpoint.

This treatment of external sources of funds is highly simplified, but captures the major essence of the capital market's interaction with the industry: equipment debt is more easily obtained than is general debt (or equity) and can only be used to finance investment in equipment.

3.2.1.2 Decreases In Net Working Capital.

Decreasing net working capital as a source of funds is allowed in the model, and the amount of the decrease (if any) is determined by the liquidity policy to be followed and the priority that liquidity is given in times of scarce funds, both of which are described in Section 3.2.3.

3.2.1.3 Cash Flow.

Cash Flow is merely ordinary income plus depreciation, and is computed by the Income Module. It should be noted that expenses, which are actually a use of funds, are subtracted from revenues to arrive at ordinary income. Hence cash flow represents a net source of funds and can be negative if expenses are high enough.

3.2.1.4 Cash From Asset Disposals.

Cash from asset disposals represents the salvage value of retired rolling stock and other depreciable assets. This source of funds is not treated as being controllable in the short run, as rolling stock and other depreciable assets are assumed to only be written off when they reach the ends of their normal average economic lives (estimated in the calibration process), supplying cash from salvage or resale. Sale of these assets before the ends of their normal lives and deferred retirements of these assets are not explicitly considered in the model. As will be explained in Section 3.3, which describes the Fixed Assets And Debt Module where this source of funds is determined, the "normal" lives estimated for these assets are based upon observed phenomena over 1963-

1973. Thus, these average lives correspond to those in effect in the past, regardless of whether these observed lives were longer or shorter than they should "normally" have been. Furthermore, the manner in which these lives are modelled, particularly in the case of equipment,¹ does not lead to the automatic retirement of an asset after exactly n years, where n is the calibrated life of this type of asset. Rather, n years represents the average life, and a group of assets installed in any one year will be retired after n years on the average, with some being retired sooner and some later, as is the case in actuality. In this manner, premature sales and deferred retirements are implicitly included in the model.

It should be noted that cash supplied by the disposal of non-depreciable assets such as rails, ties, and ballast² is not included in this source of funds in the

¹ In Section 3.3.1, equipment lives are shown to be modelled through the use of third order delays [6]. By their nature, these delays retard an input (such as a group of freight cars installed in any one year) so that an output equal in magnitude, but distributed over time about the average delay length (such as the average life of a freight car), is achieved. Thus, a group of freight cars installed in any one year will be retired, on the average, 20 years later (the calibrated life of freight cars), with some being retired sooner, and some later.

² The interested reader is referred to Chapter III of [4] for a brief, but informative discussion of the railroads' method of accounting, known as retirement accounting. A detailed exposition is given in [7].

model, as the model treats this cash flow differently. Without getting into the details of railroad accounting, suffice it to say that these assets supply cash from disposal in two ways. First, a tax shield similar to that caused by depreciation is obtained whenever these assets are retired without replacement, as their original cost net of salvage is charged to maintenance of way expense in the year of retirement, even though there has been no such expenditure of funds. These charges should therefore be added to ordinary income, as is depreciation, to arrive at cash flow. However, this source of funds has been negligible in the past [4]. Furthermore, the model does not allow network rationalization in the case of declining volume. Rather, it is assumed that the size of the network remains relatively constant in the future. Thus, this source of funds is not considered.

Second, whenever these assets are replaced, either by like kind or something else (i.e., similar or heavier rail weight in the case of rails), a charge is made to maintenance of way expense that is again net of salvage. So, regardless of whether a non-depreciable road asset is retired with or without replacement, the salvage obtained shows up as a direct reduction in maintenance of way expense. Inasmuch as the model budgets or plans

reported MW expense, and often on the basis of the 1963-1973 actual reported values, which included salvage, this cash from salvage is therefore implicit in the model's budgeted MW outlays.

3.2.2 USES OF FUNDS.

Uses of funds¹ are as follows:

- i) dividend payments;
- ii) debt repayments;
- iii) investment² in way and structures;
- iv) investment in equipment; and,
- v) increases in net working capital.

These uses of funds, and their associated sources, are determined by the policies described in Section 3.2.3. At this point, however, the manner in which these uses

¹ It should be recalled from Section 3.2.1.3 that expenses are subtracted from ordinary income and hence are modelled as a reduction in sources of funds. Thus, they are not included in the model's uses of funds.

² The terms "investment" and "capital expenditures" are used interchangeably in this study when referring to annual expenditures. "Book value" is the term applied to historical, accumulated investments on the books of the industry.

are modelled will be described.

3.2.2.1 Dividend Payments.

Dividend payments are modelled solely in terms of cash dividends, and represent a direct reduction in net working capital and retained earnings. Stock dividends, which have been negligible in the past [3], are ignored.

3.2.2.2 Debt Repayments And Interpretation Of Negative Net Working Capital.

Throughout this study, "debt" implies long-term debt including that due within one year, and the level of net working capital does not account for these imminent obligations. Short-term debt, which is accounted for as a current liability in actuality, will be qualified as such whenever referred to.

Debt repayments, the amount of which is determined in the Fixed Assets And Debt Module, are modelled as direct reductions in net working capital. This can be interpreted as actual payments being made when net working capital is positive. However, when net working capital becomes negative, as it does in some applications of the model, the interpretation is somewhat different. Devia-

tions in net working capital above or below its 1973 year end value of \$194 million earn or cost the industry (in the model) the prevailing interest rate on long-term debt, which is assumed to be the same for short-term debt. These earnings/costs are added/subtracted to other income since in actuality other income includes the net interest earned on current assets and liabilities. Because debt repayments are modelled as direct reductions in net working capital, such a reduction therefore has several possible interpretations when net working capital is negative. First of all, it might be interpreted as debt in default being treated as a current liability and costing the prevailing interest rate rather than the rate associated with the original debt issue. This might also be interpreted as the creditors' having granted renewable short-term extensions on the obligations that could not be met when they became due. Finally, it can be interpreted as the industry having obtained renewable short-term loans from elsewhere (i.e., possibly from the government) that allow them to meet their debt repayments (or other current liabilities).

Whatever the interpretation, negative net working capital represents a cost to the industry associated with money being owed to someone who has not yet been paid. If the model manages to raise net working capital

back to a positive level, it indicates the ability on the part of the industry to repay these obligations under the conditions or alternatives in effect. If net working capital becomes more and more negative, however, it indicates insolvency under the assumed conditions. Since the model does not "allow" the industry to go out of business, the indicated extent of insolvency can be misleading, as it is caused by continued operation under the assumed conditions. In actuality, something would be done (i.e., possibly government intervention of some sort, or reorganization) that is not accounted for in the assumed scenario being modelled. Therefore, when net working capital becomes hopelessly negative under a given set of assumptions, it indicates the extent of the need for either federal intervention or some other type of alternative that would arise if the industry were to continue operations in the assumed scenario.

3.2.2.3 Investment In Way And Structures.

Investment in way and structures is determined by the investment and financing policies in effect, as will be explained in Section 3.2.3. The model does not differentiate between the types of assets invested in (i.e.,

depreciable or not)¹ nor between various types of investments (i.e., new acquisitions, replacements, or improvements). Rather, investment in way is considered only in terms of its total dollar amount and the impact it has on system quality, without concern being given to the exact nature of the expenditures by the model.

It should be noted that the model therefore does not explicitly deal with the issue of the capacity of the fixed facilities and the investments necessary to increase this capacity. These investments are included in the total investments made, which increase with volume. Hence it is assumed that there is always sufficient capacity of the fixed facilities generated by the total investments made. Furthermore, it is assumed that any additions made to the system (i.e., laying of parallel trackage) do not alter the system configuration to a great extent, and therefore do not alter property taxes.

¹ As will become evident in the discussion of the Fixed Assets And Debt Module, depreciation on way and structures is computed on the basis of total gross book value of all the road accounts (including the non-depreciable assets) and the aggregate depreciation rate that would have led to the observed depreciation expense over 1963-1973 using all road accounts as the depreciation base. Thus, it is being implicitly assumed that the investments made in way and structures are divided among depreciable and non-depreciable assets in such a manner so as to maintain their relative gross book values.

While the model does not explicitly deal with the issue of the capacity of the fixed facilities, it does deal with the capacity of the rolling stock. This capacity is determined by the amount of rolling stock on line and its productivity. This productivity is affected by the quality of the fixed facilities and hence by investment (and maintenance) outlays on way and structures. Thus, inadequate investments in way and structures can constrain system capacity in the model, and this constraint is implicit in the effect of quality on the capacity of the rolling stock.

3.2.2.4 Investment In Equipment.

Investment in equipment is treated as consisting of three types of expenditures, namely those on freight cars, locomotives, and other equipment (passenger, floating, work, and miscellaneous equipment). Investment in other equipment has been rather negligible in the past [1], and thus is not explicitly determined by the model. Rather, it is treated as an exogenous input to the model which is assumed to be always carried out (regardless of the financial position of the industry) and which cannot be financed by equipment debt. In spite of the fact that passenger locomotives (and possibly passenger cars)

are actually eligible for equipment debt, the annual expenditures on them are so small that their treatment as part of "other equipment" not being eligible for this debt is not unreasonable for the purposes of this study.

In dealing with investment in equipment, the model is therefore primarily concerned with freight service rolling stock. The majority of these investments have in the past been for the purchase or building of new equipment, although there was a noticeable amount spent on rebuilding equipment (particularly cars) in the mid-sixties.¹ In spite of the current negligible expenditures on rebuilds [2], it was decided to include them in the model in an implicit manner, particularly for the purpose of model validation. This was desirable because ignoring them completely over the 1960's might have had a small, but noticeable effect on capital expenditures on equipment and hence on other interacting model components that were to be validated. Therefore, the numbers of rebuilt equipment were taken into account in initializing the retirement rates for equipment in the Equipment

¹ The reader is referred to [1] for detailed information on the numbers of rebuilds performed and the associated capital expenditures made over the data period. Their presence was most noticeable in 1967, when they represented 25% of total car installations and about 15% of total expenditures on cars.

Needs Module, as rebuilds may be thought of as retirements requiring replacement. Furthermore, the prices of additional cars and locomotives to be installed were derived by dividing total capital expenditures on cars and locomotives by their respective numbers of total installations, including rebuilds, so that the effect of inexpensive rebuilt equipment on the expenditures necessary for a given number of installations would be captured. Hence the names of the rates associated with the Freight Cars Owned Level and the Freight Service Locomotives Owned Level in Table 3-1 include rebuilds.

For the purpose of future cases, it is assumed that rebuilds play a relatively insignificant role, as the prices of additional equipment are based on those at the end of the data period, when rebuilds were rather negligible.

3.2.2.5 Increases In Net Working Capital.

Increases in net working capital, the final item on the list of uses of funds, are determined by the liquidity policy to be followed, which will be discussed in the next section along with the other policies included in this module.

3.2.3 POLICIES AND THEIR IMPLEMENTATION.

3.2.3.1 Feedback Of Decisions On Net Working Capital.

Now that the nature of the sources and uses of funds dealt with in the model has been described, the policies which govern the model's actions with respect to these flows of funds can be explained. As was evident in the preceding discussion, only certain of these sources and uses are actually decided upon at any point in time (both in reality and in the model). Others represent facts about the current state of the system, which represents the cumulative effects of all previous decisions, and these past decisions cannot be altered. Specifically, debt repayments, cash from asset disposals, and even cash flow represent facts about the current state of the system, as they are part of the current state of affairs caused by previous issues of debt, investments in equipment, and investments in way.

Thus, it can be seen that net working capital is one of the many system components affected by feedback, as previous decisions about sources and uses of funds "return" to interact with currently determined flows of funds in changing the level of net working capital. Furthermore, since the decisions reached at any point in time about sources and uses of funds are based upon the

current state of the system, it can also be seen that previous decisions, which have determined this current state, affect current decisions. Hence, the feedback effect is even more important.

Figure 3-8 represents a highly simplified symbol diagram of how the decisions reached at any point in time by the policy equations of interest here interact with the current state of the system caused by previously made decisions in determining the rates of this module. The decisions reached in this module also affect rates in other modules, as will be explained below, but for the sake of simplicity in the figure, these interactions have been omitted.

The solid lines being controlled by the "valves" (rate equations) in Figure 3-8 represent the rates of flow of money into and out of the levels. The Sources of Funds Rate and the Ordinary Income Rate and depicted as capable of flowing out of, as well as into, their respective levels. This is because negative income is always a possibility, and if it is significantly so, it can overwhelm the other sources of funds to cause a drain on net working capital.

The dashed lines in the figure represent flows of information which eventually result in the determination of a rate. As is evident even in this highly simplified

FIGURE 3-8
DETERMINATION OF RATES
FUNDS FLOW AND FINANCE MODULE

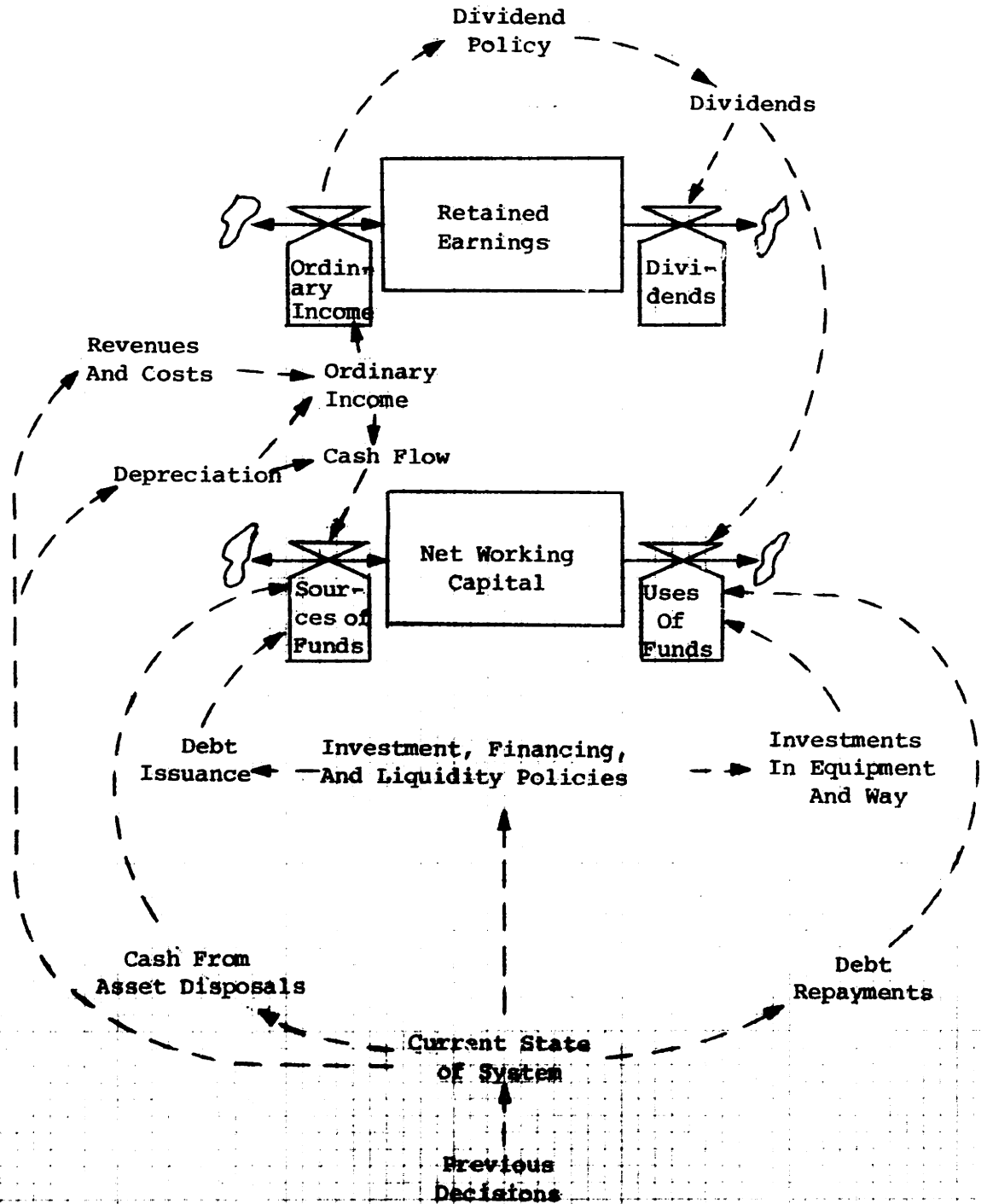


diagram of the process by which the model determines the rates of interest here, rate determination is a complex procedure which depends upon many factors. Auxiliary equations (not explicitly depicted in the figure) are therefore used to represent the many important factors which help determine a rate. Specifically, each individual source or use of funds is computed via auxiliary equations which either represent rules relating these items to the current state of the system or which represent policy statements that determine certain sources and uses based upon the current state of the system. The interest here is in how these policy statements determine the current amounts of debt issuance, investments in way and equipment, and dividends, as the other sources and uses of funds are computed in other modules, and result from these same decisions having been made in the past.

The policies described by the model's equations are very simplified. It should be recalled that the industry is being treated as one large railroad, and thus the policies presented here represent simple statements of how this "railroad" behaves, based upon the observed behavior over 1963-1973 and upon the general nature of the rules that would be followed by an individual railroad. The manner in which these policies are represented in the

model will now be discussed in turn, along with a flow-chart that should clarify their interactions in determining the sources and uses of funds, and hence the level of net working capital.

3.2.3.2 Dividend Policy.

The dividend policy is merely a statement of the percentage of ordinary income to be paid out as dividends. The model is structured such that it iterates four times per year, representing the four financial quarters. The previous quarter's income is used as the basis of the current quarter's dividends as it often is in actuality, hence the dashed line from the Ordinary Income Rate to the Dividend Policy in Figure 3-8.¹ The dividend payout

¹ Due to the nature of DYNAMO, auxiliaries computed for the previous time interval are not available in the current time interval, whereas rates are. Furthermore, rates computed for the current interval are not available for use in other equations until the next interval. This is why ordinary income and dividends appear twice in Figure 3-8. Each is represented by an auxiliary as well as a rate equation. The auxiliaries are necessary to allow the current rates of income and dividends to affect net working capital. However, this quarter's dividends depend on last quarter's income, which is only available at the start of this quarter in terms of its rate over the previous quarter. Hence the dashed line from the income rate, and not the income auxiliary, to the Dividend Policy. The interested reader is referred to [6], [8] or [9] for more details on the method of equation solution in DYNAMO.

ratio (dividends divided by ordinary income) is the parameter which determines the percentage of ordinary income to be paid out in dividends, and is only applied when income is positive. The model does not pay dividends if there was a loss during the previous quarter. The dividend payout ratio may be set to various values as part of alternative dividend policies to be tested. It should be noted, however, that dividends represent nothing more than a drain on retained earnings and net working capital in the model. That is, they do nothing to support the market price of the stock and hence the financial rating credibility of the industry as depicted in Figure 1-1, as stock is not explicitly considered as a source of funds in the model. (Hence the disjoint nature of dividends and financial rating credibility in Figure 1-2, which represents the system dealt with by the model.) Therefore, any dividend policy tested with the model would not have any of the benefits it might in the real world.

For the purpose of model validation, actual dividend payout ratios over 1963-1973 were used. These ratios were constantly in excess of 50%, and exceeded 100% on several occasions [4]. A more conservative policy was used for the future cases analyzed in Chapter 5. This policy assumes a maximum payout ratio of 25% and this

ratio varies linearly between 25% and 0 as net working capital varies between \$+100 million and \$-100 million (constant 1967 dollars). In spite of the simplicity of its form, this policy is reasonable in nature. That is, if net working capital is becoming too low, it reduces this use of funds as a means of conserving cash.

3.2.3.3 Investment, Financing, And Liquidity Policies.

Besides dividends and debt repayments, there are three other uses of funds: investment in way, investment in equipment, and increases in net working capital. It is the function of the investment, financing, and liquidity policies to determine the desired magnitude of each use (i.e., how much should be done) and the desired mix of internal/external funds for each use, as well as the actual magnitude (i.e., how much will be done) and actual financing mix in cases where the desired amounts and mixes are constrained by the availability of funds.

Some of the equations used to describe investment policies are not in this module. As can be seen by re-examining Figure 3-1, the desired investments in equipment and way, as well as the minimum investment in way (another factor used in determining sources and uses of funds) are generated in other modules, so will not be

discussed in detail here. Briefly, the desired investments in equipment represent the annual capital expenditures necessary on freight cars and locomotives to adjust the current fleet of each to a size appropriate for a forecast level of demand several years hence. Desired investments in equipment also include rather negligible desired investments in other equipment (passenger, floating, work, and miscellaneous equipment) which are assumed to be always performed regardless of the financial position of the industry. The small amounts of these expenditures (about \$40 million per year for future cases) are assumed not to be "deferrable" in order to represent the fact that some investments (not necessarily these) must continue, no matter how dismal the financial picture.

The desired and minimum investments in way are determined in the Quality Of Facilities Module. In the cases analyzed in this study, the desired investment in way represents the capital expenditures necessary as part of a quality improvement program aimed at eliminating most of the current backlog of expenditures on way over a period of about 25 years, similar in concept to the desired maintenance of way discussed in Section 3.1.4. Also, the minimum investment in way is similar to the minimum maintenance of way described in that section, representing

the continuation of past observed practices (subject to certain qualifications described later in this section).

As will be evident in the discussions of the modules which generate these desired and minimum amounts, statements of policy (i.e., policy equations) are used to determine their magnitudes given the current state of the system, as was depicted in Figure 3-8. These quantities are then passed to the policy equations of this section, which act upon the state of the system that is represented by their values.

Before explaining how the actual magnitudes and financing mixes are determined for each of the three types of uses of funds of interest here, it is necessary to explain the manner in which liquidity policy is modelled. Liquidity policy determines, among other things, the desired addition to net working capital which is the last of the three "desired" quantities to enter into the funds allocation process. In order for there to be a desired addition (or subtraction) to net working capital, it must be too low (or too high) relative to some desired level. This desired level is indicative of the amount of net working capital that would exist if the industry was profitable enough to achieve it, and is determined by an equation (part of the overall liquidity policy imbedded in the model) which specifies what this desired level is,

given the current state of the system. In modelling this aspect of liquidity policy therefore, two issues had to be addressed: a) what level of net working capital would be desirable to the industry; and b) how would this desired level be affected by the state of the system. Clearly, no data exists that gives an explicit answer to either of these questions. However, it is possible to construct a "reasonable" estimate.

Dealing with the last question first, the issue is the identification of those attributes of the system which would determine the desired level of net working capital, and the nature of the relationship between these attributes and that level. Inasmuch as the current assets and liabilities of a profitable business typically both increase with the amount of business done (i.e., volume) and generally satisfy certain liquidity ratios, the net working capital of a profitable concern (i.e., desired net working capital) would increase with the amount of business done, although the exact nature of the functional relationship is uncertain. For the sake of simplicity, it was thus assumed that desired net working capital (in terms of constant 1967 dollars to account for inflation) was proportional to volume.

The level of net working capital desirable to the industry therefore concerns the proportionality factor

of this assumed linear relationship. Because Southern District railroads in the aggregate have had the highest rate of return in the past [2], and since net working capital has been generally declining even in this district over 1963-1973 while volume was rising [2], Southern District net working capital in 1963 was used as the basis for the proportionality factor.¹ That is, it is being assumed that Southern District net working capital was at its desired level in 1963, and that it has declined since then even in this "profitable" area of the industry for the same reasons that have caused the decline throughout the industry.

Thus, desired net working capital is assumed to be proportional to volume. The desired addition (or subtraction) to net working capital is also determined in a very simple manner, as it too could not be observed in the data. Specifically, the desired addition to net working capital is determined by the following equation (after inflating the desired level into current dollars):

$$\text{desired addition} = (\text{desired level} - \text{current level})/2$$

¹ Southern District net working capital in 1963 divided by Southern District volume in 1963 (adjusted for inflation to put it in terms of 1967 dollars) is the proportionality factor used.

This equation is presented because it is exemplary of the manner in which goal-seeking behavior is typically modelled in systems dynamics applications [9]. (As will become evident later in this chapter, many of the equations which determine desired annual uses of funds in the model are similar in form.) In spite of its rather striking simplicity, this type of equation represents the important fact that managerial decisions are typically made in terms of a desired state (goal), the current state, and some adjustment time which regulates the speed of corrective action. In this case, the 2 in the divisor causes one-half the discrepancy between the desired and actual levels to be corrected per year, and causes an exponential approach to the desired level (if it is stationary). While the exact form of the equation or its parameter might not represent the "rule" which determines desired additions to net working capital in the real world, it does capture the essence of any such rule that might be followed. Specifically, a desired level would be compared to the current level, and any discrepancy would be corrected over some period of time. In the case of net working capital, one would expect a fairly short adjustment time, and hence the 2 in the divisor.¹

¹ Compared to the adjustment times used for the other types of investments determined in the model by similar equations, that of net working capital is relatively short.

Now that the "desired" uses of funds have all been discussed, other factors which are important in understanding how funds are allocated to these various uses must be explained. In developing the funds allocation process of the model, it was desirable to have investment/financing policies built in that would be representative of the policies "observed" over the calibration period, so that the effects of changes in the apparent policies and/or the effects of other system changes with these policies in effect could be studied with the model. It must be noted that the data used for the development of the model's policy equations represented the behavior caused by the policies in effect, and did not represent the policies themselves. Furthermore, the observed industry behavior was the aggregate result of the policies followed by individual railroads. Hence, deriving the industry's "policies" from the observed data entailed making extreme simplifications. Specifically, the model's policies are formulated on the basis that the industry as a whole acted as if certain policies were controlling its actions over 1963-1973. Thus, the model's policies were formulated by combining the observed behavior with some knowledge about the underlying mechanisms leading to this behavior. These observations and the assumed underlying mechanisms will now be discussed.

Over the data period of 1963-1973, the industry continuously had uses of funds in excess of sources, leading to declining net working capital [2]. In spite of this declining net working capital, the industry continued to invest in way and equipment and financed a significant portion of these investments with unsecured debt and internally generated funds that could otherwise have been used to build up net working capital.¹ Thus, the priority given to liquidity in the industry seems lower than the priority given to other uses of funds. Furthermore, it was either not possible or undesirable to finance all of the investments in way and equipment by means of debt, as can be discerned by comparing the amount of debt issued to the capital expenditures made over the period.

In the case of rolling stock, over 1963-1970 (1970 is the last year for which detailed data on sources and uses of funds was available [4]) the average amount of annual capital expenditures not financed by equipment debt was 34%,² in spite of the relative ease with which

¹ This observed industry phenomenon was not due to declining net working capital in the unprofitable Northeast coupled with capital expenditures of the other more profitable areas of the industry. Net working capital was falling and/or substantially lower than previous values throughout the industry [2], in spite of growing of stable volumes.

² This figure was obtained by the analysis of data available in [4].

this type of financing is obtained, and in spite of declining net working capital. It is possible that some of these outlays were due to extensive cash financing on the part of several of the more profitable railroads, but the magnitudes involved rule this out as the primary reason. Because of the nature of railroad finance, it is likely that most of these expenditures arose due to the 20% downpayments required on equipment trusts and due to cash payments for rebuilt equipment and equipment built in company shops that did not qualify for other types of equipment debt (such as conditional sales contracts, as equipment trusts are only issuable for new equipment).

In other words, over 1963-1970, investments in rolling stock were made in such a manner that 34% (or some slightly smaller percentage, if the effects of the more profitable railroads are not ruled out) probably did not qualify for equipment debt financing, but were made anyway in spite of the declining net working capital. Thus, the industry acted as if there were some lower bound on cash expenditures on rolling stock that would be performed regardless of the level of net working capital. This lower bound represents the results of their decisions as to the amount of cash to use for financing certain investments in equipment and the cash base necessary (i.e., down payment) for the mix of equipment debt chosen.

The above observations and considerations formed the basis for the manner in which the model approaches the financing of equipment investments. The model acts as if there is some lower bound on investment in rolling stock that is always done, and that must be cash financed (in addition to the negligible investments in other equipment). However, it is assumed that if net working capital is low enough, this lower bound will be reduced as a means of conserving funds, representing a reduction in rebuilds, etc., or a switch to debt instruments that require smaller or no cash down payments (i.e., conditional sales contracts).

Specifically, these "Necessary Cash Expenditures On Rolling Stock" (NCERS, as they are called in the model) are modelled as a certain percentage of the desired investment in rolling stock, the percentage being linearly reduced between its maximum value and zero as net working capital varies between \$+100 million and \$-100 million (constant 1967 dollars). For the purposes of model validation, the observed 34% was used as the maximum value over 1963-1973. However, as mentioned earlier, rebuilds significantly decreased after 1970, the last year for which data was available in determining the 34% figure, and about that point in time when net working capital was at new lows [2]. Thus, it is possible, but not dis-

cernable from the available data, that cash uses did decline when net working capital was at a low level, compatible with the simple policy statement used by the model. Taking this reduction in rebuilds into account, and as a means of being conservative, it was assumed that for the future cases analyzed, the maximum percentage of the desired investment in rolling stock that could not be financed by equipment debt was 15%, indicative of an assumed tendency towards debt instruments which require small or zero down payments (i.e., conditional sales contracts).

Further aggravating the decline in net working capital was investment in way and structures. Even if all the unsecured debt issued over 1963-1970 [4] were allocated to financing these investments in way, it would not have been sufficient to finance the expenditures made. Net working capital was thus used as a means of financing some of these investments. So the industry acted as if there were some minimum amount of investment in way it would perform in spite of declining net working capital and in spite of the relative unavailability of unsecured debt caused by their poor earnings. As explained in the discussion of the Quality Of Facilities Module, this minimum amount is determined in a simple fashion based upon the observed relationship between actual in-

vestments and volume over 1963-1973. However, the model adjusts this amount between the functionally determined value and zero as net working capital varies between \$+100 million and \$-100 million, as another means of conserving funds. This is not the true "rule" followed in the industry, as is evident in its simple form, but is used merely as a means of indicating that some cutbacks would likely occur if net working capital were becoming low enough.¹ This same reasoning applies to the similar treatment of necessary cash expenditures on rolling stock and the treatment of dividends.²

¹ The effect of this conservation of net working capital "rule" as applied to investment in way and structures is evident in the difference between model and actual capital expenditures in the early 1970's, as presented in Figure 4-6. This is further discussed at that point.

² It should be noted that this net working capital conservation "rule" was applied to all three factors for future cases, while its effect on dividends was omitted for the purpose of validation. Furthermore, the effect of this "rule" is to make the area around zero net working capital one that is difficult to get out of, in either direction. Thus, in the future cases analyzed in Chapter 5, the industry has to be doing very poorly for net working capital to go below \$-100 million, and it has to be performing very well for net working capital to exceed \$+100 million. Thus, the range of \$+100 million is sort of a screening mechanism to separate very poor, fair, and very good performance.

3.2.3.4 Funds Allocation Process.

Now that all the necessary concepts that enter into the model's funds allocation process have been presented and discussed, the process itself may be explained. It is assumed that if there are sufficient internal funds available for all desired uses, then no debt is issued and all the desired uses are satisfied by internal funding. However, since this is seldom the case, a simple algorithm is used to allocate both internal and external funds to the various uses. This algorithm is depicted shortly in Figure 3-9. It will become evident in its explanation that the algorithm is structured so that the model will perform in a manner similar to that observed over 1963-1973 if the overall state of the system is similar to that during this period. That is, the model will perform the minimum amount of investment in way regardless of the amount of unsecured debt available and will make the "necessary" cash expenditures on equipment, in spite of the declining net working capital that these two factors can promote. Since these two factors are based upon observed data, the model has to perform in a manner similar to that observed over 1963-1973 if it manages to recreate the state of the system which existed then (i.e., similar desired expenditures on equipment, similar debt repayments, similar cash flow and cash from

asset disposals, similar debt availability, etc.) However, it will reduce these uses of funds if net working capital is becoming too low as a means of conserving marginal liquidity. Hence the model reacts to a financial situation worse than that of 1963-1973 by reducing investment in way, cash expenditures on equipment, and dividends in order to maintain liquidity. On the other hand, if the financial condition improves relative to 1963-1973, and there are more internal or external funds available, the model will first try to improve liquidity, which is difficult, because as soon as net working capital increases, so do dividends and other cash uses if net working capital is near zero. Once the model has succeeded in performing desired additions to net working capital, it will next use any funds allowed by improved financial performance to increase the substandard investment in way observed in the past. Lastly, improved cash availability will be used to reduce the amount of equipment debt issued. (Additional unsecured debt will of course not be used to replace identical equipment debt.)

These "priorities" for the model's reactions to increased sources of funds are the base priorities used in this study, and do not necessarily represent the manner in which the industry would react to this situation. However, these priorities may be altered as part of alterna-

tive policy options to be tested with the model, since they too are part of the model's overall policies regarding investment, financing, and liquidity. It should be noted, though, that the priorities used in this study are reasonable, particularly with respect to the use of more cash to finance equipment expenditures. Since equipment debt is the most easily obtained form of external funds (both in reality and in the model), it is logical that the industry would allocate additional available internal funds to rolling stock last, as the industry has the least difficulty in performing expenditures on cars and locomotives. Whether additional funds would be allocated to liquidity or way and structures first is subject to question, but the model can be made to do either so that the effects of various priorities on these two uses can be studied. In the future cases analyzed in Chapter 5, the "priorities" on liquidity and investment in way were varied. Specifically in many of the cases discussed, the model undertook a quality improvement program in spite of the availability of funds. It was "forced" to do so by setting the minimum amount of investment (and maintenance) in way equal to its desired amount, so that funds were allocated to way and structures before they were allocated to liquidity. In cases where no explicit quality improvement programs were dealt

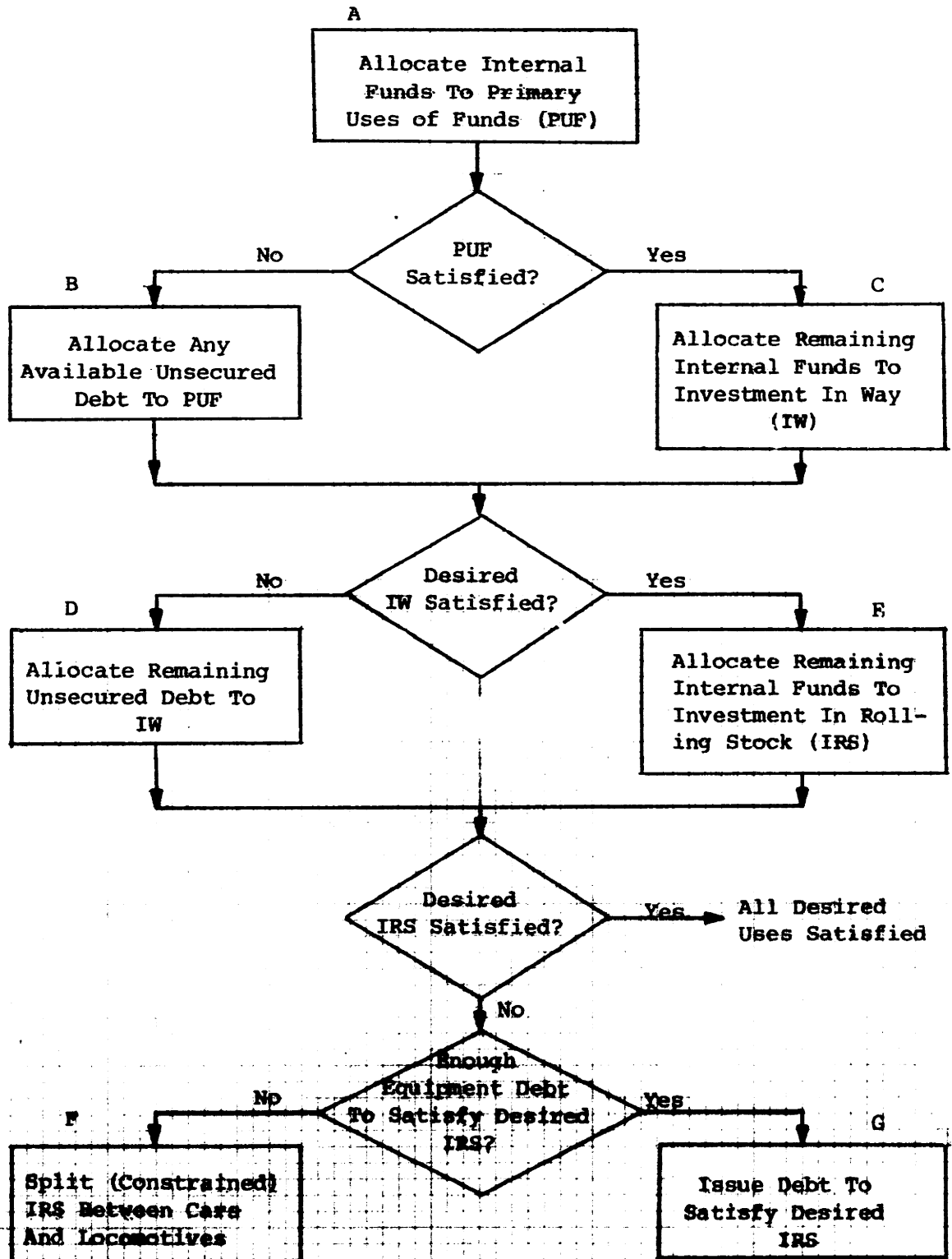
with, the above mentioned higher priority on liquidity was in effect. This led to some interesting results when a major increase in the internal funds available to the industry was caused by a drastic improvement in labor productivity (see Section 5.2.5).

The algorithm depicted in Figure 3-9 starts out in the box labelled "A" by allocating internal funds (cash flow plus cash from asset disposals) to the primary uses of funds (PUF), which are:

- i) dividends;
- ii) debt repayments;
- iii) minimum investment in way and structures;
- iv) necessary cash expenditures on equipment (necessary cash expenditures on rolling stock plus desired investment in other equipment); and,
- v) desired addition to net working capital (if net working capital is above its desired level, this quantity is negative and thus "supplies" internal funds to the system).

With the exception of the desired addition to net working capital, these primary uses of funds are always carried out by the model. If internal funds are insufficient to satisfy all of them (including the addition to net work-

FIGURE 3-9
FUNDS ALLOCATION PROCESS



ing capital), the algorithm moves to box B and tries to obtain the balance of the funds in the form of unsecured debt. This debt is constrained in availability, as will be explained in Section 3.3.4, so if there is not enough of it available, the algorithm leaves box B with all available unsecured debt having been allocated to these primary uses. Furthermore, if the total of internal and external funds was not sufficient to satisfy the first four primary uses, net working capital is reduced to cover the balance of their needs. Hence the lower priority on liquidity in the model, similar to that observed over 1963-1973.

Once the model has satisfied the first four primary uses of funds (and possibly the fifth), it is faced with the possibility of additional investment in way and rolling stock. Since equipment debt is assumed to be more readily available than is unsecured debt, way and structures are given higher priority on any remaining internal funds. Thus, if the primary uses are satisfied by internal funds alone, the algorithm moves to box C and allows the remaining internal funds to be used for investment in way (up to its desired amount which is always greater than or equal to the minimum investment in way). If these internal funds are sufficient to allow the desired investment in way, any remaining will be used to finance in-

vestment in rolling stock, as indicated in box E.

If the desired investment in way is not achieved by means of the minimum investment in way plus any additional internal funds allocated to way and structures (in box C), the algorithm proceeds to box D where it tries to obtain unsecured debt for additional investment in way. If any is available after the satisfaction of the primary uses of funds, it is therefore issued to finance additional investments in way up to their desired level.

Finally, the algorithm comes to the point where it must decide how much equipment debt to issue. If the necessary cash expenditures on rolling stock plus any additional internal funds allocated to rolling stock (in box E) are not sufficient to allow the desired investments to be carried out, equipment debt is necessary. As will be explained in Section 3.3.4 (and discussed at length in Chapters 5 and 6), equipment debt is sometimes constrained in availability, although less so than unsecured debt. If there is enough of it available to complement the funds already allocated to rolling stock in the achievement of the desired amount of expenditures, this amount of equipment debt is issued and the desired investments in cars and locomotives are made.

However, if there is insufficient equipment debt

available,¹ the desired investments in cars and locomotives cannot be carried out. The model therefore has to "decide" upon the reductions necessary in the desired installations (new and rebuilt equipment) of both cars and locomotives so that the total funds used for these investments equals the amount available. The simplest means of approaching this problem was used, namely, both areas of investment are proportionally reduced.² It should be noted that if this situation occurs, actual investment in rolling stock is less than desired, whereas cash expenditures were determined as a percentage of the desired amounts. Therefore, the actual financing mix used for rolling stock includes more "cash" (percentage-wise) than it otherwise would. The cash used represents cash used for rebuilds, cash purchases, and down payments on equipment debt, the exact mix not being determined in

¹ The manner in which the debt constraints were structured for this study always led to zero unsecured debt remaining at this time if this situation occurred. Thus, the possibility of applying remaining unsecured debt to rolling stock was non-existent.

² This simple approach somewhat distorts the car to locomotive ratio in the system from that which would exist if funds were not constrained. However, the degree of distortion is not excessive, as the model reacts to a relative shortage of one type of rolling stock by increasing its desired investment relative to that of the other. Hence, more funds are allocated to the type of rolling stock which is in short supply, and this prevents excessive distortion of the car to locomotive ratio from occurring.

the model, but being implicit in the amount of debt issued.

Thus, the funds allocation process begins by allocating internal funds (and unsecured debt, if necessary) to the primary uses of funds which are representative of the behavior caused by the policies of the industry over 1963-1973. If there are sufficient funds to also increase liquidity, this is carried out. Next, it tries to raise investment in way and structures above its minimum level, which is based upon the observed amounts spent over 1963-1973. If it manages to raise these investments, they are increased up to their desired levels which would represent those currently necessary plus those associated with eliminating any deferred investments. (Since the model was calibrated and structured based upon 1963-1973, investment in way will remain at its minimal level unless some drastic change occurs in the availability of funds, or unless the model is forced to spend more. For the cases involving quality improvement programs in Chapter 5, this "normal" funds allocation process was bypassed, as the model was forced to perform its desired investments in way.) Finally, it determines the amount of investment performed in rolling stock. Throughout, it tries to use internal funds whenever possible, leaving most of the investment in rolling stock to be financed by (usually) eas-

ily obtained equipment debt.

The policies embedded in the model's equations are extreme simplifications of reality, but will lead to investment/financing/liquidity decisions in the model similar to those observed over 1963-1973 if in fact the model is able to recreate these conditions. As will be evident in Chapter 4, which discusses model validation, this was achieved to a fair degree. Furthermore, the model's policies provide reasonable responses to improved or worsened financial performance relative to that observed in the past, and can be altered to allow the comparison of various policy issues such as: more or less investment in way, more or less cash financing of equipment investments, more or less preference for liquidity, etc. Thus, in spite of its simplicity, the model can be used to deal with some interesting issues.

3.2.4 FUNDS FLOW AND FINANCE MODULE SUMMARY.

The major function of this module is the determination of sources and uses of funds, given policies regarding dividends, liquidity, investment, and financing described by its equations, and subject to the availability of internal and external funds, as computed by other mod-

ules. In determining the sources and uses of funds, previously made decisions about investment and financing, as well as those currently made, play an important role. Specifically, previous decisions have determined the present state of the system upon which the current decisions must be made, and have also determined such flows of funds as debt repayments, cash supplied by asset disposals, and even cash flow. Thus, the importance of feedback on net working capital, as well as on other system components, is evident.¹

This module accepts inputs from the Fixed Assets And Debt Module describing the debt payable, constraints on debt issuable, and cash supplied by asset disposals that help in the determination of sources and uses of funds. It also accepts inputs from statements of investment policy in other modules, notably the minimum and

¹ It should be noted that in the model, debt repayments, cash from asset disposal, and even cash flow are completely determined by previous decisions, due to these factors being determined by specific rules which act upon the current state of the system. In actuality, while not completely determined by previous decisions, these factors are heavily dependent upon past decisions, as past decisions have determined the amount of debt that should be repaid, the age and condition of assets and thus the numbers that should be retired, etc. Whether or not these debts are repaid and these assets retired is of course subject to current decisions not included in the model. However, even in the actual system, the importance of feedback in affecting current decisions can be seen to be very important.

desired investments in way and the desired investments in freight cars, locomotives, and other equipment, as well as the volume of traffic which is used to determine the desired level of net working capital and hence the desired addition (or subtraction) necessary in the current level of net working capital. It then determines the sources and uses of funds by a rather simple process, taking all these inputs into account. In so doing, this module plays an important role in determining rates, both its own and those of other modules. Specifically it determines the rates of debt issuance, interest addition, and capital expenditures of the Fixed Assets And Debt Module; the rates of car and locomotive installations of the Equipment Needs Module; and the investment portion of the rate which supplies quality to the fixed facilities in the Quality Of Facilities Module.

The Funds Flow And Finance Module can therefore be seen to be one of the most important segments of the model, as it performs a significant amount of the decision-making which guides the model's behavior. Its decision-making process can be altered to study such interesting issues as: the degree of cash financing desired for rolling stock acquisitions; the priority given to liquidity as a use of funds; and, the amount of investment to perform in way or equipment. As will be seen in Chapter 5,

where some of these options are tested, the model provides valuable insight into the overall dynamic system behavior caused by such policy changes.

3.3 FIXED ASSETS AND DEBT MODULE.

The major function of this module is to perform all the accounting associated with the balance sheet items representing fixed assets and long-term debt. Because balance sheet items record the accumulation over time of accounting transactions, this module contains many levels. Specifically, the levels representing balance sheet items that are included in this module are:

- i) Long-Term Debt;
- ii) Gross Book Value of Cars;
- iii) Accumulated Depreciation on Cars;
- iv) Gross Book Value of Locomotives;
- v) Accumulated Depreciation on Locomotives;
- vi) Gross Book Value of Other Equipment;
- vii) Accumulated Depreciation on Other Equipment;
- viii) Gross Book Value of Way and Structures; and,
- ix) Accumulated Depreciation on Way and Structures.

In keeping track of these levels, this module must deal with their associated rates. Each of the above levels has both an input and an output rate, representing the annual transactions that would increase or decrease the appropriate balance sheet item. These rates were identified in Table 3-1, and because the levels and rates for

the various types of fixed assets represent similar accounting entities, the information provided in Table 3-1 may be summarized as shown in Table 3-2.

Capital expenditures and debt issuance are determined in the Funds Flow And Finance Module by the investment/financing policies embedded in its equations while all the output rates and depreciation expenses are computed within this module. Much of the discussion in this section therefore deals with how these rates are determined. It should be noted that the cash supplied by asset disposals, a major source of internal funds (in addition to depreciation) is computed within this module also, and is a function of the write-off rates, as will be discussed later in this section.

Besides keeping track of the fixed assets and debt levels and computing most of their associated rates, this module also performs two other important functions. First, it keeps track of the fixed charges associated with the outstanding debt.¹ This is done by means of a level so that

¹ Fixed charges are modelled as interest expense associated with long-term debt, whereas in actuality they include (negligible) amortizations of discounts on debt issued and the interest associated with the leasing of equipment and facilities. These leasing interest charges represent only about \$60 million per year [3], or approximately 10% of total fixed charges, so they were not separated from the interest on long-term debt for the purposes of this study.

TABLE 3-2

FIXED ASSETS AND DEBT BALANCE SHEET LEVELS
AND ASSOCIATED RATES

<u>TYPE OF LEVEL</u> <u>(units)</u>	<u>TYPE OF INPUT RAT.</u> <u>(units)</u>	<u>TYPE OF OUTPUT RATE</u> <u>(units)</u>
Gross Book Value (\$)	Capital Expenditures (\$/yr.)	Write-Offs (\$/yr.)
Accumulated Depreciation (\$)	Depreciation Expense (\$/yr.)	Depreciation Write-offs (\$/yr.)
Long-term Debt (\$)	Debt Issuance (\$/yr.)	Debt Repayment (\$/yr)

the effects of various interest rates on new debt issues at different points in time is captured by the model's fixed charges. Secondly, this module is responsible for determining constraints on the availability of unsecured and equipment debt, which it does by means of simple interest (i.e., fixed charges) coverage rules.

The ensuing discussion will therefore be presented in four parts. Section 3.3.1 deals with the modelling of the equipment accounts, as these are handled differently than the accounts associated with way and structures, which are the topic of Section 3.3.2. In Section 3.3.3, the manner in which debt and fixed charges are modelled is explained. Finally, the interest coverage constraints on debt issuance are the topic of Section 3.3.4.

3.3.1 Balance Sheet Accounting - Equipment.

Most railroads use what is known as group or composite depreciation accounting¹ for their various kinds of rolling stock and other types of equipment. A significant

¹ The reader is referred to [10] for a discussion of this method of depreciation accounting versus others. Personnel at the Boston and Maine Railroad were helpful in explaining its application to railroads, and are extended the author's many thanks.

feature of this type of accounting is that no gain or loss is recognized in the income statement when an asset is sold or otherwise disposed of. Rather, the gross book value of the released asset is removed from the total gross book value recorded for all similar assets, and, the difference between the original cost (gross book value) of the asset and the cash proceeds from its disposal is accounted for as a reduction in the total accumulated depreciation of the group to which it belongs (i.e., box cars). This procedure assumes that gains on some sales or disposals (relative to the net book value of the asset disposed of) are offset by losses on others. Hence, the income statement is not involved.

Another important feature of this method of depreciation accounting, particularly in the case of railroads, is that annual depreciation is computed on the basis of the total original cost of all the assets in a group which are still in service, regardless of age. That is, the expected salvage value is not taken into account in forming the depreciation base, and an asset continues to generate depreciation as long as it is in service. These two features of the method are compensated for by the depreciation "rate" (not to be confused with rates in the model) specified for a particular group of assets. The I.C.C. sets these rates for each group of assets for

each railroad, and they are based upon the current age, expected life, accumulated depreciation to date, and expected salvage value of the assets in each group, as reported to the I.C.C. by the railroad.

These concepts were used in formulating the model equations that handle the balance sheet items which represent cars, locomotives, and other equipment. In the model, freight and passenger cars are treated as one group, as are freight and passenger locomotives, and other equipment.^{1,2} The depreciation rates for each of

¹ Passenger equipment is included in each of the six levels which keep track of gross book values and accumulated depreciation for cars, locomotives, and other equipment for several reasons. First, they were not to be excluded from the model because of their contribution to net investment and the cash flows associated with passenger equipment. Secondly, their relatively small values with respect to those of freight equipment did not warrant detailed separate treatment in the model. Third, data available in [1] did not give the exact separations of locomotive and other equipment accounts between freight and passenger services, although the similarity of the equipment in either service would have allowed these separations to be estimated based upon relative depreciation charges. Finally, the similarity of passenger and freight cars with respect to depreciation rates is rather striking, so that for the purposes of modelling them, they too could be assumed to be part of the same group.

² It should be noted that other equipment, as defined here, represents floating, work, and miscellaneous equipment. In Section 3.2.2.4, passenger rolling stock was also categorized as "other". For the purposes of the Funds Flow And Finance Module, passenger rolling stock is a part of other equipment, as it represents an exogenously specified annual capital expenditure which must be performed. However, the expenditures on

these aggregated groups were determined on the basis of the ratio of depreciation expense to total gross book value of the assumed groupings over 1963-1973. Where a trend was apparent in these "observed" depreciation rates, the model's depreciation rates were set equal to those observed at the end of this data period, to account for changes which were occurring in expected asset lives and salvage values (due to inflation), average age of the equipment in service, etc.

By comparing actual write-offs of gross book value in each aggregate grouping to those of accumulated depreciation, it was possible to get an estimate of the cash supplied by the disposal of these assets, which is measured by their difference. Hence, the model computes cash supplied by the disposal of these assets in a similar manner. Based upon the observed ratios of depreciation write-offs to gross book value write-offs, the normal (average) fraction of value lost between the time a capital expenditure was made for purchasing, building, or rebuilding an asset and the time the asset was disposed of was estimated. This parameter is used in the model to determine the depreciation write-offs from the

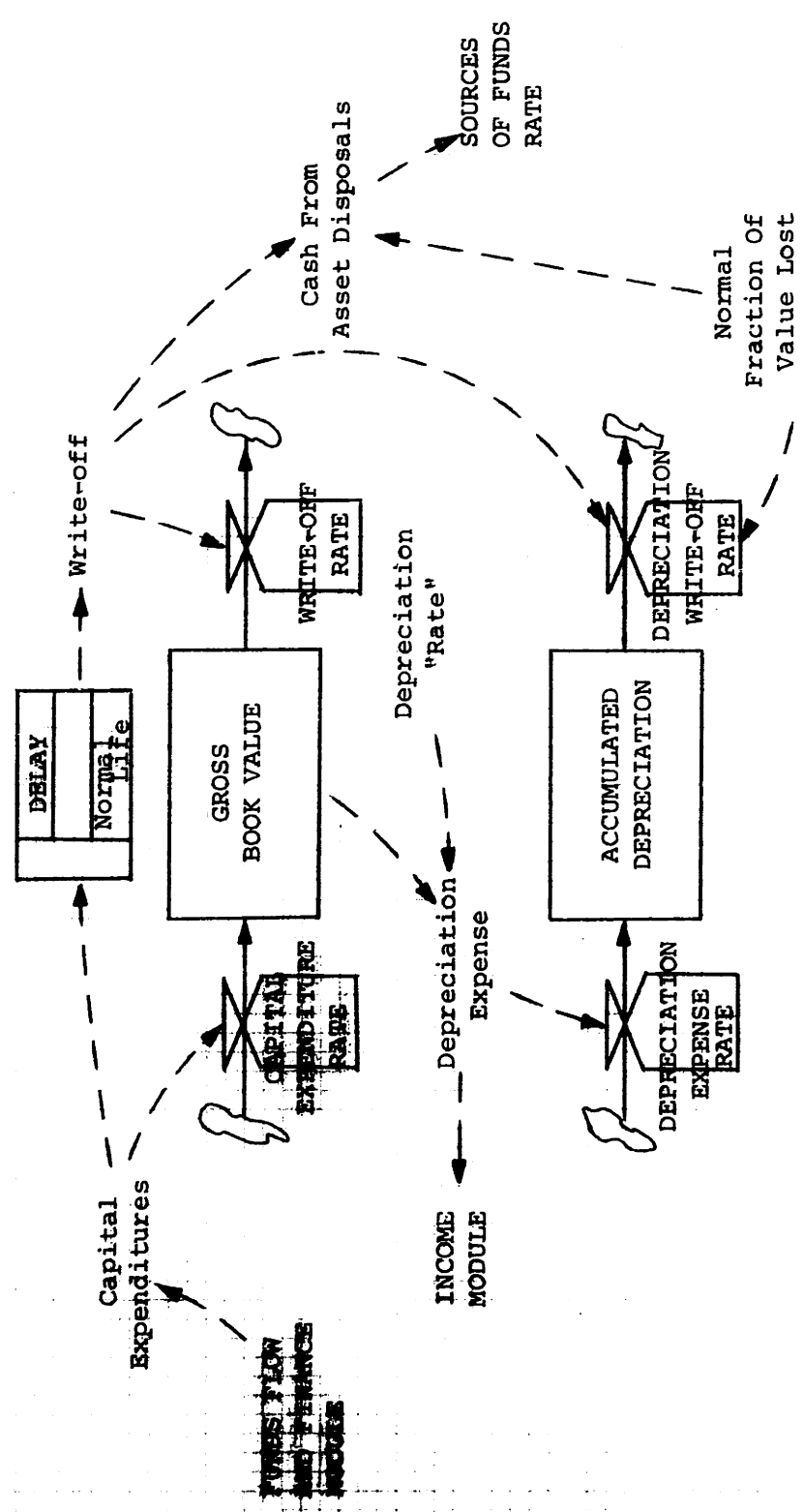
passenger rolling stock are accounted for in this module with the expenditures on freight rolling stock, as they are similar with respect to asset lives and depreciation rates.

gross book value write-offs during any time interval, and thus is also used in determining the cash from asset disposals, which is computed in the model for each group of assets by means of an equation of the following form:

$$\begin{aligned} \text{cash from asset disposals} &= (1 - \text{normal fraction of value lost}) \\ &\quad \times \text{gross book value write-offs} \end{aligned}$$

The relationships between capital expenditures, write-offs, depreciation expense, etc. for each of the three groups of equipment assets may be envisioned as they appear in Figure 3-10. Capital expenditures determined in the Funds Flow And Finance Module determine the input rate to gross book value. These expenditures also pass "through" a third order exponential delay [6], [8], [9], which causes them to be delayed on the average by the normal life of the assets in the group (these lives are discussed below). "On the average" is emphasized because this type of delay does not cause an input to be delayed for exactly this amount of time. Rather, it creates an output distributed over time, such that the output has been delayed on the average for the normal life of the assets. For example if capital expenditures on, say, freight cars on the order of \$1 billion were made in 1970, these expenditures would not all be written

FIGURE 3-10
BALANCE SHEET ACCOUNTING - EQUIPMENT



~~INVESTMENT AND FINANCE MODULE~~

off exactly twenty years later (which is the model's parameter value for the normal life of cars, as discussed below). Instead, some would be written off sooner and some later, as they would be in actuality,¹ such that on the average they were written off after twenty years. Third order delays produce deterministic, and not stochastic, outputs. Thus, each time a case is run with the model, the outputs from the delay will not change if its inputs are the same.

Once the capital expenditures "leave" the delay, they are written off, as the associated assets are assumedly being disposed of. This leads to cash from asset disposals and the writing off of depreciation, both factors being determined by the normal fraction of value lost for this group of assets. During the time the expenditures were on the industry's books, they generated depreciation expense (along with all the other capital-

¹ Some would be written off sooner, and some later in actuality, but the actual distribution over time is not necessarily the same as the model's distribution over time. The model is necessarily a simplification of reality, so it cannot be expected to determine the exact shape of the actual distribution. However, third order delays were used because the distributions over time that they create are probably more representative of the nature of the actual distributions than would be those caused by second or first order delays [6], which were the other options possible for modelling this phenomenon.

ized expenditures still on the books). This expense is computed by multiplying the depreciation "rate" for each group of assets by their gross book value, and controls the input rate to accumulated depreciation. It is also used in the Income Module to determine income and cash flow.

The manner in which the normal lives for each of these asset groups were derived is worthy of mention. First of all, data available in [11] indicates that in 1969, approximately 80% of all freight cars in the industry had been in service less than 21 years, with time being measured from the date of purchase (or construction) of new and secondhand cars, and from the date of rebuilding for rebuilt cars. Furthermore, for cars purchased new (85% of the total cars dealt with), 75% were less than 21 years old. For locomotives, 84% were less than 20 years old, although the data source does not give the mix of rebuilds and secondhand purchases included in this total.

It should be noted that the above figures include the time-dependent effects of changing fleet sizes, so they can only be used as guides to the normal lives being sought. It should also be noted that the lives being sought were those that were indicative of the effects of rebuilds, etc., on the average time an expenditure re-

mained on the industry's books, as the model does not differentiate between expenditures made on new equipment and those made on rebuilds, etc. (However, as the above data points out, these effects are probably very minor for ages derived from the 1963-1971 data period.)

Thus, it was decided to derive the normal lives of the asset groups from available data, such that the effects of rebuilds, etc., would be manifested in these lives (regardless of how minor the effect) while the effects of dynamic changes in fleet sizes could be ignored. These normal lives are implicit in the relationship between depreciation rates and normal fraction of value lost. If the total accumulated depreciation on a piece of equipment is to equal the loss in value it undergoes while it is in service (so that on the average, the group accounting method offsets gains on some assets by losses on others), the average number of years it remains on the books must be inherent in the ratio of the average fraction of value lost to the annual depreciation rate. This is shown mathematically as follows:

$$\text{Life} \sum_{t=1} \text{depreciation rate} \times \text{cost} = \text{fraction of value lost} \times \text{cost}$$

$$\text{Life} \times \text{depreciation rate} \times \text{cost} = \text{fraction of value lost} \times \text{cost}$$

$$\text{Life} = \frac{\text{fraction of value lost}}{\text{depreciation rate}}$$

This was the method used to derive the normal lives of cars, locomotives, and other equipment for the model, based on observations over 1963-1971. The various parameters associated with each group of equipment in the model are presented in Table 3-3, and represent the general nature of the overall industry accounting observed in the data period.¹

As will be explained in the next section, cash supplied by equipment disposals only, determined by the normal fractions of value lost, are used in the model to explicitly measure cash from asset disposals.

¹ The relatively low normal fractions of value lost resulted for several reasons. First of all, write-offs occur for sales of assets intact, as well as for the scrapping of equipment. Secondly, inflation over the life of an asset raises its resale or scrap value relative to its original cost. Future cases run with the model assumed a 7% rate of general economic inflation, not too unlike that observed in the past. If major changes are made in the inflation rate (i.e., 0% or 20% per year), the depreciation rates and fractions of value lost would have to be adjusted accordingly, maintaining their relationship with the normal life of the asset group concerned.

TABLE 3-3PARAMETERS FOR EQUIPMENT ACCOUNTS

<u>Asset Group</u>	<u>Depreciation Rate</u>	<u>Fraction Of Value Lost</u>	<u>Normal Life</u>
Cars	3.25%	65%	20 years
Locomotives	4.80%	78%	16.25 years
Other Equip- ment	5.70%	72%	12.6 years

3.3.2 Balance Sheet Accounting - Way And Structures.

Balance sheet accounting for way and structures (i.e., the road accounts) is handled in a much simpler manner than it is for equipment. Specifically, the gross book value level includes the gross book values of both depreciable and non-depreciable¹ road assets, whereas the accumulated depreciation level only deals with depreciable road assets, by its very nature. No attempt was made to separate the gross book values of the two types of road assets because the model does not explicitly deal with the issue of which type is being invested in. Capital expenditures on way and structures are only considered by the model in terms of their total dollar amount and the impact they have on system quality.

Because gross book values are combined, depreciation expense is computed on the basis of the gross book value of all the road assets, including those which are non-depreciable. The depreciation rate used is therefore based upon the ratio of observed depreciation expense to total gross book value over 1963-1971 (a value of 0.88% was found to be very accurate for this purpose), implicitly assuming that the investments made in way and struc-

¹ Examples of non-depreciable assets are rails, ties, ballast, tunnels, grading, etc.

tures will be divided among depreciable and non-depreciable assets in such a manner as to maintain their relative gross book values.

Another area of simplification has to do with the determination of write-off rates for these assets. The method used for determining equipment write-offs would be very meaningless here, particularly in the case of non-depreciable assets which comprise the majority (70%) of the gross book value of way and structures. This is because asset "lives" would be difficult to interpret with respect to determining write-off rates for non-depreciable assets. The lives of these assets have been subject to a great deal of management discretion in the past as part of the overall undermaintaining of the fixed plant. Also, these assets are not written off the books if they are replaced at the end of these highly discretionary lives. Due to the nature of retirement accounting, their replacements are expensed. Thus, the first reason for not modelling way and structures write-offs in a manner similar to that presented in the previous section is that asset lives, which played an important role in the interpretation of the method used for equipment, are fairly meaningless when speaking of the non-depreciable assets which constitute the majority of road assets.

Secondly, write-offs were determined as they were for equipment in order to determine the cash supplied by asset disposals. Non-depreciable assets, our major concern when speaking of way and structures, supply negligible cash from asset disposal that is not already accounted for by the model. As was explained in Section 3.2.1.4, salvage associated with these assets shows up as a direct reduction in reported maintenance of way expense, and the model deals with reported MW based upon observed values over 1963-1973, which included the effects of these salvage values. Thus, the model accounts for salvage obtained on these assets implicitly in its MW expense. Also, retirements without replacement have been negligible in the past [4], and the model does not allow fixed plant rationalization in the event of low volumes. Thus the small depreciation-like cash flows generated by these retirements have been ignored. So it can be seen that the cash supplied by the disposal of most of the road assets has been accounted for, without having to rely upon write-off rates in order to obtain them.

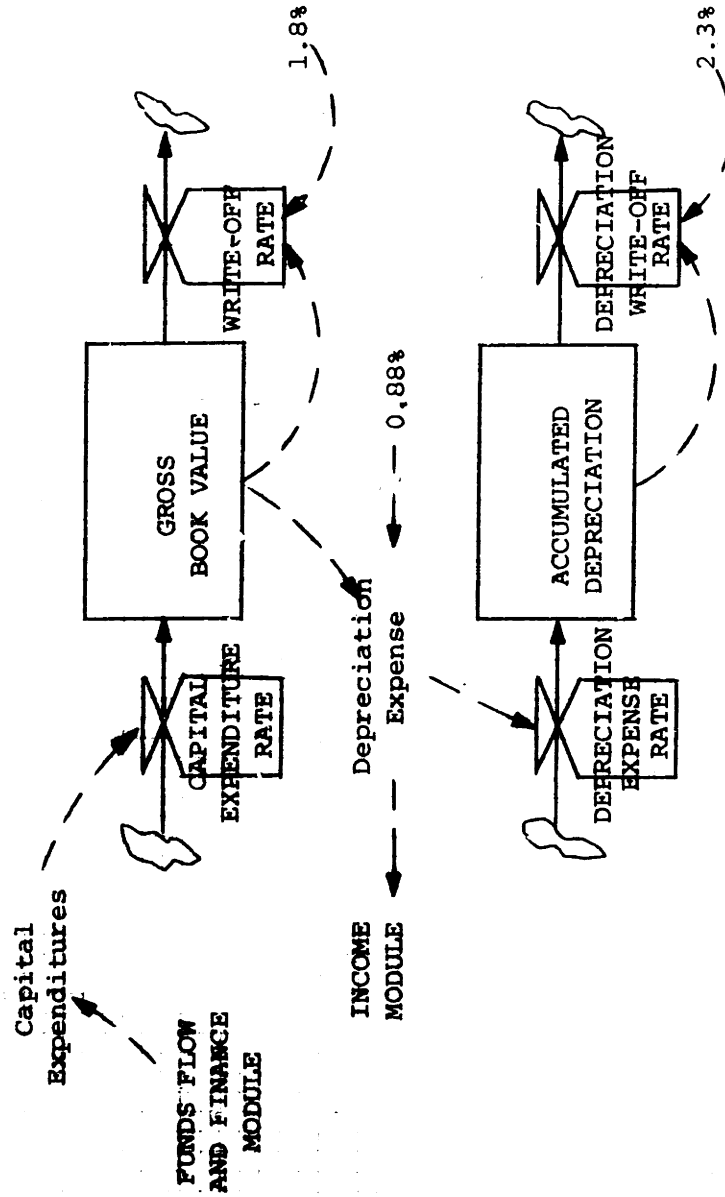
For the above reasons, way and structure write-off rates were not modelled similarly to those of equipment. Rather, it was assumed that cash from the disposal of de-

preciable road assets was zero.¹ Hence, the write-off rates for gross book value and accumulated depreciation of way and structures were treated in a very simple, unrelated manner. Specifically, they are determined as functions of their associated levels, based upon the observed average ratios of the write-off rates to their respective levels over 1963-1971, gross book value write-off being 1.8% of gross book value, and depreciation write-off being 2.3% of accumulated depreciation.²

¹ This assumption cannot be verified, but, as the above discussion points out, is probably unimportant.

² This type of relationship, in which an output rate is determined as a given fraction of its associated level, is known as a first order exponential delay in systems dynamics [6], [8], [9]. While strikingly simple, it represents the fact that the more there is in the level (i.e., gross book value), the more that is likely to come out of the level at any point in time. Specifically, a higher level of gross book value implies more assets or more inflated asset costs. Given that any one asset is eventually written off, more assets (or more inflated costs) would cause annual write-offs to increase. Furthermore, because this is a type of delay, whatever goes into the level does have an associated average "life" in the level, only it is less obvious than in the case of the third order delay used for equipment. In the case of way and structures gross book value, the average delay or "life" of a dollar entering is $1/.018$ or 56 years, and for accumulated depreciation it is $1/.023$ or 43 years. The reader is referred to [9] for further discussion of first order delays.

FIGURE 3-11
BALANCE SHEET ACCOUNTING - WAY AND STRUCTURES



The relationship between the levels and rates of the way and structures accounts is depicted in Figure 3-11. As was the case with the equipment accounts, capital expenditures determined in the Funds Flow And Finance Module determine the input rate to gross book value. Gross book value is used in determining both the depreciation on way and structures and its own write-off rate by means of simple ratios observed over 1963-1971. Depreciation expense controls the input rate to accumulated depreciation and is also passed to the Income Module for the computation of income and cash flow. Finally, accumulated depreciation determines its own output rate based upon the average ratio observed between it and this rate in the past. While accumulated depreciation write-offs are not used for determining cash from asset disposals as they were in the case of equipment, they are still desirable in the model because they affect accumulated depreciation, which is needed in the measure of net investment.

3.3.3 Debt And Fixed Charges.

Debt and fixed charges are both modelled by means of levels. The Long-Term Debt Level (hereafter referred to as the Debt Level) represents the accumulation over time

of debt issuance less debt repayments, both of which are modelled as rates. As noted earlier, it is assumed that there are only two types of debt, equipment debt and unsecured debt, and that these two types of debt are treated identically in terms of maturity, yield, and payment schedule. Once the Funds Flow And Finance Module determines how much of either type of debt to issue, unsecured and equipment debt cease to become separate entities, as will soon become evident. They could have been treated separately, so that different yields, etc., for the two types of debt might be tested as part of an alternative to investigate with the model. This was not considered for the purposes of this study, but the model could be easily altered to accommodate separate treatment of the two types of debt.

Fixed charges are modelled by a level so that the effects of dynamic changes in the interest rate on new debt issues can be captured. The annual interest expense associated with a new debt issued is added to fixed charges, and the model is structured so that as the principal is repaid, the associated interest expense is reduced accordingly.

Due to the many types of debt instruments available to the industry, all with various terms of repayment, it was not possible nor desirable to structure the model in

a fashion that dealt with the many possible complex financing terms. Rather, a simple rule was used in the model which captured the important aspects of the industry's debt structure. Specifically, debt repayments are modelled as $1/14$ of outstanding debt, and the associated reductions in fixed charges are computed similarly.¹ While this rule is strikingly simple, its form has the important property of additional annual debt repayments being caused immediately by an additional issue of debt, and causes interest expense associated with a debt issue to be reduced in accordance with the principal repayments. Thus it has the general characteristics of equipment debt, the industry's major source of external funds, even though it does not promote equal annual payments for a fixed number of years as is the case in the real world. The specific value of $1/14$ chosen for this repayment rule parameter was based upon studying how industry debt and fixed charges over 1963-1970 would have behaved, given actual debt issuance and prevailing interest rates and various settings of this parameter.

In spite of the simplicity of the debt repayment rule, it can be given various parameter values in order

¹ Debt and fixed charges are thus treated as first order exponential delays, which were briefly discussed in the previous section.

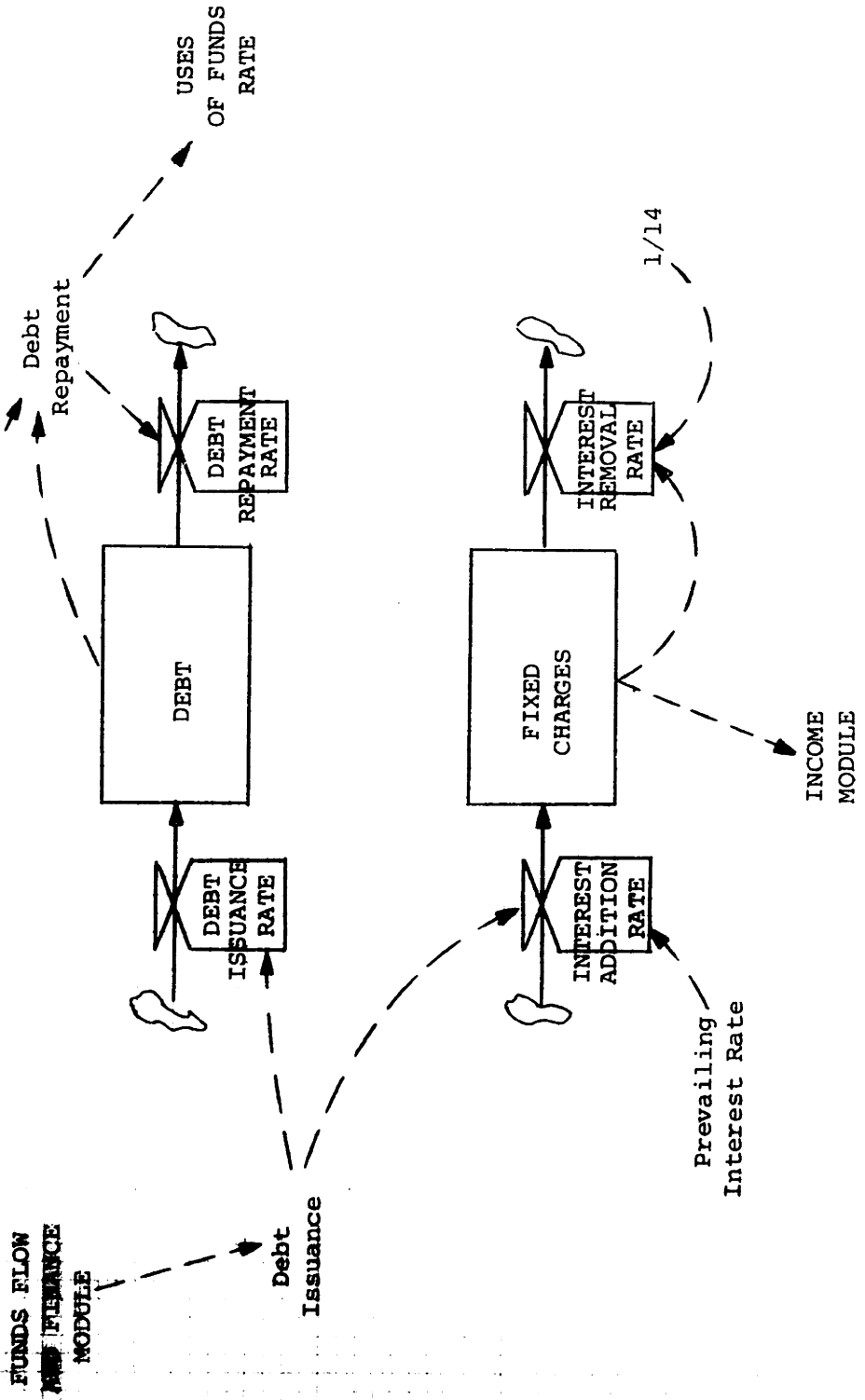
to study the effects of longer or shorter payout periods. Furthermore, a different, but still simple, form of rule might be used in its place to test the effects of such options as no debt repayments (nor reductions in fixed charges) for several years, "balloon" repayments in which all of the principal is repaid over a short span of time at some future date, etc.

The Debt and Fixed Charges Levels and their associated rates are depicted in Figure 3-12. The Debt Issuance Rate is determined by the amount of debt issuance (unsecured and equipment debt) prescribed by the Funds Flow And Finance Module. This is coupled with the prevailing interest rate on long-term debt (a time-dependent parameter of the model¹) to determine the interest added to fixed charges. Fixed charges are used in the Income Module to determine income, and are also used in this module to determine the amount of external financing available, as explained in the next section. Finally, debt repayments and the associated reductions in fixed charges are computed by the simple rule discussed above, with debt repayments also being used in the Funds Flow

¹ For the purpose of model validation, the average interest rate on new equipment debt issues for each of the years 1963-1973 was used. For the future cases analyzed in Chapter 5, 10% was usually the assumed rate, as is explained in that chapter.

FIGURE 3-12

DEBT AND FIXED CHARGES



And Finance Module as a use of funds.

3.3.4 Constraints On Debt Issuance.

As was noted in the review of the industry's financial condition (Section 1.1), many railroads have been unable to attract external funds other than equipment debt due to their poor earnings records and already highly leveraged capital structures. This inability, together with the insufficient cash flow which promotes it, has led to inadequate expenditures on way and structures in the past, thus aggravating the earnings deterioration cycle associated with the declining quality of the fixed facilities.

The highly leveraged capital structure of the industry is in part due to the relative ease with which equipment debt has been obtained in the past. This type of debt has been available because of the excellent security which the equipment (used as collateral) provides to the creditor and because of the seniority of the claims on earnings of the creditors compared to the claims of bondholders and stockholders [4].

Equipment debt, while making the financing of equipment acquisitions fairly easy, has also increased the dif-

difficulty with which unsecured debt is obtained. This is because the growth in earnings generated by the additional investments in equipment has not kept pace with the additional costs of servicing the equipment debt, leading to the decline in ordinary income discussed in Chapter 1. Because earnings have not improved relative to fixed charges, and because more and more "senior" claims on these dwindling earnings are being generated by the equipment debt issued, unsecured debt and equity have been difficult to issue in the past.

In spite of the relative ease with which equipment debt has been obtained in the past by the industry in general, railroads with poorer than average earnings have been unable to attract this type of financing [4]. Also, the excellent security provided to creditors by equipment debt rests upon their ability to sell repossessed equipment to another railroad which can service the debt, in case of the original railroad defaulting. If financial conditions throughout the industry continue to worsen, the number of railroads that can service equipment debt (either on new or repossessed equipment) will be reduced. Hence, at some poor level of overall industry financial performance, even this type of debt must become difficult to obtain.

The above considerations were all taken into ac-

count in the formulation of the model's debt issuance constraints. These constraints are very simple in form and do not necessarily represent the "true" constraints on the availability of external funds. Rather, they represent the important concepts that poor earnings will typically lead to decreased debt availability, and that equipment debt is more easily obtained than is unsecured debt. Furthermore, they represent only one representation of the industry's interaction with the capital markets. Thus, they can be altered in order to test the relative effects of more or less debt availability as compared to the availability they allow.

Both constraints operate on the interest coverage principle, in this case dealing with the coverage of fixed charges provided by (ordinary) Net Income Before Tax and Fixed Charges (referred to by the acronym NIBTFC in the ensuing discussion). NIBTFC is exponentially smoothed¹ to represent the fact that capital markets (or the industry) would not take a sudden change in earnings completely into consideration in measuring the industry's ability to cover fixed charges. However, if the change had persisted for some time it would indicate that this

¹ The reader is referred to [6] for a more detailed discussion of exponential smoothing in systems dynamics.

ability had indeed been altered. The smoothed value of NIBTFC is used to determine the maximum fixed charges the industry could support, given they are to maintain a certain coverage ratio. The maximum fixed charges which can be covered are then related to a maximum debt level by means of the prevailing interest rate on new debt issues. Finally, it is assumed that the capital markets (or the industry) would react to this maximum debt level by constraining annual debt issuance in such a manner that the actual debt of the industry would not be allowed to reach the maximum level too quickly.

In the case of unsecured debt, the constraint used in the model is:

$$\text{maximum annual unsecured debt issuance} = (\text{maximum debt} - \text{current debt})/5$$

$$- \text{equipment debt issuance}$$

The maximum debt level in this constraint is based upon an assumed minimum coverage ratio of two. A value greater than one was sought since a coverage ratio of one would imply zero ordinary income. The value of two, coupled with the five in the denominator of the above equation, was chosen because it would cause zero unsecured debt availability over the data period if the model was capable of recreating the rest of the financial conditions

which existed during that interval of time.¹ Furthermore, it would make unsecured debt very difficult to obtain unless financial conditions significantly improved, representative of the true state of affairs. Of course, this constraint can be altered to test the effects of increased or decreased debt availability on the model's outputs.

An interesting aspect of the above equation is the subtraction of equipment debt issuance from the maximum amount of unsecured debt issuable. The coverage ratio of two defines the maximum fixed charges and debt of either type that the industry could have with its current earnings if it is to attract unsecured debt. It is assumed that the gap between the current debt level (including equipment debt) and the maximum debt level (again including equipment debt) will be closed no faster than 20% per year, including equipment debt issuance. This represents the fact that investors would be less likely to provide unsecured debt in any year if they knew that a railroad (i.e., the industry in this case) was also is-

¹ Inasmuch as little unsecured debt was issued during 1963-1970 [4], this constraint was designed to cause no debt availability over that period. However, for the sake of validating this highly interactive model, actual debt issuance over the data period was treated as an additional source of external funds the model could draw on if it so decided.

suing equipment debt. This equipment debt could be detracting from interest coverage and would have a senior claim on earnings. Hence the form of the above equation.

The constraint on equipment debt is as follows:

$$\text{maximum annual equipment debt issuance} = (\text{maximum debt} - \text{current debt})/5$$

The maximum debt level in this constraint is based upon an assumed minimum coverage ratio of one. A value less than that used for unsecured debt was sought in order to make equipment debt more readily available. Furthermore, the tendency of the industry towards growth, and the fact that equipment debt would only become unavailable if interest coverage was significantly low also dictated a rather low value for the minimum coverage ratio. A value of one was selected because it would allow the model to obtain at least as much equipment debt as was actually the case over 1963-1973 (although this constraint became mildly binding after 1973 in the model), and because a lower value would allow them to borrow themselves into bankruptcy, which the constraint is designed to prevent.¹

¹ A value of one did not have to be used for the minimum coverage ratio, as a value of 1.1 would probably have caused similar results in the validation period. One was chosen as the value, though, because it was the lowest reasonable value to use (regardless of the denominator of the equipment debt constraint), given that equipment debt issuance would probably be curtailed only if income reached zero.

It should be noted that unsecured debt issuance is not subtracted in this equation. The primary reason for excluding it is that simultaneous equations would result in the debt issuance process, something that DYNAMO cannot handle. However, this is not a serious shortcoming, as investors in equipment debt do not have to concern themselves with unsecured debt as much as unsecured debt investors have to concern themselves with equipment debt, due to the relative seniority of the two types of instruments in the real world. Furthermore, the model's constraint on unsecured debt is so much more binding than the equipment debt constraint that it usually leads to zero unsecured debt availability whenever equipment debt issuance is constrained.

The constraints on debt issuance accept Net Income Before Tax and Fixed Charges from the Income Module, while they provide financing constraints to the Funds Flow And Finance Module, as depicted earlier in Figure 3-1. While simple in form, they are based upon the important aspects of the industry's interactions with capital markets. Furthermore, they can be given various parametric settings for minimum coverage ratios or debt adjustment times (the denominators of the equations presented above) to allow the analysis of more or less debt availability. They can also be altered in form so that different "rules" about

debt availability can be tested.

3.3.5 Fixed Assets And Debt Module Summary.

The Fixed Assets And Debt Module is concerned with all the accounting necessary to keep track of major industry balance sheet items, and with all the cash flows, expenses, and debt constraints associated with these items. Specifically, it keeps track of gross book values and accumulated depreciation on both equipment and way and structures so that depreciation expense, net investment, and cash from the disposal of assets can be computed at any point in time. It also keeps track of debt and fixed charges in a manner that allows the effects of dynamic changes in prevailing interest rates on new debt issues to be reflected in the industry's fixed charges. Finally, it computes debt repayments that are due and the constraints on debt issuance in terms of the interest coverage provided by income.

The manner in which this module performs all these functions is relatively simple, yet a reasonable representation of reality. Inasmuch as no decisions or policies are included in its structure, few policy options can be tested by altering its parameters. However, vari-

ous other options can be investigated in this manner, such as different debt repayment plans, time-varying interest rates on new debt issues, lower or higher interest rates, more or less debt availability, etc.

Inasmuch as the levels of a system determine its current state through the accumulation of past decisions and other activities, the Fixed Assets And Debt Module plays an important role in determining the current state of the system as it includes ten of the model's sixteen levels. It also computes additional important information based upon these levels. Specifically, net investment, depreciation expense, fixed charges, cash from asset disposals, debt repayments, and constraints on debt issuance are all functions of the current state of the system, and are computed in this module for use in other modules in the determination of their rates.

3.4 QUALITY OF FACILITIES MODULE.

One of the focal points of this study is the earnings deterioration cycle that is associated with the quality of the industry's fixed facilities, as was discussed in Chapter 1. In Chapter 5, various maintenance and investment in way policies will be tested with the model to study their overall impact on the financial performance on the industry. Since these policies and their impacts are both related to the quality of the fixed facilities, an understanding of the concepts and functioning of this module is important to the understanding of the overall study. The basic concepts will be explained along with the associated module functions, which are:

- i) keeping track of the Quality Of The Fixed Facilities Level (hereafter referred to as the Quality Of Facilities Level);
- ii) computing the effects of quality on costs and productivities;
- iii) providing inputs to the maintenance budgeting section of the Income Module as to the desired and minimum amounts of maintenance of way; and,

- iv) providing inputs to the Funds Flow And Finance Module as to the desired and minimum amounts of investment in way.

Central to this module is the meaning of the Quality Of Facilities Level and its associated rates. Thus, Section 3.4.1 deals with the interpretation of these model components. In Section 3.4.2, those system elements which are affected by quality are identified, and the nature of their relationships with quality discussed. Since the Quality Of Facilities Level and its associated output rate play an important role in the budgeting of maintenance and investment in way, Section 3.4.3 explains how these model components tie into these budgeting processes. Also, the Quality Of Facilities Module is highly interactive with the rest of the model, and this is discussed in Section 3.4.4. Finally, Section 3.4.5 discusses the overall nature of the model's cost functions. Because MW expense in the model, the only cost category not fully explained up to this point, is heavily dependent upon the processes occurring in the Quality Of Facilities Module, this overall discussion of model cost functions was postponed until this part of the chapter.

3.4.1 MODELLING QUALITY OF THE FIXED FACILITIES.

Quality by its very nature is an abstract notion, especially at the macroscopic level of this model. It is represented by the Quality Of Facilities Level, which can be interpreted as an aggregate measure of the overall quality of all the industry's fixed facilities. That is, it does not deal with the quality of any given segment of the network in isolation. Rather the entire network is considered. Furthermore, it is a measure of the quality of a relatively constant sized network, as it is assumed that the current industry network, with all its duplicate facilities, is not significantly altered in size to handle extra volume.

Inasmuch as most of these facilities are employed in providing right of way (i.e., the non-depreciable assets such as rails, ties, ballast, tunnels, grading, etc.), no attempt is made to explicitly separate the interactions between various system components and depreciable road assets from those of the non-depreciable assets. Rather, all road assets are treated as if they provide right of way, requiring repair or replacement due to the volume of traffic passing "over" them.

Although quality is an abstract notion, there are two things that are known about it a priori. Traffic running over the facilities causes wear and tear and un-

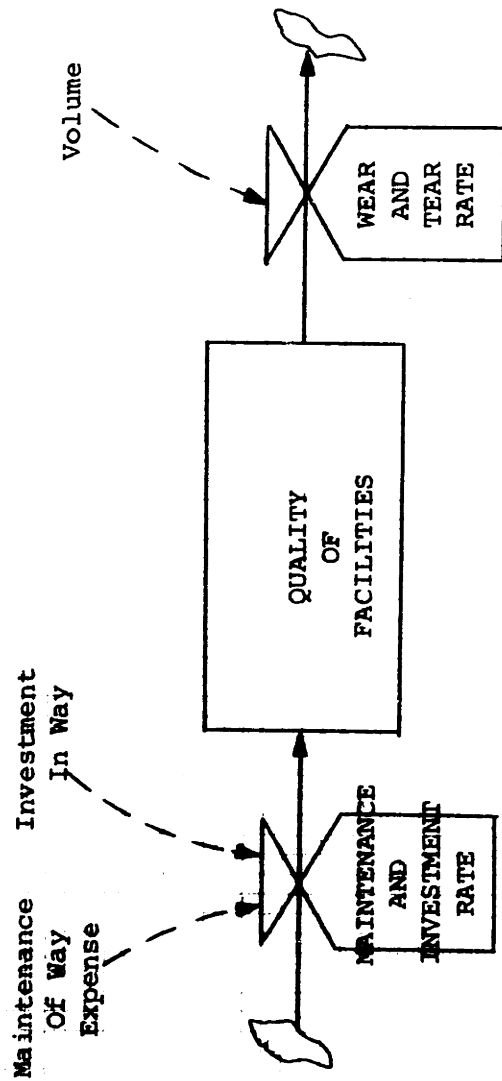
less sufficient money is spent, quality declines. Since money spent on the fixed facilities is accounted for either as maintenance or investment in way, it can be seen that both maintenance and investment in way "supply" quality to the system, although they may do so to varying degrees. If these expenditures are less than those necessary to replace and/or repair the assets worn out completely or partially by the traffic using them, quality declines, and if they are greater than those necessary, quality improves.

Thus, quality is modelled as a level affected by two rates, both of which represent flows of money. A simplified¹ representation of this is depicted in Figure 3-13. Flowing out of the Quality Of Facilities Level is the Wear And Tear (On The Facilities) Rate, representing the amount of money that should be spent each year (either as investment or maintenance) to make up for the wear and tear caused by traffic. Flowing into the level is the Maintenance And Investment (In Way) Rate which is determined by the amounts that are spent each year (determined elsewhere in the model). Because the Quality Of Facilities Level is affected by monetary flows, it too is

¹ There are more relationships involved than are depicted in Figure 3-13. The others will be discussed later in this section.

FIGURE 3-13

QUALITY OF THE FIXED FACILITIES



measured in monetary terms. As will be explained below, it and its two rates are measured in terms of constant dollars, so that the effects of inflation in reducing the amount of quality supplied by a given expenditure are taken into account.

One of the major assumptions made with respect to quality is that maintenance and investment outlays, while accounted for separately for tax purposes in the model, are identical with respect to the impact they have on quality. A major reason for commingling these two flows of funds has to do with the method of retirement accounting used in the industry. Replacements of non-depreciable assets are charged to maintenance of way expense under retirement accounting, whereas they would be categorized as investments under depreciation accounting. Thus, in actuality there is similarity between some maintenance expenses and investments. However, not all railroad maintenance expenses represent "investments" in the usual sense of the word, as many are associated with what is typically defined as maintenance (i.e., repair). Also, all investments made by the industry could not be defined as repair, because they represent outlays for the replacement of depreciable road assets or for the betterment or addition of either type of road asset.

In spite of the differences which exist between in-

vestments and maintenance under either method of accounting, they both represent expenditures of money. Thus, it seems reasonable to combine them. Due to the aggregate nature of this model, the issue of exactly what this money is being spent on is not explicitly dealt with. Rather, it is implicitly assumed that the money spent is used effectively, whether it is for the repair, replacement, upgrading, or addition of assets.¹ Maintenance and investment are only treated separately for the purposes of the income statement and balance sheet, and the distinction between the two is determined by a parameter which dictates how much of these expenditures to charge to expense. The historical percentage (approximately 80% maintenance) was used in this study, but could be varied for the purpose of studying the impact of more or less maintenance expense. However, it is emphasized that the overall impact on quality will be the same for the same total expenditure.

3.4.1.1 Interpretation Of Quality.

Now that the commingling of maintenance and invest-

¹ Again, it is being assumed that any additions and betterments do not significantly alter the size of the network, and hence the associated property taxes.

ment dollars in the supply of quality has been discussed, quality, as treated in the model, can be given a fairly concrete interpretation. Because quality is a level, it represents the accumulation of all previous inflows and outflows, and can be described by the following equation:

$$Q(T) = Q_0 + \sum_{t=1}^T [M_t + I_t - W_t]$$

where:

$Q(T)$ = quality at Time T

Q_0 = quality at time zero (i.e., quality at the start of any particular period of time being considered)

M_t = MW expenditures in time period t (i.e., financial quarter t in the model)

I_t = investment expenditures on way in time period t

W_t = wear and tear (i.e., total expenditures necessary to keep quality constant) in time period t.

The quality of a brand new system may be interpreted as its replacement cost in constant dollars (quality is measured in constant dollars), as Q_0 would represent an investment inflow at time zero to initialize the quality level of this new system, and the amount of the inflow

would be the system's cost. The wear and tear during period t represents the total expenditures necessary to maintain a constant quality network, as its name implies.¹ If a zero quality network is defined as one in which the average asset has just reached the point of requiring replacement (and a negative quality network as one in which the average asset is past this point), the value of $Q(T)$ can be seen to be similar to net book value under depreciation accounting adjusted for inflation and over- or under-maintenance. Furthermore, if a certain level of quality is defined as that which would exist if no maintenance or investment had ever been deferred, then the difference between this "desired" level and the current level of quality is a measure of the total amount of deferred expenditures on way and structures. In this study, a parameter representing the "desired" quality of facilities is used for this specific purpose.

In setting the initial value (and the desired value) of the quality level, it was desirable to use a figure

¹ On a brand new network, one would expect that constant quality would not be maintained. Rather, maintenance only would be performed and this maintenance would be less than the wear and tear as some of the assets would be allowed to wear out slowly through use (i.e., "depreciation" is also implicit in the wear and tear rate, this "depreciation" being replaced by reinvestment once the system quality became low enough).

that would be representative of the above interpretation of quality of the fixed facilities. Only a rough estimate was needed, as quality is used exclusively in a relative manner in the model (i.e., in forming ratios or differences with other values of quality, as will soon be discussed). Based upon data available in [4], such an estimate was possible. It was assumed that quality, as defined here, was \$35 billion in 1963,¹ the year in which the model is initialized.

3.4.1.2 Conversion Between Current Dollars And Constant Quality Dollars.

As explained above, quality is similar to net book value under depreciation accounting adjusted for over- or under-maintenance and inflation. That is, the chang-

¹ The data available in [4] sets the replacement cost of all industry assets (including equipment) less accrued depreciation at about \$55 billion (1967 dollars) in 1963. This figure represents what the cost would be if depreciation were computed for non-depreciable as well as depreciable assets. Furthermore, this data is deflated to account for changing construction costs over time. Hence it is compatible with the interpretation of quality in this study, which is measured in constant 1967 dollars. In order to arrive at the \$35 billion used to initialize the quality level, it was assumed that equipment accounted for about \$15 billion (1967 dollars), as net book value was about \$10 billion in 1963. Also it was assumed that deferred maintenance of way, which is not accounted for in [4], was on the order of \$5 billion. Hence \$20 billion was subtracted from \$55 billion to arrive at the initial value of quality.

ing value of the dollars used in supplying quality must be taken into account.

In the discussion of the Income Module, the aggregate "amount" of maintenance of equipment performed was presented as being measurable by the constant dollar value of materials used in ME. Similarly, with respect to MW and investment in way, the aggregate "amount" of maintenance (or investment) performed is also measurable by the constant dollar value of materials used (i.e., miles of rail, number of ties, etc., assuming the mix of materials is fairly constant from year to year), as a surrogate for the amount of material handled. Furthermore, the material/labor ratio (constant dollars of material cost per man-year) was presented as representing maintenance "productivity" in the case of ME, and changes in this ratio together with changes in unit material and labor costs (including fringe benefits) determined what the current cost of a given "amount" of maintenance of equipment would be.

These same concepts are important in relating current dollar expenditures on MW or investment in way to the amount of quality supplied by them. The amount of quality supplied by a given outlay for labor and materials is the constant dollar cost of the "amount" of MW or investment performed including the associated labor

cost. The deflator used to convert current expenditures into "quality dollars" thus takes into account the changes in material and labor unit costs (including labor fringe benefits), as well as changes in the material/labor ratio (i.e., road crew productivity). This latter factor must be included because it helps determine how "much" maintenance actually gets done by a given total dollar outlay for labor and material. For example, if road crews became more productive without a commensurate pay increase, then a given amount spent on maintenance or investment in way would allow more material to be handled and/or laid in (i.e., tons of ballast, miles of rail, etc.) and thus would supply more quality to the system.

The deflator used in converting between current dollars and constant "quality dollars" is known as the Price of Constant Quality Dollars (PCQD) in the model, and is a function of time.¹ It is applied to both maintenance and investment in way expenditures under the assumption that the material/labor ratio in each is identical. In fact, the material/labor ratio function for maintenance and investment in way that is used for this deflator was derived by analyzing the ratio of constant dollar material costs to man-years for the sum of maintenance and investment in

¹ The derivation of this function is given in Appendix C.

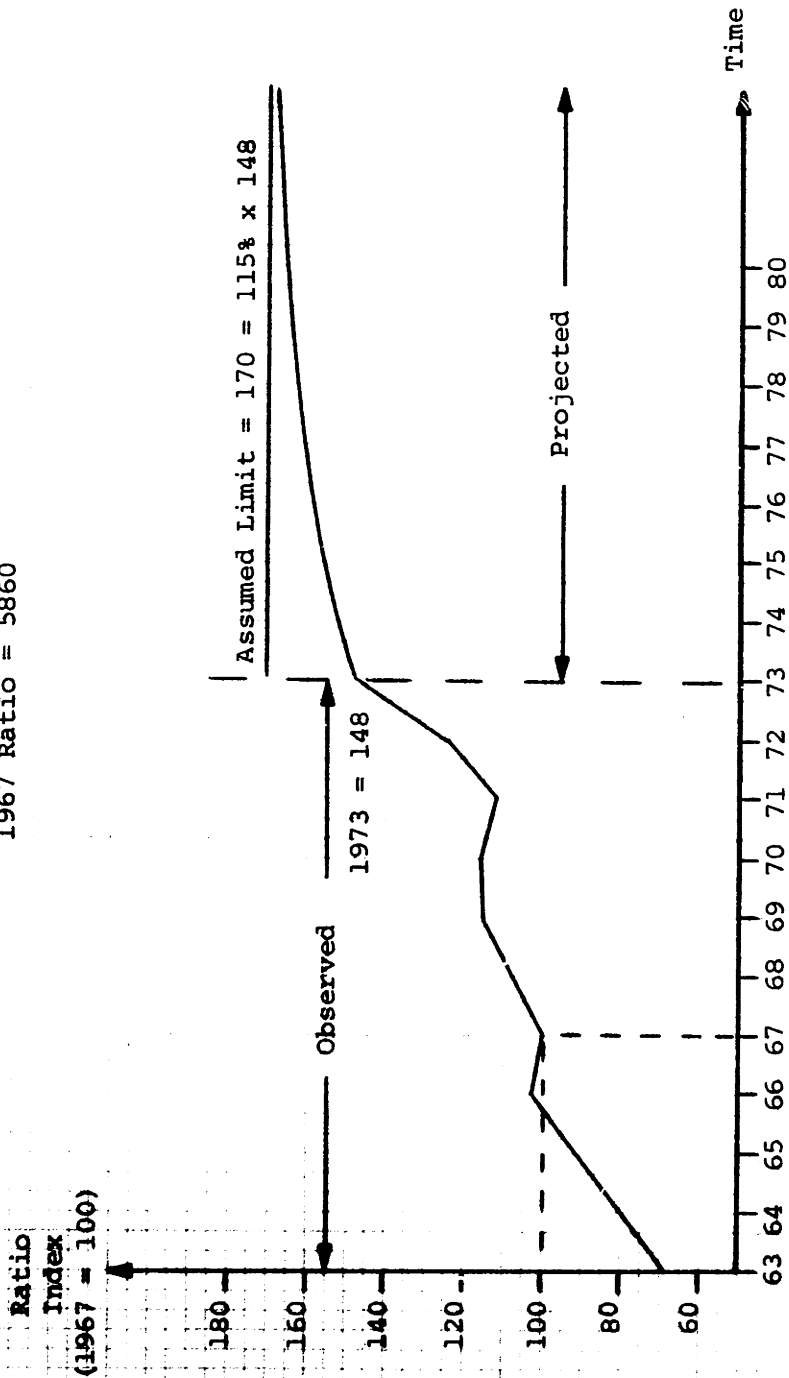
way. This material/labor ratio, identical in concept to that for maintenance of equipment (Figure 3-6), is presented in Figure 3-14.¹ As with ME, there has been a general upward trend in this "productivity". For the sake of model validation, actual values² over 1963-1973 were used, and for the future cases analyzed in Chapter 5, this ratio was assumed to approach 115% of its 1973 value in an exponentially decaying manner as depicted in Figure 3-14. It should be noted that while the model uses the ME material/labor ratio to compute ME labor costs, it does not use the MW material/labor ratio for this purpose. The model does not (although it could) explicitly determine material costs and labor costs for way and structures separately. The only use of the MW material/labor ratio and the unit costs of material and labor is in the computation of the deflator used to relate current dollars to quality dollars, and vice versa. The reverse conversion is necessary in providing current dollar inputs to the MW and investment in way budgeting processes else-

¹ This function and all other cost factors discussed in this section are derived in Appendix B.

² As was also the case with ME material/labor ratio, the 1963-1973 values here represent the ratio of model-computed constant dollar material costs to actual man-years rather than the ratio of actual constant dollar material costs to man-years. Again this was done to avoid unnecessary error in validation.

FIGURE 3-14
MAINTENANCE AND INVESTMENT IN WAY
MATERIAL/LABOR RATIO

Annual Constant 1967 Dollar Material Cost Per Man-Year
 1967 Ratio = 5860



where in the model based upon such items as the Wear And Tear Rate, which forms the basis for the minimum feasible MW discussed in Section 3.1.4. The Wear And Tear Rate, which is the focus of the next section, is also measured in terms of constant quality dollars per year as it and the Maintenance And Investment Rate (and hence the quality level) must have the same units of measure.

3.4.1.3 Wear And Tear Rate.

The Wear And Tear Rate, measured in terms of constant quality dollars per year, is by definition the amount of expenditures (in constant dollars) necessary to maintain a given level of quality. For the purpose of model development therefore, it was necessary to both specify and calibrate a mathematical relationship that would provide the model with this rather nebulous quantity as a function of the current overall state of the system. In approaching this problem, simplifications necessarily had to be made.

The first step in developing a wear and tear function was the identification of those factors which contribute to wear and tear of the fixed facilities. For a given segment of track, or for an entire network, gross ton-mileage per mile and average train speed are probably the

two most dominant factors in affecting MW [12]. As will be discussed in Section 3.4.2, the quality of the facilities themselves also plays an important role in determining MW expense [13]. Since operating policies are not explicitly dealt with in the model, train speed was not considered here.¹ Thus, the issue addressed was the relationship between necessary system expenditures and gross ton-mileage, as the size of the network is assumed to remain fairly constant and traffic patterns are assumed not to change much.²

In developing a relationship between system gross ton-mileage and necessary expenditures, several factors had to be considered. First of all, literature on the topic is scarce. Second, functions available in the literature found in this study [12], [14] were all non-linear

¹ However, train speed is an issue that has to be addressed. This is discussed further in the next section.

² That is, volume changes are assumed to occur proportionally on all segments of track. Furthermore, the effects of parallel trackage laid for the purpose of improving system quality are not considered, even though such trackage could halve gross ton-miles per mile of track on certain parts of the network. (If MW is non-linear in gross ton-miles per mile then halving the traffic density by splitting the volume onto two tracks does not necessarily lead to the same total MW for that part of the network.) Rather, it is assumed that such additions would only be made on a small part of the network and would not change system gross ton-miles per mile significantly.

and applied to one segment of track, so their use for the industry in the aggregate would depend upon the mix of traffic densities over the industry's network, an issue not dealt with in this study. Third, wear and tear in this study is a somewhat more abstract notion than might be found in the literature, as it deals with mixed accounting expenditures (maintenance and investment).

For the above reasons, none of the (scarce) available literature was used as the basis for a function which would determine the Wear And Tear Rate. Instead, observed maintenance and investment in way over 1963-1973 was used as data for an empirical derivation of the necessary function. Inasmuch as these expenditures have been inadequate in the past [5] while they were at the same time large enough to keep NROI and net working capital at poor levels, it was hypothesized that the industry acted as if there were some lower bounds on these expenditures that would be met regardless of their short-term financial impacts. As was discussed in previous module descriptions, the minimum amounts of maintenance and investment in way are determined in the model based upon those observed over 1963-1973. This is because these observed amounts were assumed to represent a certain percentage of what should have been spent to main-

tain constant quality, and hence were used in the derivation of the wear and tear function. This function is in turn used in the model to compute the lower bounds on maintenance and investment in way such that these lower bounds represent the behavior observed over 1963-1973. Thus, the model can be used to compare the effects of maintenance of way policies different from those which were assumed to be in effect in the past.

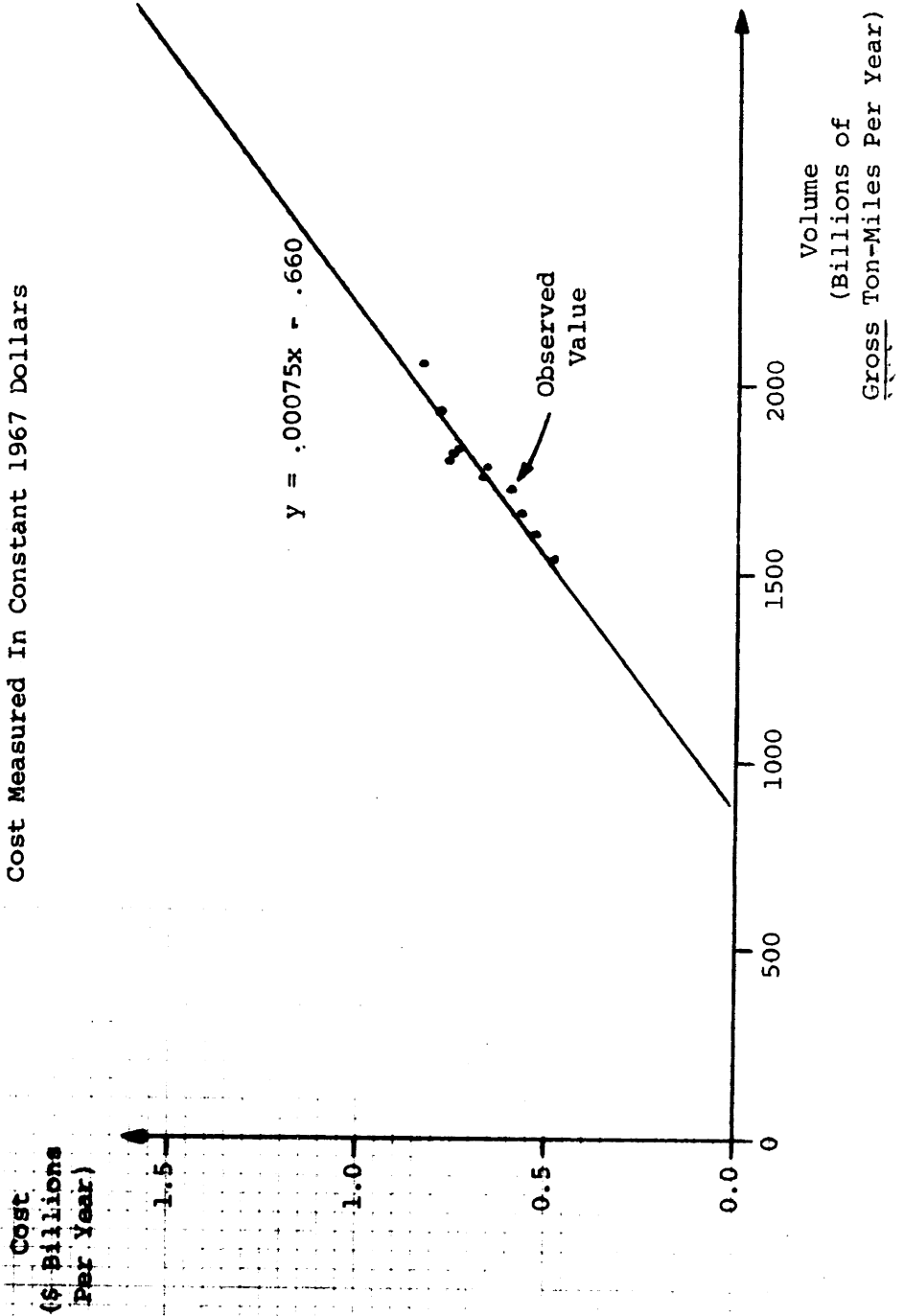
The derivation of the wear and tear function, which is completely described in Appendix B, first related constant dollar material costs¹ to gross ton-mileage, as depicted in Figure 3-15. As is evident in the figure, these costs increased more than proportionally with gross ton-mileage.

This somewhat unexpected result could have arisen for a variety of reasons, the most notable being the highly discretionary nature of these expenditures. However, the strong correlation between these outlays and gross ton-mileage casts some doubt on this type of explanation. As will be discussed in Sections 3.4.2 and 3.4.5, gross ton-mileage was increasing over 1963-1973, so it is very possible that improper deflation of the data or some other time-dependent factor (such as de-

¹ As with maintenance of equipment, the deflator used was the material cost index available in [2].

FIGURE 3-15
MAINTENANCE AND INVESTMENT IN WAY
MATERIAL COSTS

Cost Measured In Constant 1967 Dollars



clining quality) led to this observed phenomenon.

Besides the arguments against the nature of this observed function, there are also arguments in favor of it. The non-linear MW cost functions in the available data sources were all convex to the origin, so it is possible that the observed data is an aggregate manifestation of this. More important however is the fact that the model is to be used as a comparative tool. Slightly increasing unit MW expense with volume (as is caused by the convex wear and tear function derived from the function in Figure 3-15) will affect all the alternatives tested with the model, as will all the simplifications and assumptions made here. Even though this phenomenon might¹ lead to increasing total unit costs in any one case analyzed, causing profitability to increase less than proportionally with volume, it will do so in all cases. Because cases will be compared in order to analyze the relative effectiveness of alternatives, this assumption should not detract from the model's usefulness as a comparative tool.

Given the material cost function depicted in Figure

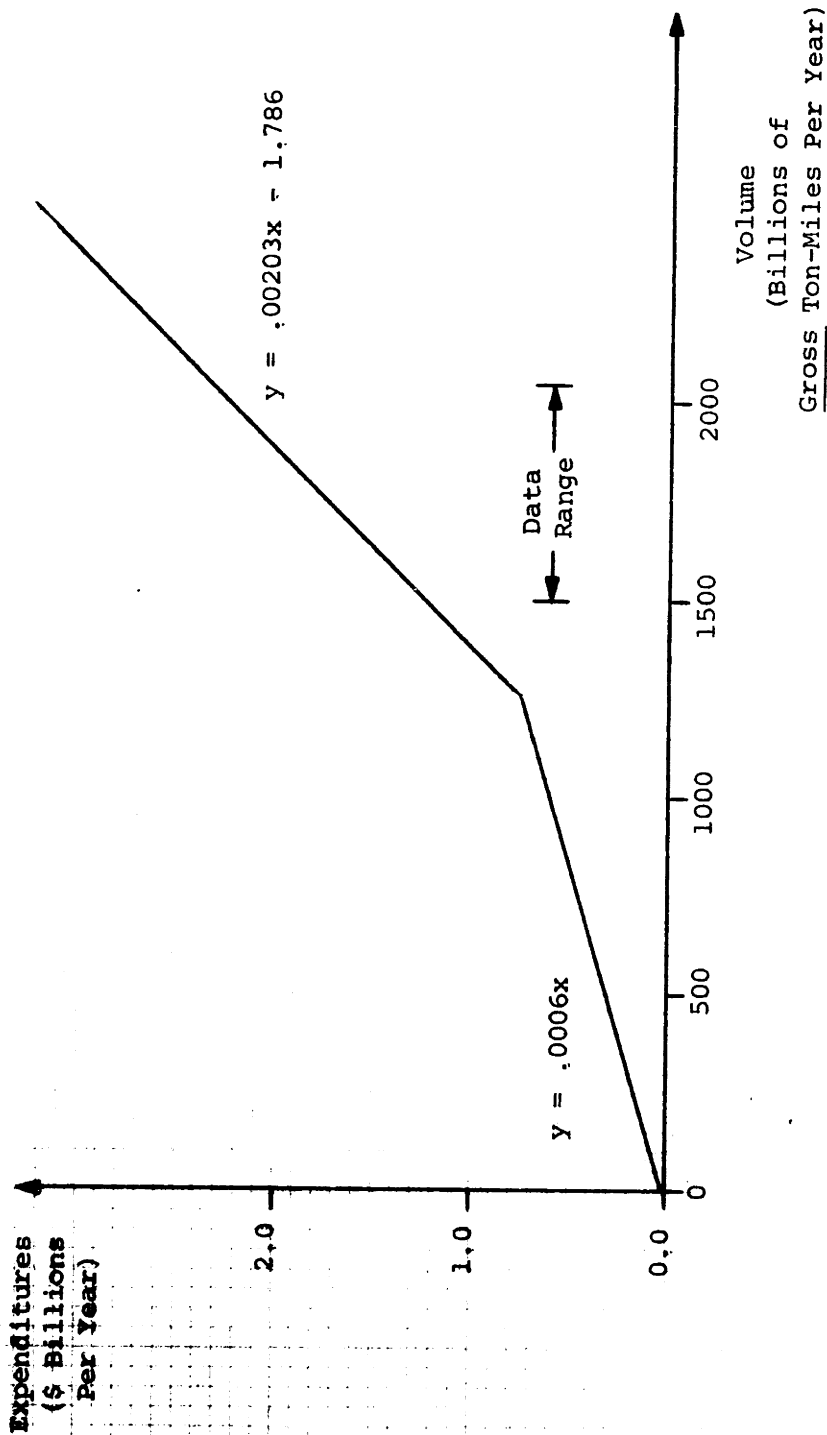
¹ It turns out that all the cost assumptions combined, including those made with respect to passenger expense, which is treated as a fixed cost, lead to total costs increasing about proportionally to freight volume. This is evident in the future case outputs of Section 5.2.1.

3-15, it was possible to derive a function that approximated the total expenditures made over 1963-1973 (maintenance and investment in way) in terms of constant quality dollars. This latter function is proportional to the material cost function because constant quality dollars are measured in terms of a constant labor unit cost (including fringe benefits) and a constant material/labor ratio. Because this function is proportional to that depicted in Figure 3-15, it will not be presented here. However, it is discussed in detail in Appendix B.

Given this function which approximated total expenditures made over 1963-1973, it was possible to determine a wear and tear function. In so doing, it was assumed that actual expenditures were less than those necessary over the data period (i.e., expenditures were being deferred and quality was falling) and that they were a constant percentage of the necessary expenditures in any year. Hence, wear and tear was assumed to be proportional to the function which approximated past actual expenditures on way. Because this latter function is proportional to the material cost function depicted in Figure 3-15, the assumed wear and tear function is also proportional to this representation of material costs. The wear and tear function used in this study is depicted in Figure 3-16, and is explained below.

FIGURE 3-16
ASSUMED WEAR AND TEAR FUNCTION
(EXPENDITURES NECESSARY TO MAINTAIN CONSTANT QUALITY)

Expenditures Measured In Constant 1967 Quality Dollars



In deriving this wear and tear function, an important issue was the proportionality factor between observed expenditures (i.e., "minimum feasible") and wear and tear, as this determines the annual shortfall in expenditures and hence the rate at which deferred expenditures are accumulating. In the absence of any data on the subject at the outset of this study, a simple assumption was made which led to observed expenditures being 87% of those that were necessary.¹ Later in the study, data became available which estimated that the annual expenditure shortfall could be as high as \$1 billion in 1975, and since the \$1 billion was an upper bound and was only a rough estimate, no changes were made to the model's wear and tear function. Thus, it was assumed that the wear and tear function was $1/.87$ times the "observed" Maintenance And Investment Rate function. Because the assumed wear and tear function was increasing more than proportionally with volume² in the data range, it had to be modified in the lower volume range so that negligible (or negative) wear and tear would not occur. Thus, 1250 billion gross ton-miles was arbitrarily chosen

¹ This is explained in Appendix B.

² The independent variable is gross ton-miles per year. In the model, gross ton-miles are computed as 2.4 times revenue ton-miles, based upon an almost perfect fit of this relationship to observed data.

as the break point, and wear and tear was assumed proportional to gross ton-miles for volumes less than this. The implications of this and all other cost-related functions and assumptions are discussed in Section 3.4.5.

Thus, the Wear And Tear Rate, which represents the annual expenditures necessary (in terms of constant quality dollars) to maintain constant quality, is determined in the model by a simple convex function which was derived by the analysis of observed expenditures and assumptions about the extent of their shortfall with respect to what "should" have been spent. While the function derived is most likely not the "true" wear and tear function, it is consistent with industry behavior over 1963-1973. In turn, this can be used as a basis against which to compare the effects of more or less maintenance and investment in way, relative to the amounts generated by the assumed industry policies in effect over the last decade.

3.4.2 QUALITY EFFECTS ON COSTS AND PRODUCTIVITIES.

3.4.2.1 Quality Effects On Costs Not Dependent Upon Productivities.

Besides keeping track of the quality of the facili-

ties, this module must compute the effects of changing system quality on costs and productivities. In terms of costs (other than those related to productivities such as transportation labor costs, which are discussed in Section 3.4.2.2), declining quality is assumed to cause increases in:

- i) necessary maintenance of way (wear and tear caused by a given volume);
- ii) operating costs due to increased fuel consumption by locomotives running on poorer track and/or at sub-optimal speeds caused by slow orders (TTGM fuel costs);
- iii) operating costs due to damage to lading caused by running on rougher tracks (other TTGM costs);
- iv) operating costs due to increased derailments and the subsequent non-labor costs of clearing wrecks and damage to lading (other TTGM costs); and,
- v) maintenance of equipment due to increased wear on the equipment caused by running on poorly maintained tracks and/or derailling more frequently (the "amount" of ME, i.e., materials, and hence also ME labor costs).

The above list of costs currently represent about 45% of total industry costs (including fixed charges) before federal income taxes. Hence, the percentage changes assumed to occur in them as a result of changing quality (which is discussed below) represent smaller percentage changes in total costs. However, even small percentage changes in total costs can have enormous impacts on earnings, due to the magnitude of total costs relative to earnings.

Perhaps most striking in the above list is the first assumption that a poor quality system requires more maintenance to keep it at this same poor quality than a high quality system requires to keep it at a high level of quality. There is some literature available which supports this [13]. Furthermore, it makes intuitive sense, as a given load travelling at a given speed over a segment of track that is in poor condition would probably cause considerable additional damage (i.e., the forces exerted by the load would interact with already loose ties and joints to worsen their condition considerably), while a similar load passing over good track would have few already-present defects to interact with, and hence would cause less additional damage.

It should be noted, however, that average train speeds, which are affected by the track conditions, would

be reduced on a lower quality system due to slow orders and rougher riding. Thus, while the model does not explicitly deal with operating policies, they are assumed to be adjusted to conform with the feasible operating conditions allowed by the quality of the fixed facilities. This has important implications for the wear and tear caused by a given volume of traffic. Since explicit consideration was not given to train speeds in deriving the wear and tear function, these effects must be included in the effect of quality (which dictates speed) on wear and tear. Hence, declining quality has two opposing effects on wear and tear. First there is the increase associated with poorer quality, speeds assumed the same. Second, there is the decrease associated with lower speeds, quality assumed the same. The overall effect of both quality and speed is the one of interest here, and due to lack of information on this total effect, it is assumed that the quality effect is dominant. That is, as quality declines, the wear and tear caused by a given volume is assumed to increase, in spite of the lower speeds occasioned by the lower quality.

Another important fact that should be noted is that while quality is assumed to affect all these cost factors (as well as costs related to productivities), these effects were ignored in deriving the model's cost functions

from the 1963-1973 data.¹ As was cited in Chapter 1, there is evidence that some of these costs (notably those associated with derailments) were being affected by quality over that period. However, accounting for the effects of quality on these various cost categories would have required knowledge about what their relationships with quality were over the data period. As is discussed below, the exact nature of the effects of quality on costs is unknown and is one of the major issues addressed with the model through sensitivity analyses.

Thus, the calibrated model cost functions for TTGM fuel usage, TTGM other costs, and ME material costs (i.e., the amount of maintenance of equipment to perform) presented in Section 3.1, as well as the wear and tear function presented earlier in this section are assumed to be affected by the quality of the fixed facilities.² Although

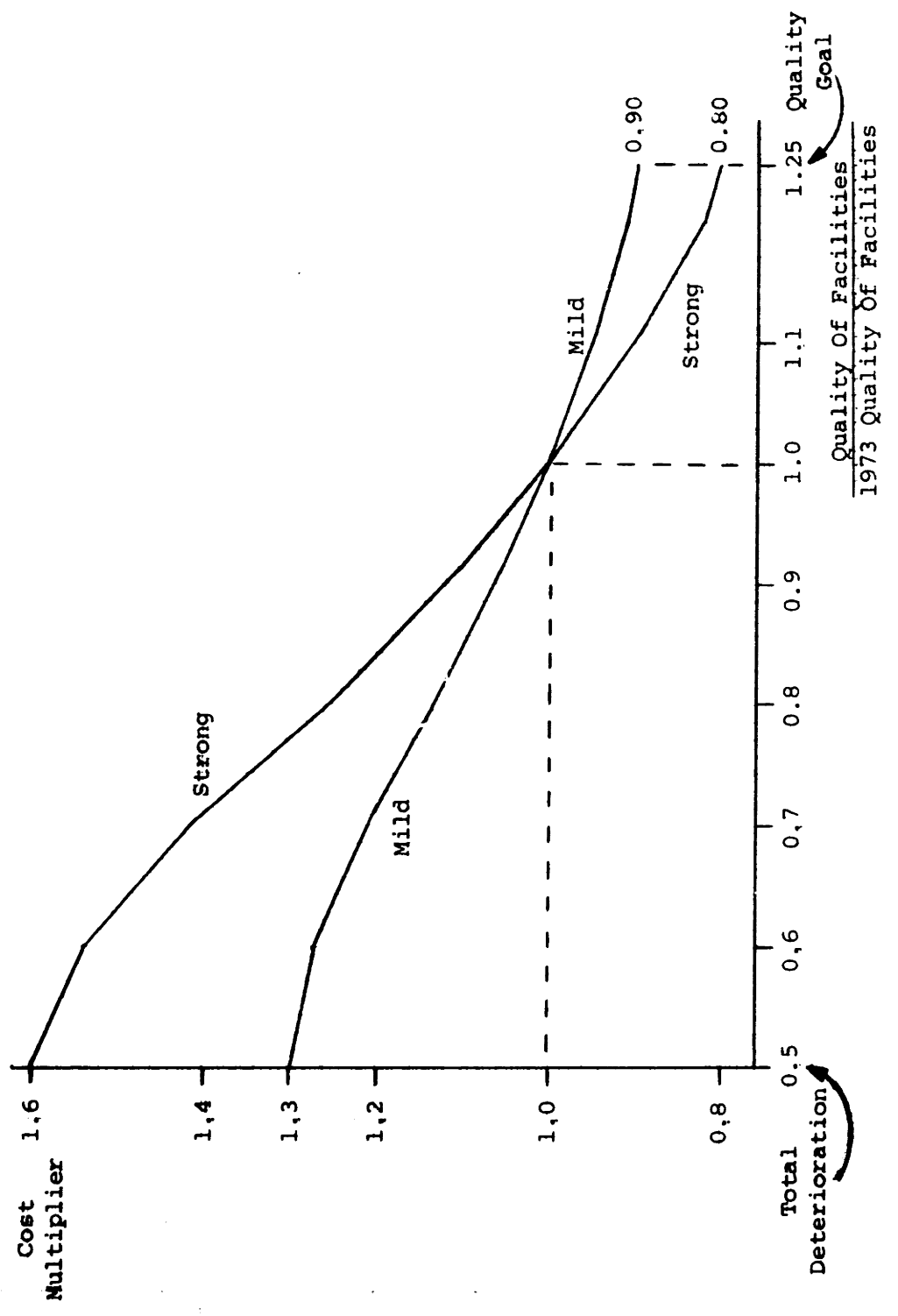
¹ However, since volume was highly correlated with time over 1963-1973, and since quality was declining over this period, it is likely that the calibrated cost functions are manifesting some quality effects in their relationships with volume. This could be one of the reasons why the wear and tear function "observed" was so steep, and could also help explain why no fixed costs appeared in the ME material and TTGM "other" functions.

² The first three factors are also affected by the quality of the rolling stock, but this issue is not dealt with in the model. It is assumed that rolling stock quality does not change in the future cases analyzed, as equipment lives and ME are based upon observed past values dependent upon (and leading to) the quality of the rolling stock over the data period.

there is some literature available [13] which deals with the effects of track conditions on MW costs, it is not directly applicable to the aggregate wear and tear function dealt with here. Furthermore, no literature was found which dealt with the effects of quality on the other areas of cost. Due to uncertainty with respect to these interactions, therefore, a simple approach was taken which easily lent itself to sensitivity analysis with respect to quality effects. Specifically, all four functions were assumed to be affected by quality identically, so that in effect their sum (plus ME labor cost, which depends on ME constant dollar material cost) is affected in the same manner as each individual component of the sum. Thus, in performing sensitivity analyses on the unknown relationships between quality and these various costs any one relationship tested can be thought of as representing a wide variety of individual relationships with the various cost components such that the aggregate effect of these various relationships is the one relationship being tested.

Two overall relationships were tested, as depicted in Figure 3-17. One represents "strong" quality effects and the other represents "mild" quality effects, with the marginal change in costs with strong effects being double that of mild effects at any level of quality. The

FIGURE 3-17
QUALITY COST MULTIPLIER



vertical axis, representing the "cost multiplier" is the number by which each of the individual cost functions mentioned above (and hence their sum) is multiplied to account for changes in system quality from year end 1973. (Because quality effects are inherent in the calibrated cost functions, the functions depicted in Figure 3-17 are only applied to these calibrated functions in years after 1973, the last year of data from which they were derived. Thus, for the purpose of model validation, the effect of quality on the calibrated cost functions is assumed to be 1.0.) The horizontal axis represents the ratio of system quality to that of year end 1973. As is evident in Figure 3-17, when quality is at its 1973 value, the multiplier is 1.0. When quality is higher than its 1973 value, costs are lower and vice versa (ignoring inflation).

It should be noted that sensitivity analyses were performed on the numerical values of the relationship and not on its shape, as both the "mild" and the "strong" quality effect curves are similar in shape. This shape is assumed to be correct and is based upon the economic theory of decreasing marginal returns (ignoring the extreme left-hand portion for the time being). That is, one would expect a greater change in costs as the result of, say, a billion dollar capital improvement program on a

fair quality system than on an already high quality system. This is inherent in the shape of the curves to the right of the "total deterioration" quality range. As quality falls, therefore, the opposite occurs. Starting with a high quality system, one would expect a negligible change in costs if quality was allowed to fall somewhat. However, as quality continually declined the effect of each increment of quality lost would become more pronounced, up to a point. That is, if quality were allowed to fall far enough, the system would be in such poor shape that additional deferral of expenditures (i.e., quality loss) would probably not increase these operating costs noticeably above their already high values. Since the industry's network cannot be referred to as totally deteriorated, it was assumed that it is still in the area of decreasing marginal returns.

The "quality goal" and "total deterioration" can be given more concrete interpretations that is apparent in the quality ratios of Figure 3-17. In terms of 1967 constant quality dollars, quality at year end 1973 is computed to be \$32 billion within the model. The quality goal was set at \$40 billion (i.e., 1.25×1973 quality, as depicted in Figure 3-17), as the \$8 billion difference between this value and the model's 1973 value of \$32 billion represents the approximate extent of deferred ex-

penditures on way and structures which exists in the industry today.¹ Total deterioration is assumed to occur if this expenditure backlog is tripled in size from its current \$8 billion to \$24 billion, hence the ratio used to define total deterioration in Figure 3-17.

The numerical values of the end points of these curves were chosen to reflect a reasonable range of values that could be associated with either the elimination of the current expenditure backlog or with its tripling in size. Elimination of the current backlog will reduce ME, TTGM fuel costs, TTGM other costs, and necessary MW by 10% with mild quality effects and 20% with strong quality effects. It must be realized that these percentages are not that large considering they are assumed to result from a quality improvement program on the order of \$12.5 billion (1975 dollars). Furthermore, they only apply to certain areas of cost. These costs currently represent about 45% of total industry costs (including fixed charges) before federal income taxes, so a 10% to 20% reduction in them would cause a 4.5% to 9% reduction in total costs. However, these small percentage changes can have enormous impacts on earnings, due to the magnitude of the total expenses which they effect. This will

¹ This is discussed in detail in Chapter 5, and is based on data available in [5] and [15].

be discussed further in Chapter 5. The assumed percentage changes in these costs due to quality improvement are thus not that large, and probably represent a reasonable range of values.

The exact magnitudes of the changes in costs caused by these two assumed curves are discussed at length in Chapter 5, where quality improvement programs designed to raise the quality of the industry's fixed facilities to their desired level (quality goal) are tested with the model.

In the case of total deterioration, the assumed extreme values are a 30% increase in these costs with mild quality effects and a 60% increase with strong quality effects. Given that these increases only represent 13.5% to 27% increases in total costs (at today's volume levels) due to a tripling of the already large backlog in expenditures on way, these extreme values of the mild and strong quality effect curves, while large, do not seem unreasonably so. The model will be useful in computing the interim dynamic effects that occur throughout the financial system if quality is allowed to decline to the level of total deterioration. This too is analyzed in Chapter 5.

3.4.2.2 Quality Effects On Productivities And Productivity-Dependent Costs.

Besides affecting the above costs, declining quality also affects the productivities¹ of transportation labor and rolling stock, and hence the associated costs of labor and of equipment (depreciation and fixed charges). These productivity-dependent costs are computed separately from those discussed above, as was discussed in Sections 3.1 and 3.3, and are not affected by the "cost" multiplier of Figure 3-17, in spite of its name. Rather, the productivities which give rise to the costs of interest here are affected by a productivity multiplier, as will now be explained.

The slow orders encountered on a poorly maintained network as well as the more frequent derailments lead to higher manpower and equipment requirements to move a given volume of freight. Also higher maintenance requirements for equipment running on poor track (and derailing

¹ The productivities referred to in this study are the maximum reasonable productivities of labor and rolling stock. That is, they are used to relate capacity to available resources. Actual productivities depend on the demand which occurs given the capacity of the resources. In the case of labor, these two measures of productivity are assumed to be equal as labor is assumed to be instantaneously adjustable to the volume carried. However, in the case of rolling stock, they are not always the same.

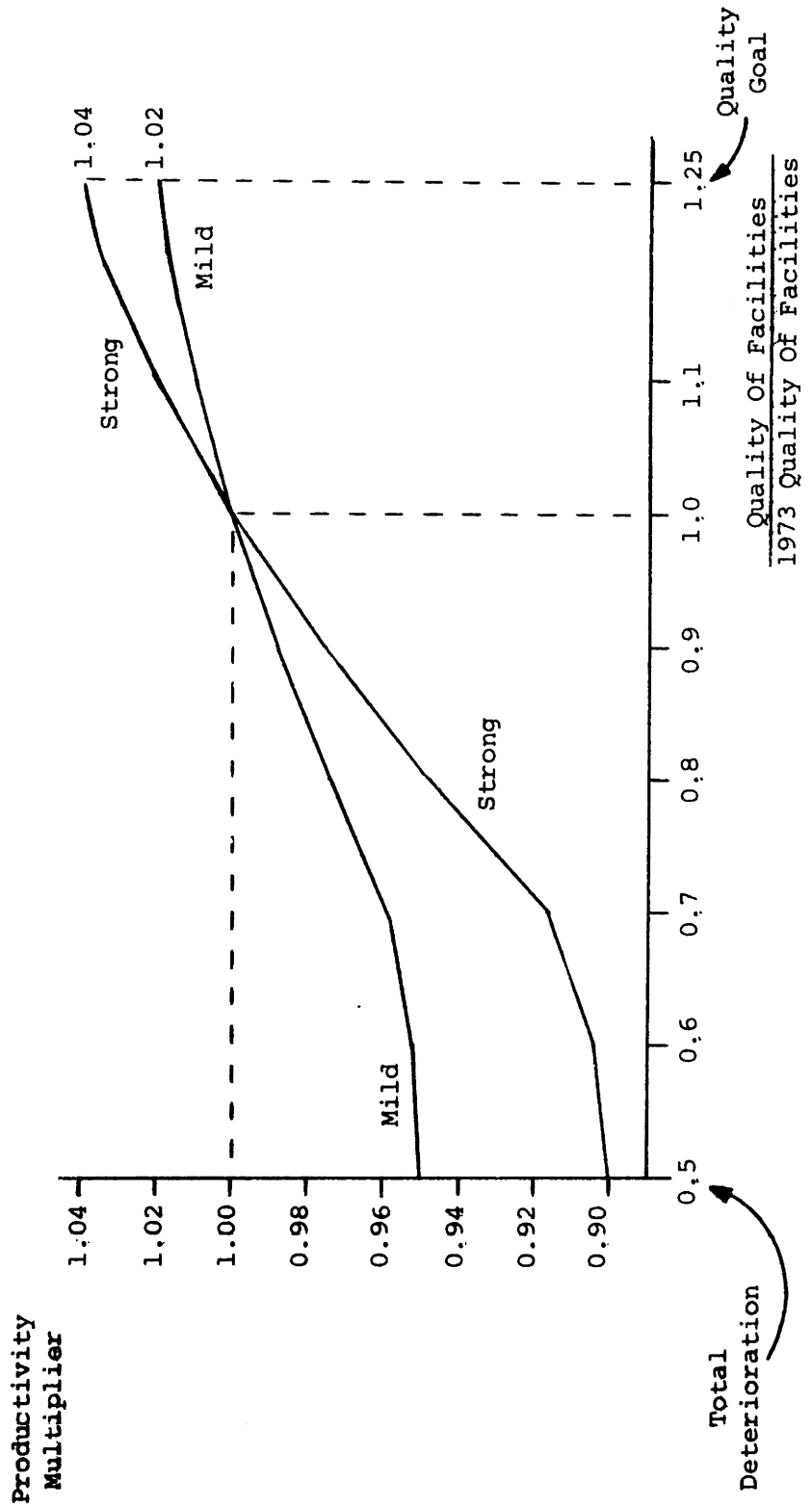
more frequently) leads to increased in-shop time for repairs. Thus, quality has an effect on rolling stock productivity through car-miles per serviceable car-day and through serviceable car-days per car-year (the same is true for locomotives). Transportation labor productivity is primarily affected by slower train speeds and inefficient handling of freight cars at low quality classification yards.

As was the case with the costs discussed previously, there is uncertainty as to what the numerical effects of quality on these productivities are, but the shape of the relationships should again manifest decreasing marginal returns to quality improvement (except in the range of "total deterioration"). Thus, again two similarly shaped curves were assumed, one associated with mild quality effects, and one with strong quality effects, as depicted in Figure 3-18.¹ TTGM labor productivity (TTGM labor is primarily transportation employees) as well as rolling stock productivities are assumed to be affected identically, due to uncertainty about their individual relationships with quality.

Rather minor deviations in these productivities are assumed for both quality improvement and quality decline.

¹ As was the case with quality effects on the costs discussed previously, these curves are only applied after 1973, and the effect of quality on productivities over 1963-1973 is assumed to be 1.0.

FIGURE 3-18
QUALITY PRODUCTIVITY MULTIPLIER



With the assumed curves, productivities only increase by 2% to 4% due to the elimination of the industry's large backlog of deferred expenditures on way, and only decrease by 5% to 10% due to the tripling in size of this backlog. However, these minor deviations can cause significant savings or additional costs because the costs they affect represent a major portion of the industry's expenses and because they are variable (in the long run anyway) in volume, as will be explained in Chapter 5. TTGM labor plus rolling stock ownership costs currently represent about 40% of the industry's total costs (including fixed charges) before federal income taxes. Thus, a 2% to 4% increase in productivities would cause a decrease in total expenses on the order of 0.8% to 1.6% at today's traffic levels. On the other hand, a 5% to 10% decrease in these productivities would cause an increase in total expenses in the order of 2% to 4% at today's traffic levels. Again, these rather minor percentage changes can have significant effects on earnings due to the magnitudes of the expenses they are applied to. This is discussed at length in Chapter 5.

While the "cost multiplier" presented in Figure 3-17 is applied to the calibrated cost functions presented in previous figures, the "productivity multiplier" is applied to the model's productivity functions. The assumed

TTGM labor productivity function was presented in Figure 3-2, and the functions which determine rolling stock productivity are presented later in this chapter. All of these productivities are assumed to be increasing functions of time, everything else (i.e., quality) being the same. Thus, the productivity multiplier is applied to these functions, and causes productivities to change from what they otherwise would have been if quality remained at its 1973 level. It is therefore possible that productivities can increase with time in spite of declining quality, and this occurs whenever the "normal" increase in productivity over time outweighs the dynamic decrease caused by worsening quality.

3.4.3 RELATIONSHIP OF QUALITY AND WEAR AND TEAR TO MAINTENANCE AND INVESTMENT BUDGETING PROCESSES.

In the discussions of the Funds Flow And Finance Module and the Income Module, the model processes which "decide" upon maintenance and investment in way were explained. These decisions are reached by giving consideration to the minimum and desired amounts of maintenance and investment in way which are computed in this module. The ensuing discussion tells how these quantities are

determined by the maintenance/investment in way policies embedded in the equations of the Quality Of Facilities Module. The Wear And Tear Rate and the Quality Of Facilities Level are used as the bases for the determination of these quantities. Hence, their explanation has been postponed till this point in the chapter.

Minimum expenditures on way (maintenance plus investment) are determined as a specific percentage of the wear and tear to occur in the upcoming quarter,¹ converted into current dollars by means of the Price of Constant Quality Dollars. The percentage currently used in the model (87%) causes these minimum expenditures to approximate the observed relationship between maintenance and investment outlays and volume over 1963-1973, but could be altered as part of various maintenance/investment in way policies to be analyzed with the model. The minimum total expenditures on way are then split into minimum maintenance and minimum investment by means of a parameter which

¹ While the upcoming wear and tear cannot actually be precisely known in advance, it is assumed that this is the case in the model strictly for the purpose of simplicity. The model could easily be altered so that current decisions were based upon the perceived or expected wear and tear at any point in time. However, the model is not being used to analyze the effects of delayed information in the processes which budget the allocation of funds. Thus, adding this minor complication to the model would be of no value to the purpose of this study.

dictates how much of the total outlays on way should be charged to expense. This parameter is currently set at the observed average percentage of total expenditures which were classified as maintenance (about 80%) over 1963-1973, but could be altered as part of a different policy to be tested. However, as mentioned in Section 3.4.1, the only effect of changing it is in the accounting performed to record the expenditures. Maintenance and investment are assumed to be identical with respect to their marginal impact on quality, so regardless of the accounting split, the same total expenditures have the same effect on quality in the model.¹

The wear and tear function was derived under the assumption that observed expenditures over 1963-1973 were the minimum possible given the policies in effect during that time interval. These assumed policies are represented by the 87% minimum total expenditures and 80%/20%

¹ There is also a minor difference that could occur in total expenditures. As mentioned in the discussion of the Funds Flow And Finance Module, minimum investment in way is linearly reduced between its functionally determined value (i.e., 20% x 87% x wear and tear) and zero as net working capital varies between \$+100 million and \$-100 million (constant 1967 dollars). This type of reduction is not applied to maintenance, as it is assumed that replacements and repairs are not as deferrable as improvements or additions. Hence, a larger maintenance share of the minimum total expenditures can lead to more expenditures being carried out if net working capital is low.

maintenance/investment split embedded in the model's parameters. These parameters may be altered so that the effects of policies other than those which were apparent or assumed over 1963-1973 may be implemented in the model and their results compared to those of the assumed "base" policies.

The minimum amounts of maintenance and investment in way are always performed in the model, and as currently determined, lead to quality decline. The other inputs to the maintenance and investment budgeting processes, the desired amounts, are only executed if the model finds sufficient earnings and/or funds available with which to perform them, as previously explained. They may also be carried out if the model is "forced" to do so as part of a quality improvement program, regardless of their short-term financial impacts. In Chapter 5, many cases are presented where this forcing is in effect.

In determining the desired amounts of maintenance and investment in way, the model first determines the desired total expenditures on way and then splits them into desired maintenance and desired investment by means of the same parameter used to perform this task for the minimum expenditures.¹ The determination of the desired

¹ The same M/I split is assumed for desired amounts as it is for minimum amounts. That is, whether the split

total expenditures is the important point addressed here, and this is done by means of a "goal-seeking" equation similar in form to that used for the desired addition to net working capital. The equation which determines the desired total annual expenditures, in terms of constant quality dollars, is:

$$\text{desired expenditures}^1 = (\text{desired quality} - \text{current quality})/10 \\ + \text{current wear and tear}$$

As mentioned previously, the desired quality (or quality goal) in this study represents what quality would be if there had never been any deferred expenditures on way. Based upon available data as to the extent of the deferrals in 1973 and the model-computed value of quality for that year (\$32 billion), the quality goal was set at \$40 billion indicating a backlog of \$8 billion (constant quality dollars). Because this backlog is so large, it cannot be expected to be made up in a short period of time. Hence a large number was sought as the divisor

is 80/20 or 60/40, both desired and minimum amounts are split in these proportions. The model could easily be altered to allow different splits to apply to desired versus minimum expenditures.

¹ These desired expenditures are checked for negativity and are set to zero in this case. However, negative desired expenditures can only occur if quality is above its desired level, a condition which never occurs in this study.

of the equation, and 10 was arbitrarily chosen. This value for the Time to Adjust Quality of Facilities (TAQF) causes 10% of the remaining backlog to be eliminated each year and thus causes an exponential approach to the quality goal of \$40 billion, with an \$8 billion backlog being almost reduced to zero after 25 years. Both the quality goal and the divisor could be altered to test various magnitudes and speeds of desired quality improvement programs. (The quality goal could also be set below the current quality if the system is "too good" and it is desirable to reduce its quality.)

It should be noted that the above equation includes the current wear and tear as an additive term. Since total expenditures on way and structures are determined by this equation in the absence of financial constraints (or if the model is forced to perform the desired expenditures), these expenditures must cover current maintenance and investment needs as well as make up for any deficiency in past expenditures. Also, if current quality is the desired quality, all of the current wear and tear must be matched by current expenditures if quality is to remain at its desired level. Hence this additive term is included.

To convert the desired expenditures into "current" (i.e., inflated) dollars, the Price of Constant Quality

Dollars is again used,

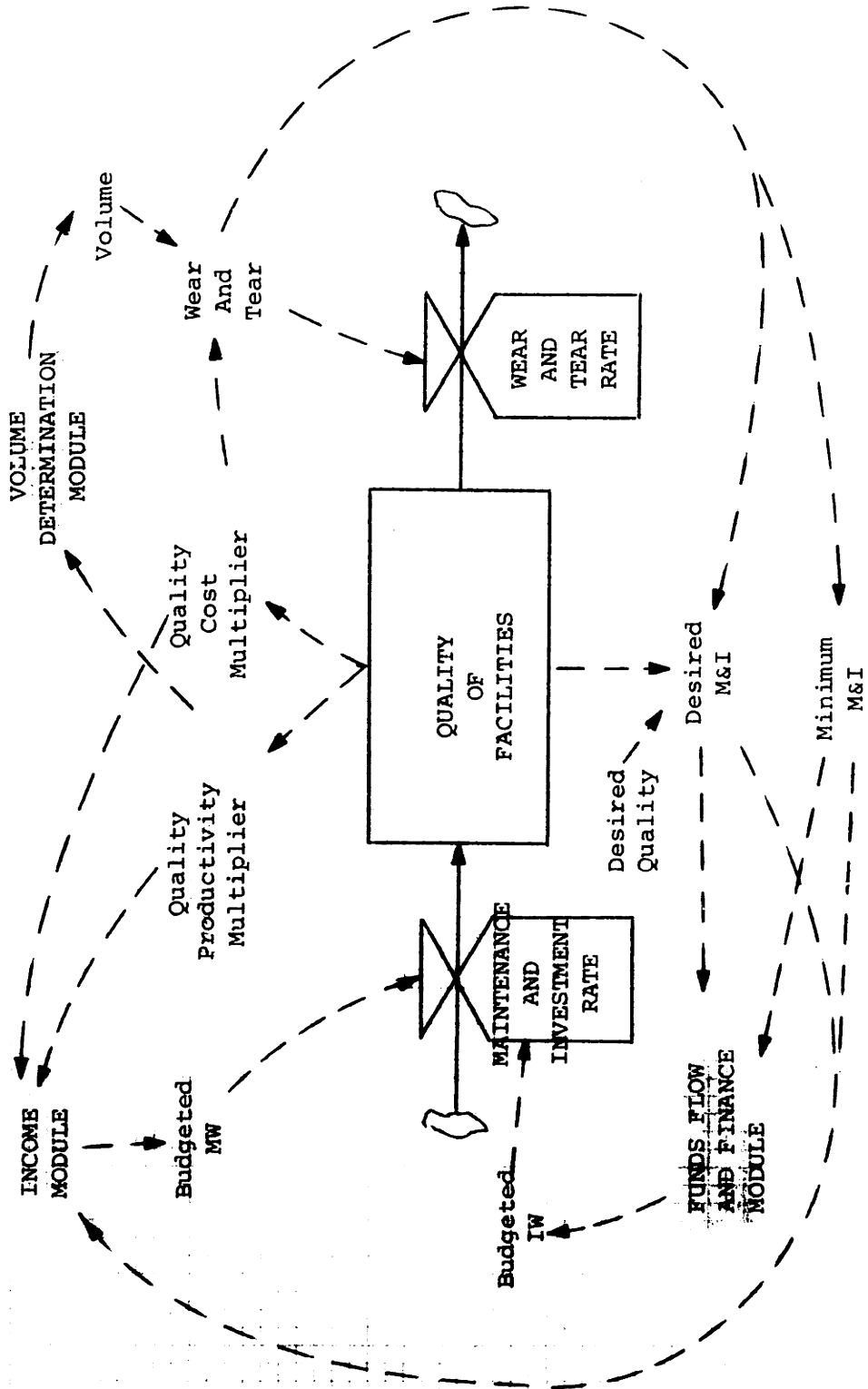
3.4.4 INTERACTIVE NATURE OF QUALITY OF FACILITIES MODULE.

Now that all the aspects and functions of the Quality Of Facilities Module have been explained, Figure 3-13 can be presented again, including all the features of this module. This is depicted in Figure 3-19. As is evident in Figure 3-19, the Quality Of Facilities Module interacts with the Income Module, the Funds Flow And Finance Module, and the Volume Determination Module, providing information to, and receiving information from, all three of them.

The Volume Determination Module receives the quality productivity multiplier from this module, and uses this information in determining the productivities and hence the capacities of the freight car and locomotive fleets. These capacities and demand are used to determine volume, which in turn helps determine wear and tear.

The Funds Flow And Finance Module accepts the minimum and desired investments in way (IW) from the Quality Of Facilities Module. It uses this information in determining the actual investments to be made, given the availability of funds and its investment/financing policies. These budgeted investments are then converted into constant quality dollars and help determine the Maintenance

FIGURE 3-19
QUALITY OF THE FIXED FACILITIES



And Investment Rate which supplies quality to the system.

The Income Module accepts the quality cost multiplier and the quality productivity multiplier and uses these to determine costs and income (and hence funds available for maintenance and investment in way). It also accepts the minimum and desired maintenance of way, and uses these inputs together with the maximum affordable maintenance of way (which is a function of income) to determine the actual maintenance to be performed. The budgeted MW is then converted to constant quality dollars and helps determine the Maintenance And Investment Rate.

As Figure 3-19 and the above discussion point out, the Quality of Facilities Level is highly interactive with the rest of the overall system. Furthermore, because quality is a level, it accumulates the results of all previous maintenance and investment decisions as to expenditures on way and structures. The accumulation of all these decisions "feeds back" on the processes which determine them, as quality affects costs and productivities, and hence the internal and external funds (due to the interest coverage allowed by income) which are available for financing expenditures on way. Hence the feedback loop between quality, income, "investment" and back to quality again is quite obvious.

3.4.5 DISCUSSION OF THE MODEL'S COST FUNCTIONS¹ - A DIGRESSION.

Now that all the functions used in the model to determine operating expenses have been presented, it is perhaps worthwhile to step back and review them on an overall basis. This section therefore summarizes the manner in which operating costs are determined in the model, deals with the implications of the assumed industry cost functions, and discusses the rationale behind their choice.

Operating expenses are typically treated as falling into six accounting categories: maintenance of way, maintenance of equipment, traffic, transportation, general, and miscellaneous. In the model, the latter four categories are combined, so that model expenses fall into three groups which are represented by the acronyms: MW, ME, and TTGM. These expenses are determined in the model (for freight service) by simple functions which provide "deflated" cost bases which are subsequently inflated or priced to give current costs. Specifically, the model uses functions to determine:

- i) TTGM labor requirements (man-years, deter-

¹ The discussion here deals with the cost functions before they are affected by the appropriate multiplier to account for changes in system quality. Hence, the effects of quality on costs and productivities are ignored.

mined by the TTGM labor productivity function in Figure 3-2 and the current volume of traffic);

- ii) TTGM fuel consumption (gallons of diesel oil, determined by the fuel consumption function in Figure 3-3 and the current volume of traffic);
- iii) TTGM other costs (constant dollars, determined by the "other" TTGM cost function in Figure 3-4 and the current volume of traffic);
- iv) ME material costs (constant dollars, determined by the ME material cost function in Figure 3-5 and the current volume of traffic);
- v) ME labor requirements (man-years, determined by the ME material/labor ratio in Figure 3-6 and the ME material costs dictated by the current volume via Figure 3-5); and,
- vi) MW expense (ignoring expenses incurred to reduce a maintenance backlog, this cost is determined as a constant percentage of the wear and tear function in Figure 3-16 which relates necessary expenditures, in terms of constant qual-

ity dollars, to volume).

If one were to ignore inflation and changes in labor productivities, it would be possible to derive an explicit mathematical statement of the total operating cost function implied by the summation of the above cost factor functions (priced and/or inflated according to the conditions in effect in any one year). However, the important issue here is the form of the assumed total operating cost function, and this form is invariant over time. Thus, this discussion proceeds in a fairly qualitative manner, dealing with the general nature, and not an exemplary explicit equation, of the total operating cost function implied by the assumed individual cost factor functions.

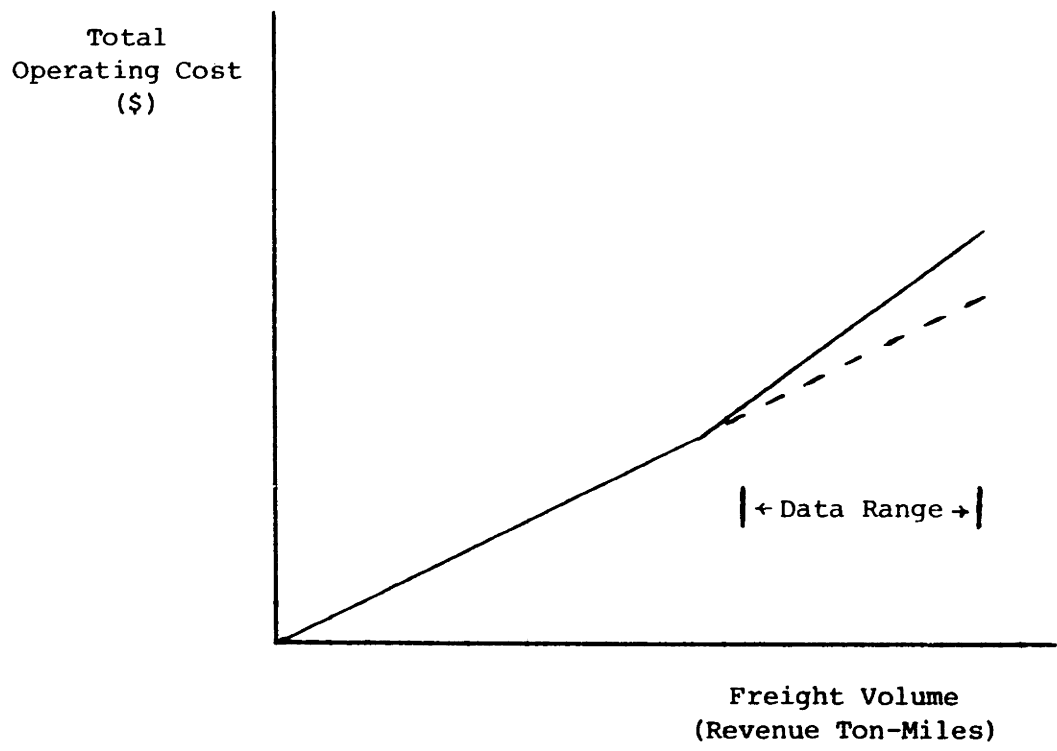
As is indicated in the above-mentioned figures, the functions for TTGM fuel, TTGM other, and ME material cost were all assumed to be linear in volume with no fixed cost, on the basis of the observed data. Furthermore, all labor (including salaried employees) was assumed to be variable, as the number of men required for TTGM and ME are both determined through productivity measures which (ultimately) relate to the current volume of traffic. Thus, if inflation and dynamic productivity changes are ignored, labor costs for both TTGM and ME

are also linear in volume with no fixed cost. Lastly, the wear and tear function, which helps determine MW expense was assumed to be convex to the origin and piecewise linear in volume, so that in the range of volumes observed, this measure of necessary (deflated) maintenance cost increased more rapidly than did volume. By "adding" the various linear forms of all these cost components, the form of the assumed total operating cost function is arrived at. This function is depicted in Figure 3-20.¹ It should be noted that the MW and ME components of the function do not include any depreciation expenses, and that labor cost components include payroll taxes as well as salaries, wages, and health and welfare benefits. Thus, the definition of "operating costs", as used here, differs somewhat from its usual form.

There are two aspects of this function that deserve discussion. First, there are no fixed costs. Second, and not completely independent of the absence of fixed costs, there are increasing unit costs in the higher vol-

¹ Wear and tear, and hence MW, is actually a function of gross ton-miles in the model, and not revenue ton-miles as depicted in Figure 3-20. However, in the model, gross ton-miles are computed as 2.4 times revenue ton-miles. Hence it is possible to restate the wear and tear function in terms of revenue ton-miles without altering its shape.

FIGURE 3-20
GENERAL FORM OF TOTAL OPERATING COST FUNCTION
FOR FREIGHT SERVICE



ume ranges. Each of these aspects will be discussed in turn, beginning with the absence of fixed costs.

It is important to realize that the operating costs depicted in Figure 3-20 do not include depreciation expenses, which, along with fixed charges, represent the high non-variable costs associated with the large amount of capital employed in the industry. Both depreciation and fixed charges, which are "fixed" in the short run, are handled in the model, and in a manner similar to reality, but are treated separately from the costs being discussed here. Property taxes and the rental or lease costs of fixed or equipment assets, which also may be fixed in the short run, are also dealt with separately by the model. The only fixed costs that might be included in the categories labelled as operating costs are therefore the salaries of some of the management structure, and certain other aspects of corporate overhead.¹ Since the model deals with long-term financial performance, and

¹ Data available in [3] shows that the salaries of executives, officials, and staff assistants, which are probably the most fixed of all management structure salaries, only accounted for \$342 million in 1973, or about 5% of all wages and salaries. While there is no data available which explicitly deals with fixed industry overhead (other than taxes, depreciation, fixed charges, leases, etc., which are accounted for separately in the model), it is likely that these costs too are relatively insignificant.

since all costs are variable in the long run, all labor costs were treated as variable. While this assumption might somewhat detract from the model's ability to accurately predict labor costs in any one year, it should give a fair approximation to the long-run behavior of these costs. The same argument may be applied to corporate overhead. Thus, the basic defense of the absence of fixed costs from the operating cost functions lies in the fact that they are to be used to model long-run behavior, and that all costs are variable in the long run. This is particularly true of those included in the operating cost components of the model, as they represent the costs directly associated with operations.

Arguments can also be made for the fixedness of some labor and overhead costs and reasons given for the failure of the data to manifest fixed costs in the cases of TTGM other and ME material costs. Specifically, in these two latter cases, time series data was used to derive the cost functions. Thus it is possible that improper deflators were used. Furthermore, these cost functions are hypothesized to be affected by declining quality in this study, yet quality effects were not taken into account in their simple derivations.¹ Hence it is possible that there are

¹ These derivations, as well as all other cost function derivations, are given in Appendix B.

some fixed costs which are being ingored in this study. However, arguments for and against the nature of the cost functions used must be judged in terms of the functions' purpose. In this study, all that was sought were some simple approximations to operating costs. Inasmuch as the model is used as a tool for the comparison of the relative effectiveness of alternatives, precise cost functions are not necessary. Rather, the fair approximations provided by the simple functions derived are felt to be sufficient, as they affect all the alternatives compared with the model. Their only shortcoming is that they possibly do not allow the model to accurately predict the precise numerical effects of any one alternative. While this might be important in other types of studies, and while it would certainly add to the usefulness of the model developed here, it was not the reason for which the model's cost functions were derived.

The slope of the wear and tear function and the fact that it leads to a convex operating cost function and slightly increasing unit operating costs is the next issue to be addressed. The maintenance costs obtained from this function in the model represent the accounting costs termed as maintenance of way, and thus include actual maintenance outlays and expenditures that would be classified as investments in other industries. As was explained

in Section 3.4.1, no data source was found which gave an industry-wide accounting cost function for maintenance of way, as was needed in this study. Hence, the wear and tear function, which is used in the model to approximate the amount of expenditures on way and structures necessary to maintain constant quality, was derived based upon the observed expenditures, the notion that they should increase with volume, and the fact [5] that the observed expenditures were less than "necessary". Thus, given our relatively limited knowledge about the macroscopic behavior of this abstract entity, the function used in the model is probably as good as any other for the purpose of this study, as it represents the mathematical statement of our entire knowledge (which includes the empirical evidence) about the factor of interest.

In spite of all the above arguments about the validity of the functions used in the model, the weaknesses inherent in them will not be ignored. Specifically, the "true" functions which they approximate are much more complex than the functions used here, which are primarily statistically based and relate costs solely to volume. The linearity of the functions, while a common modelling approach, might also be questioned. Furthermore, the assumptions of no fixed operating costs and a convex wear and tear function lead to increasing unit operating costs,

and therefore the model's functions are possibly pessimistic predictors of accurate values for earnings. This total variability of operating costs could also cause the model to find volume expansion less desirable than it actually is, due to the lower marginal return on additional investment (i.e., in freight cars) associated with the greater variability of costs.

All of these weaknesses have to do with the model's ability to match reality. While such a matching is desirable, the degree to which it can be achieved with any model is limited. Thus, a model must be judged as a simplification of reality and in comparison to alternative means of fulfilling the purposes for which it is used. The purpose for which a model is used should also take into account the simplifications necessary in the model. This model is used as a comparative tool, and its inability to accurately predict costs and earnings is acknowledged, and is taken into account in forming conclusions. The type of conclusions sought here are those that do not depend on the complete accuracy of the cost functions, so that the simplifications made in developing these functions are felt to be less than critical in terms of the conclusions of this study.

3.4.6 QUALITY OF FACILITIES MODULE SUMMARY.

All of the functions performed in this module are centered around the quality of the fixed facilities which is represented by a level. In spite of the abstract nature of the concept of quality, it is a property of the system that is affected by the difference between the amounts that should be spent each year to keep quality constant and the amounts which are spent each year. Thus quality is modelled as a level which is measured in terms of dollars, and associated with this level are two rates. Flowing out of the quality level is the Wear And Tear Rate, which represents the amounts which should be spent each year to keep quality constant. Flowing into the quality level is the Maintenance And Investment Rate, which represents the total annual amount which is spent for the sake of quality. If the actual expenditures are more than those necessary to keep quality constant, it improves, and if they are less, quality becomes worse. Furthermore, because quality declines if actual annual expenditures are consistently below those necessary to keep quality constant, the difference between the current level of quality and some quality goal (or desired quality) is a monetary measure of the amount of deferred expenditures which must be made up in order to

raise quality up to its desired level.

Due to the abstract nature of wear and tear, a simple approach was taken to derive a functional form for it in the model. Specifically, since the industry as a whole has been deferring expenditures on way [5], it is obvious that maintenance and investment in the real world have been less than wear and tear (i.e., less than the expenditures necessary to prevent deferrals from accumulating). Hence, observed expenditures over 1963-1973 were used as the basis for the model's wear and tear function, under the assumption that actual expenditures were a constant percentage of those which should have been performed each year.

Declining quality of the fixed facilities can have adverse effects on operating costs and equipment productivities. In this study, quality is assumed to affect TTGM labor productivity (and hence TTGM labor costs), fuel consumption, all other TTGM costs, maintenance of equipment, necessary maintenance of way, and rolling stock productivity. Reasonable, theoretically based estimates of the shapes of the relationships between quality and these factors were used in this study. However, the specific numerical relationships between quality and each of them is unknown. Therefore, this study focuses around sensitivity analyses with respect to these unknown numerical

relationships. Because the specific effects of quality on each of the above factors is unknown, those with similarly shaped relationships with quality are all assumed to be affected identically. This facilitates sensitivity analyses, because any relationship applied identically to each of them is in effect applied to their sum. Hence any one relationship tested can be representative of a wide variety of individual relationships applied to the factors in the sum, since this one relationship is indicative of the overall effects of quality on all the factors of interest.

Two degrees of quality effects are addressed in this study, namely, mild and strong. Both types of effects are assumed to be identical in terms of the shapes of the relationships between quality and costs (not dependent upon productivities) and quality and productivities (and hence costs which do depend upon productivities). However, strong quality effects are assumed to have twice the marginal impact on costs and productivities than do mild effects. The magnitude of these two degrees of quality effects were chosen so as to represent a reasonable range of values to be associated with "total system deterioration" and system quality improvement to a level where there would be no deferred expenditures. Specifically, it is assumed that the system becomes totally deter-

iorated if the amount of deferred expenditures on way triples from its current value of approximately \$8 billion (constant quality dollars) to \$24 billion. In this case, mild quality effects cause a 30% increase in the cost categories identified in Section 3.4.2.1 and a 5% decrease in TTGM labor and rolling stock productivities. Strong quality effects represent a 60% increase in these costs and a 10% decrease in productivities if "total deterioration" occurs. In the case of the elimination of the present \$8 billion backlog of expenditures on way, mild quality effects are assumed to reduce the affected costs by 10% and increase productivities by 2%, whereas strong effects decrease these costs by 20% and raise productivities by 4%.

The Quality Of Facilities Module is highly interactive with the rest of the model. The effects of quality on costs and TTGM labor productivity are passed to the Income Module, as they affect income. Also, maintenance "policies" built into the Quality Of Facilities Module determine the "minimum feasible" and desired amounts of MW based upon the wear and tear occurring in the system and the current discrepancy between quality and its desired level. These two concepts about the current state of the system (computed by auxiliary equations) are also passed to the Income Module, where more maintenance poli-

cy equations determine how much MW will be performed. The budgeted MW is then used in the Quality Of Facilities Module where it helps determine the Maintenance And Investment Rate which supplies quality to the system.

Besides having a two-way interaction with the MW budgeting process, this module also supplies information to and receives information from the process which determines investment in way in the Funds Flow And Finance Module. Again, desired and minimum amounts are supplied by the Quality Of Facilities Module based upon wear and tear and the current discrepancy between quality and its desired level, and again the resultant budgeted investments are supplied to this module. Both this budgeted amount and the budgeted MW depend on the funds available for supplying quality to the system, and these available funds are dependent upon earnings which are affected by quality and hence by all previous expenditure budgeting decisions. Thus the feedback involved between earnings and quality is quite evident in the structure of the model.

The Volume Determination Module also has a two-way interaction with this module. Quality affects the productivity of the rolling stock and hence the capacity of the fleet. This capacity in turn constrains volume, which "feeds back" to determine wear and tear, and hence

quality.

Thus, the Quality Of Facilities Module, which deals with some rather abstract concepts, plays an important role in the model (because quality and wear and tear play an important role in the system of interest). In spite of the simple manner in which the abstract notions of quality and wear and tear are modelled, their representations are very meaningful and applicable to their real world counterparts.

3.5 EQUIPMENT NEEDS MODULE.

The Equipment Needs Module is responsible for determining the desired investments in freight cars and locomotives.¹ In conjunction with performing this task, it must keep track of the current numbers of cars and locomotives on line, and is also responsible for determining the numbers of retirements of each that will occur during any year in the simulation.

It is helpful to understand how the model keeps track of the current fleets of cars and locomotives and how it determines retirements before the manner in which desired rates of investment are set is explained. Thus, Section 3.5.1 discusses how fleet size and retirements are determined in the model, followed by the explanation of how desired investments are decided upon, which is the topic of Section 3.5.2.

¹ As mentioned in Section 3.2.2.4, desired investments in "other" equipment, which includes passenger service rolling stock, are treated as an exogenously supplied constant in the model. There are no levels which keep track of the "numbers" of other equipment. Rather, only their gross book value and accumulated depreciation are modelled as levels, or in the case of passenger cars and locomotives, are included in the balance sheet levels for all cars and locomotives. Hence, the extent of the treatment of "other equipment" in the model has already been explained in previous sections, and this equipment will not be discussed in this section.

3.5.1 MODELLING FLEET SIZE.

There are two fleets of freight cars and two fleets of freight service locomotives in the model. One fleet of either type of rolling stock is owned by the industry, and the other is "rented" (i.e., leased, rented per diem, etc., from car companies and shippers). In model applications, the concern is primarily with the owned fleets, as the numbers of rented cars and locomotives are assumed not to change after 1973, with all additional capacity being purchased by the industry. Thus, the sizes of the rented fleets of cars and locomotives are treated as exogenously supplied constants after 1973, and as exogenously supplied variables over 1963-1973 (for the purpose of model validation), with the values supplied in any one year representing the actual numbers of rented cars and locomotives on line. The ensuing discussion therefore focuses on modelling the owned fleets, and rented rolling stock will not be dealt with again until Section 3.5.2, where it will be seen that changes in the numbers of rented cars and locomotives have an impact on the desired investments in owned equipment in the model.

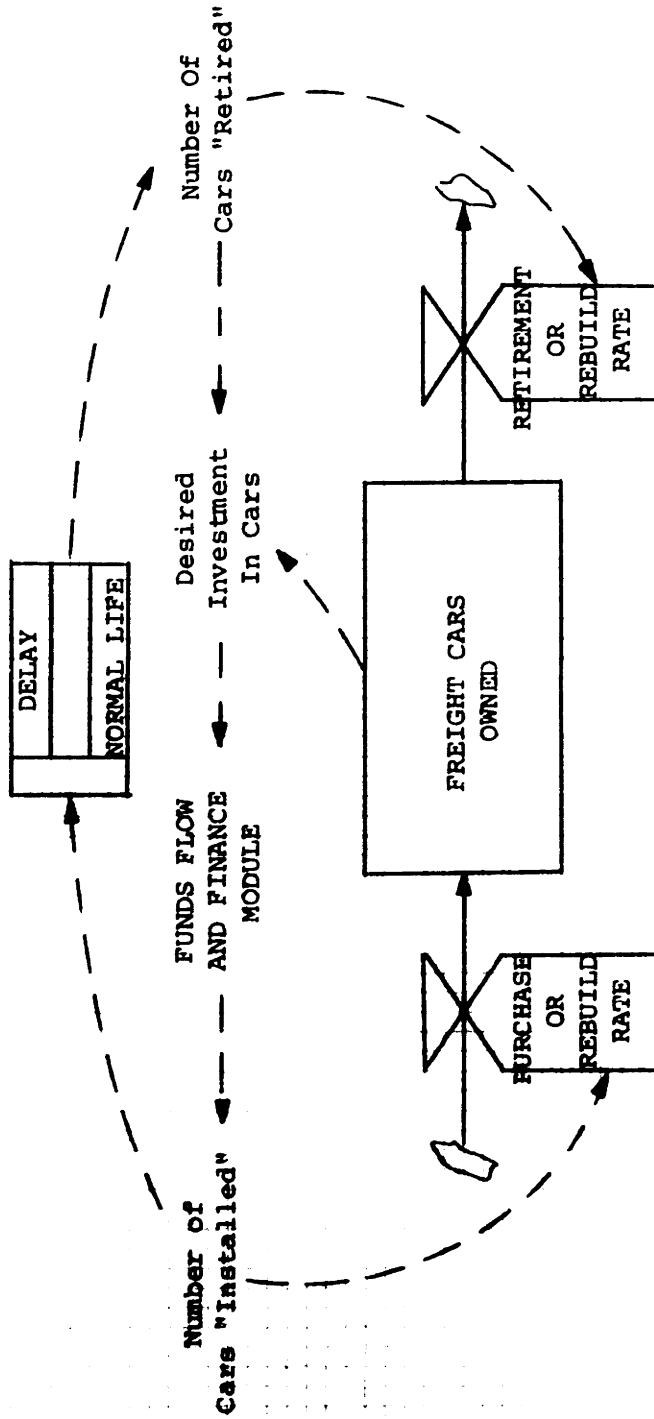
The numbers of owned freight cars and owned freight service locomotives are both represented by levels af-

ected by two rates. Since the treatment of both fleets is identical, only freight cars will be dealt with in detail here as an indication of how both owned fleets are modelled.

The size of the owned freight car fleet is modelled by means of the Freight Cars Owned Level. As depicted in Figure 3-21, flowing into the level is the Purchase Or Rebuild Rate, and flowing out of it is the Retirement Or Rebuild Rate. Before going any further in the explanation of the figure, the role of rebuilds should be clarified. Rebuilds were included primarily for the sake of model validation, and are assumed to play an insignificant role in the future cases analyzed with the model. This is explained as follows.

As discussed in Section 3.2.2.4 (Funds Flow And Finance Module) there were a fair amount of rebuilds performed in the mid-sixties. Thus, it was desirable to include them in the model in an implicit manner for the purpose of model validation, as they comprised a small but noticeable portion of capital expenditures during the validation period. In order to include them, two steps had to be taken. First, because the third order exponential delay controlling the Retirement (Or Rebuild) Rate in Figure 3-21 required initialization, the value used was based upon the average number of retirements and rebuilds

FIGURE 3-21
 MODELLING THE SIZE OF THE OWNED FLEET



over the data period, and not just on the number of retirements. This would cause the model to treat rebuilds as retirements requiring replacement. Second, because the "replacement" of a rebuild is relatively cheap, the effect of low-cost rebuilds had to be included in the average cost of equipment "installed" (i.e., purchased, built, or rebuilt). Thus, the prices of "additional" cars over the data period were derived by dividing total capital expenditures by total installations, including rebuilds.

For the sake of future cases analyzed, it is assumed that rebuilds play a relatively insignificant role, as the prices of additional equipment are based upon those at the end of the data period, when rebuilds were rather negligible. Furthermore, as the discussion in Section 3.3.1 (Fixed Assets And Debt Module) pointed out, the average lives derived for equipment are only insignificantly affected by the presence of rebuilds over the data period. This is because rebuilds, while a noticeable portion of the annual installations for several years in the mid-sixties, only represent a negligible portion of the total equipment on line. Hence, on an overall basis, rebuilds play an insignificant role in the future cases analyzed with the model and may be ignored for the remainder of this discussion. For the sake of

simplicity, therefore, all purchases and rebuilds will be referred to as installations and all retirements and rebuilds will be referred to as retirements. This is how they are depicted in Figure 3-21, the explanation of which may now resume.

The number of installations performed each year is determined in the Funds Flow And Finance Module, where the budgeted investment in cars is divided by the price of the cars to arrive at the number installed. These installations then enter the Freight Cars Owned Level by means of the Purchase Or Rebuild Rate which they completely determine. At the same time, they enter the third order exponential delay which will cause them to be retired on the average 20 years later. The same length of delay is used here as is used for delaying capital expenditures to determine write-off rates, since an asset is written off when it is retired. Also, as was the case with the delaying of capital expenditures to determine write-off rates, the cars installed are retired on the average 20 years later, with some being retired sooner and some later. Furthermore, retirements cannot occur sooner or later than that point in time dictated by the delay's output. That is, the "decisions" to scrap or sell equipment at any point in time (either before or after the average 20 years) are implicit in the output distribution

from the delay, about the 20 year average life. Thus, the model is not allowed to decide upon premature sales if there is an excess of cars, and is not allowed to decide upon deferrals of retirements if there is a shortage of cars. It must retire them, and can only retire them, at that point in time dictated by the delay.

Retirements, as well as the current number of cars on line, play an important role in setting the desired investments in cars, as will now be explained.

3.5.2 DESIRED INVESTMENTS IN ROLLING STOCK.

As mentioned previously, there are two fleets of locomotives and two fleets of freight cars in the model, one fleet of either type of rolling stock being owned, and the other "rented". The sizes of the rented fleets are not determined by the model, but are supplied to it as exogenously determined variables over 1963-1973 and as exogenously determined constants after 1973. Hence, in setting desired investments in rolling stock, the model is solely concerned with the owned fleets. In doing so, however, it must take into account the exogenously supplied changes in the sizes of the rented fleets, as will be explained below.

In the model, freight car productivity¹ is the only measure of rolling stock productivity explicitly dealt with. Hence, the fleet planning process is based upon adjusting the freight car fleet to meet a forecast level of demand, given a forecast of freight car productivity. Locomotive needs and productivity are based upon those of freight cars and the dynamically specified car to locomotive ratio in the system, as will be explained in detail below. Locomotives are treated in this manner because freight cars are assumed to be the primary concern in rolling stock capacity planning, with the associated needs for locomotives being a result of the needs for cars and the operating policies in effect to move the cars. These operating policies, which are not explicitly dealt with by the model, are implicit in the assumed car to locomotive ratio.

Because freight car fleet planning forms the basis for overall rolling stock fleet planning in the model, it will be discussed first, followed by an explanation of how locomotive acquisitions are planned. After the treat-

¹ Productivities, whenever referred to in this study, mean "maximum reasonable" productivities. That is, they imply the capacity of the rolling stock given the current (rented plus owned) fleet sizes. They do not mean actual productivities, which can be less than the maximum reasonable productivities if demand is less than capacity.

ment of both cars and locomotives has been presented, the rationale behind the model's method of planning rolling stock acquisitions will be discussed.

3.5.2.1 Desired Investments In Freight Cars.

In planning investments in rolling stock, whether in the model or in actuality, the first requirement is some target level of volume, and hence of freight cars (and locomotives) required to carry this volume. In this study, the railroads are assumed to base their volume targets on the demand for rail service. That is, the volume policy of the industry is assumed to be one in which all shippers desiring to use rail transport are served. This volume policy is not to be confused with the related, but separate investment/financing policies of the model. That is, the volume policy dictates how much volume the industry would like to carry if it can be afforded. However, financing constraints on investments in rolling stock might prevent them from acquiring sufficient capacity to meet their desired volume level.

Freight cars cannot be acquired immediately if there is currently a discrepancy between demand and fleet capacity due to delays inherent in the car production process. Furthermore, the industry most likely does not use the

discrepancy between current demand and current capacity as the basis for planning investments. If they did, and if the equipment suppliers could alter production rates so as to allow it, the railroads could over-invest during short-term demand peaks, and under-invest during demand lulls.

Taking the above two considerations into account, freight car (and hence locomotive) acquisitions in the model are based upon demand forecasts for some point in the future. An intermediate time span (5 years is used in the model) was felt to be appropriate, as this would allow the industry (and its equipment suppliers, who are not explicitly represented in the model) to adjust its investments (and the necessary production) in a smooth manner to the demand forecast. That is, if projected demand for n years in the future is used as the basis for equipment needs, and if the industry adjusts its rolling stock fleet $1/n$ of the way to the required size each year, then current changes in demand would only entail relatively small changes in the rate of investment by the industry (and hence small changes in the rate of production by the equipment suppliers). This would prevent over- or under-investment by the industry in response to short-term changes in demand (and would take into account the constraints involved in the equipment supply process).

As a result of the validation process, the original estimate of a 5-year time horizon proved to be quite effective in allowing the model to match actual behavior with respect to changes in fleet size over time. (See Section 4.2.)

Coupled with this 5-year demand projection is a 5-year car productivity projection. That is, due to changing car sizes, lengths of haul, and system quality, the maximum productivity of the cars will be different at that point in time for which the demand projection is made. Thus, the model determines the amount of equipment needed 5 years hence based upon the forecast demand for rail service at that point in time as well as on the forecast equipment productivity.

Forecasts of both demand and productivity are performed through exponential smoothing with trend correction [16], one of the few forms of forecasts implementable in a systems dynamics model [6]. While this is undoubtedly not the specific method used in actuality, it represents the fact that current knowledge must be used by management in forming their future expectations, and as noted above, the model was quite capable of matching observed behavior in spite of the simplicity of this approach.

Since both car productivities and demand (as well

as volume, which is less than or equal to demand) are determined in the Volume Determination Module, the Equipment Needs Module accepts the current car productivity and demand level from that module in order to update its forecasts of each. Given the 5-year forecasts of these two factors, the total number of cars (rented and owned) needed 5 years hence is computed. This value is then used in a goal-seeking equation similar to those used for desired additions to net working capital and for desired expenditures on way to determine the desired freight car installations, and hence the desired investment in freight cars, over the next year.¹ The equation is:

$$\begin{aligned} \text{desired car installations} &= \left(\frac{\text{cars needed}}{5 \text{ years hence}} - \frac{\text{current num-}}{\text{ber of cars}} \right) / 5 \\ &+ \text{owned car retirements} \\ &- \text{increase in number of} \\ &\quad \text{rented cars} \end{aligned}$$

¹ As mentioned in Section 3.5.1, the model cannot dispose of more owned cars in any one year than dictated by the delay controlling retirements. Hence if the desired installations are computed to be negative, indicating a large car surplus, the desired installations are set to zero, and the model must wait for the excess cars to be retired in the usual fashion dictated by the delay.

The total cars needed 5 years hence represents the sum of the owned and rented fleets, as does the current number of cars on line. Thus, the model determines the total change in both fleets desired in any one year as 20% of the discrepancy between the forecast total needs and the current total number of cars on line. Increases in the number of rented cars, which are zero for years after 1973 (as the rented fleet remains constant in size) and are exogenously input to the model over 1963-1973, reduce the need for car purchases and are thus subtracted from the total installations required. Retirements, on the other hand, must be replaced if the total fleet size is to be adjusted 20% of the way to the desired level, and thus are added to the total installations required. The treatment of retirements and changes in the size of the rented car fleet as facts known in advance of planning car installations, which they most likely are not in the real world, will be discussed in Section 3.5.2.3.

The total cars needed 5 years hence in the above equation is determined as follows:

$$\text{cars needed} = \left(\frac{\text{demand forecast}}{\text{productivity forecast}} \right) \times \text{forecast safety factor}$$

The forecast safety factor is a means of representing all the various factors not included in the model's simple

equipment planning process, and was the only parameter that required changing in order to obtain a good validation fit to observed fleet sizes over the data period. Its final calibrated value was 1.10, representing the fact that the model's assumed 5-year planning process was on the average 10% too low with respect to equipment needs.¹

¹ It should be noted that if demand and car productivity are growing in a smooth manner, the model's simple forecasting techniques will tend to predict both factors quite accurately. Hence a forecast safety factor of 1.10 can cause a 10% excess investment in rolling stock in the long run. The future cases analyzed in this study do have this smooth growth in demand and productivity, but the forecast safety factor was kept at its calibrated 1.10 value so that future policies would be based upon those "observed" in the past. This in turn led to excess rolling stock investments in the cases where the industry was profitable enough, or was forced, to meet all the demand for its service. However, due to the relatively small amount of over-investment caused by the forecast safety factor itself (always less than 10%), it plays a relatively insignificant role in affecting the results of the cases analyzed, and hence the conclusions of this study.

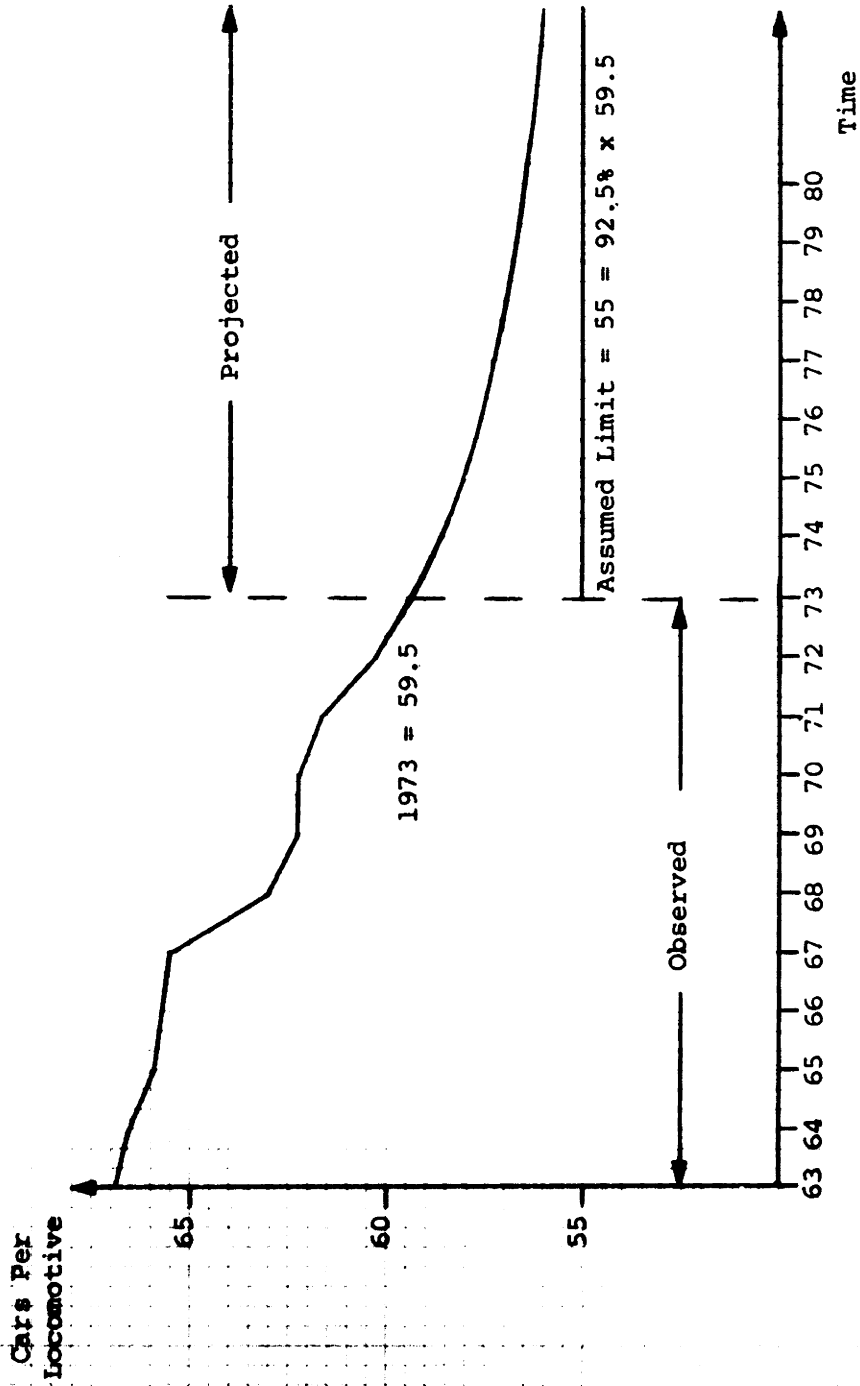
3.5.2.2 Desired Investments In Locomotives.

Locomotive requirements are tied to those of freight cars through the "planned" car to locomotive ratio depicted in Figure 3-22.¹ The "planned" ratio is so called because it represents the effects of the operating policies being followed in determining the ratio of cars and locomotives that would lead to maximum utilization of both types of equipment in a capacity constrained situation. That is, if the actual car to locomotive ratio in the system is at its planned level, there is no excess capacity in either fleet. If it is higher, there are excess cars relative to the number of locomotives and the operating policies in effect. If it is lower, there are excess locomotives.

This function is based upon the actual (as opposed to planned) ratios observed over 1963-1973, which for simplicity were assumed to represent the "planned" ratios dictated by the operating policies in effect over that

¹ The ratios depicted in Figure 3-22 for 1963-1973 were derived by dividing total freight-carrying cars on line plus cabooses [3] by estimated freight service locomotives. The number of locomotives in freight service were estimated by adding locomotive units assigned to road freight service [3] to estimated yard switching locomotives in freight service (estimated by splitting total yard switching locomotives [3] by means of the ratio of freight to passenger service yard switching locomotive unit-miles).

FIGURE 3-22
FREIGHT SERVICE "PLANNED" CAR TO LOCOMOTIVE RATIO
OWNED PLUS RENTED FLEETS



period. These observed ratios may have differed from those "planned" due to the timing of installations and retirements of either type of equipment, but this is ignored here.

As is evident in Figure 3-22, the planned car to locomotive ratio was erratically decreasing over 1963-1973 and is assumed to exponentially decay to a lower limit of 55 in the future cases analyzed in this study. This limit is 92.5% of the observed 1973 value, and was "arbitrarily" chosen based upon the past trends in the data. It was also assumed that the industry would set their desired installations in locomotives so as to maintain the actual car to locomotive ratio at its planned level, given the cars to be installed by the 5-year car planning process. That is, locomotive installations would be made so that the car installations and locomotive installations over the next year would lead to the actual ratio being equal to the planned ratio one year hence. While this method does not entail an intermediate-range outlook for locomotives when viewed in isolation, it does tie their installations to those of cars, which are based on a longer-term perspective. Hence, the overall rolling stock acquisition process is one of a 5-year perspective, with freight cars being treated as the primary concern, and with locomotives being installed in accord with

car installations. While highly simplified, this method of determining locomotive installations represents the fact that excess capacity in either fleet should be avoided.¹

The equations which determine desired locomotive installations are therefore as follows. First, the expected² number of cars one year hence (owned plus rented), given the desired car installations, is:

$$\begin{aligned} \text{expected cars} &= \text{current number of cars} + \text{desired car installations} \\ \text{one year hence} & \qquad \qquad \qquad + \text{increase in number of rented cars} \\ & \qquad \qquad \qquad - \text{owned car retirements} \end{aligned}$$

Again, retirements and changes in the size of the rented car fleet are assumed to be known in advance. Given the expected number of cars one year hence, the required number of locomotives (owned plus rented) is:

¹ However it can lead to excess capacity in both fleets if the demand forecast 5 years hence is sufficiently above the current demand, and if the expected demand in the interim years does not materialize.

² Actual cars will be less than expected if there are financing constraints. However, locomotive installations will also be less than desired in this case.

$$\text{locomotives needed one year hence} = \frac{\text{expected cars one year hence}}{\text{planned car to locomotive ratio one year hence}}^1$$

And the desired locomotive installations are:

$$\begin{aligned} \text{desired locomotive installations}^2 &= \text{locomotives needed one year hence} \\ &\quad - \text{current number of locomotives} \\ &\quad + \text{owned locomotive retirements} \\ &\quad - \text{increase in number of owned locomotives} \end{aligned}$$

As was the case with the equation for desired car installations, this equation determines the necessary installations of owned equipment, as the model does not determine the installations of rented equipment. Furthermore, the first two terms in the above equation apply to total locomotives, so their difference represents the total increase in fleet size required. Hence, the exogenously supplied increase in rented locomotives is subtracted to help determine the number of owned locomotives which must be installed. Also, as was the case with cars, retirements are added to the total increase in fleet size required because these retirements must be replaced if the installations performed are to lead to the proper number

¹ It is assumed that this is known one year in advance.

² This value is set to zero if it is negative, and the model must wait for excess locomotives to be retired as dictated by the delay controlling these retirements.

of locomotives one year hence,

The above equations represent the model's locomotive fleet planning process, and were used for both validating the model and for the analysis of future cases. However, towards the end of this research, it was discovered that these equations could not be used to analyze some of the cases that were to be studied. Specifically, some of the future cases analyzed would involve a step increase in car productivity resulting from a hypothetical reduction in yard times, as will be explained in Chapter 5. These yard time reductions are assumed to cause no change in total locomotive requirements for a given level of volume. In such a situation, the structure of the above equations would cause irrational behavior, and thus had to be altered for these specific cases. The alteration, which will not be discussed in detail here, is available in the model listing in Appendix A. As is apparent there, it recasts the above equations in terms of a 5-year perspective, similar to that used in the car planning process. Furthermore, the altered form causes the same number of locomotives to be installed each year as do the above equations if the planned car to locomotive ratio is only slowly changing as it is in the future cases anal-

alyzed.¹ Hence, it possibly should have been used throughout the study, as it is more consistent with the "theory" behind the car acquisition equations. However, due to its "discovery" late in the research, this was not done.

3.5.2.3 Discussion Of Model's Fleet Planning Process.

Worthy of discussion here is the treatment of retirements and changes in the amounts of rented equipment in the model's fleet planning process. It is assumed that the industry knows how many cars (or locomotives) it will retire and how many additional cars (or locomotives) it will rent over the next year at any point in time, and that this knowledge is used in determining how many cars (or locomotives) to purchase (or rebuild). It is likely that the exact opposite is true. That is, given the number of purchases the industry has committed itself to, controllable retirements and additional rentals may be adjusted so that the total fleet size can serve the current demand, which may be above the level which was expected when the orders for new equipment were placed.

¹ This can be proven mathematically, although the proof will not be given here. The altered form causes slightly different behavior if the planned ratio is rapidly changing, as it was over the validation period. Validation results in Chapter 4 are for the original, and not the altered, form.

This possible reversal of the true sequence of events in the model must be viewed in light of the purpose for which the model has been constructed. First of all, the model is to be used for the study of long-run behavior. While retirements may be deferred as a short-term measure, in the long run they all have to be performed. Hence the treatment of retirements as a predetermined fact (by the delay which controls them) is fairly realistic in the long run. Secondly, the model has not been developed to deal with the lease/buy decision. Thus, in validating the model, the interest was in its ability to determine total long-run equipment needs, and hence the total number to install each year, as the model would be purchasing all of these cars in the future cases analyzed. Changes in the size of the rented car and locomotive fleets over 1963-1973 were included only to prevent the model from purchasing this equipment, as this would entail additional equipment debt, repayments, and fixed charges which did not exist in actuality, and which could have serious impacts on the rest of the model during the validation runs. As long as the model could decide upon the proper total amounts of rolling stock to install, therefore, its fleet planning process could be validated.

3.5.3 EQUIPMENT NEEDS MODULE SUMMARY.

The Equipment Needs Module is responsible for keeping track of current numbers of cars and locomotives on line, as well for setting desired rates of investment in each and for the determination of how many must be retired at any point in time. In keeping track of the owned fleets of cars and locomotives, it is interactive with the Funds Flow And Finance Module, which supplies the actual numbers installed as a result of its funds allocation process. This process in turn acts upon the desired investments in rolling stock generated in the Equipment Needs Module by the volume and fleet planning (i.e., investment) policies embedded in its equations. These policies may be altered to test such options as a no-growth volume policy, slow or fast adjustment to forecast rolling stock requirements, short- or long-term forecasting, etc.

The Equipment Needs Module also interacts with the Volume Determination Module, which supplies the current demand for rail service and the current maximum reasonable¹ car productivity for use in the forecasting processes of this module. The Volume Determination Module also ac-

¹ Again, the model deals with maximum reasonable productivity which gives the capacity of the rolling stock when multiplied by fleet size.

cepts information from this module with respect to the current fleet size, so that it can compute the capacity of the locomotive and freight car fleets. These capacities determine the capacity of the system, and hence the maximum volume that can be carried.

3.6 VOLUME DETERMINATION MODULE.

This module is very small and performs three simple inter-related functions:

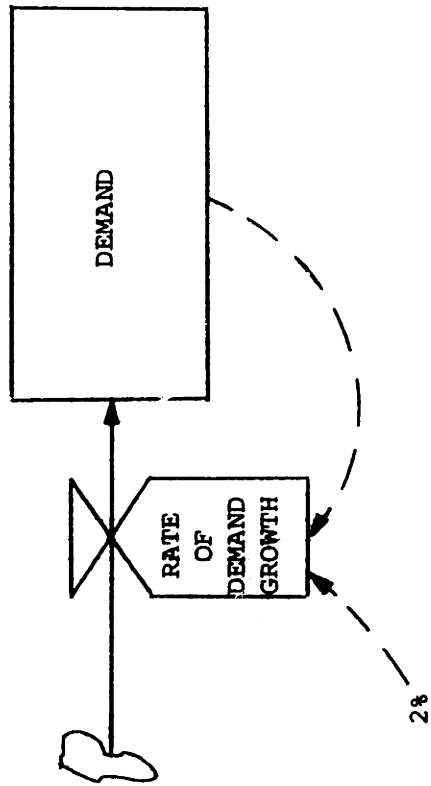
- i) determination of demand;
- ii) determination of capacity; and,
- iii) determination of volume, which is the minimum of demand and capacity.

In spite of its simplicity, this module is very important, as volume is an input to almost all the other parts of the model. This is of course necessarily so, as the amount of traffic handled by the industry is the prime driving force in determining revenues, expenses, and investments, the three basic factors that railroading, or any business, is all about.

3.6.1 DETERMINATION OF DEMAND.

Since data on volume, and not on demand, was available for 1963-1974, it was assumed that demand over this period was equal to the volumes carried (measured in terms of revenue ton-miles per year). This is a major assumption, as it is most likely wrong. However, it only af-

FIGURE 3-23
2% ANNUAL GROWTH IN DEMAND



fects the assumed car productivity function described later in this chapter and the forecasting equations of the fleet planning process described in Section 3.5.2.1. Furthermore, it most likely affects both these factors rather negligibly on an absolute numerical basis, and is completely irrelevant in judging the model's validity as a comparative tool. Hence, this assumption is unimportant, in spite of its probable inherent error. For years after 1974, demand in this study was assumed to grow inelastically at 2% per year, and this was modelled by means of the Demand (For Rail Service) Level and its associated Rate Of Demand Growth. The Rate Of Demand Growth is determined by simply multiplying the current demand, as measured in the Demand Level, by 2%. The Demand Level and its associated rate are depicted in Figure 3-23.

3.6.2 DETERMINATION OF CAPACITY AND VOLUME.

As was mentioned in Section 3.2.2.3, capacity is assumed to be "solely" constrained by the rolling stock. Investments made in way and structures prior to a given point in time are assumed to have increased the capacity of the fixed facilities sufficiently to handle the current volume without significantly altering the "size" of

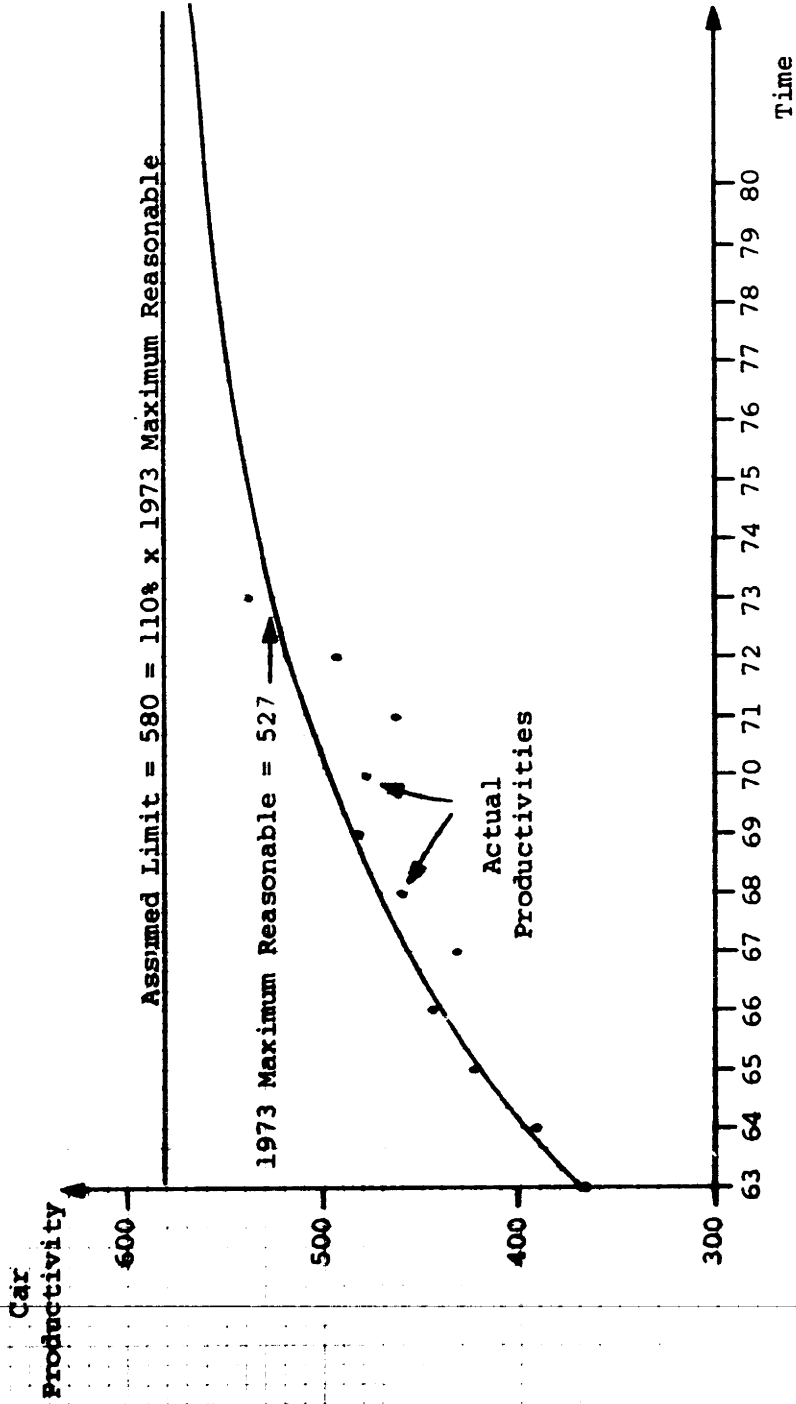
the network from that over 1963-1973. The fixed facilities are therefore assumed to only restrict capacity by the effect of their quality on rolling stock productivity. Hence, in determining capacity, this module has to determine the maximum reasonable productivities of the cars and of the locomotives on line given the quality of the fixed facilities. These productivities, when multiplied by the numbers of each type of rolling stock, determine the capacities of the locomotive and the freight car fleets. The minimum of these two capacities is the overall capacity of the rolling stock, and the minimum of rolling stock capacity and demand determines volume.

The only item that requires explanation here is the determination of the maximum reasonable productivities of the freight car and locomotive fleets, as these productivities determine the capacities of the two fleets. The productivity of the freight cars, which also forms the basis for the locomotives' productivity, will be explained first.

Maximum reasonable car productivity, measured in revenue ton-miles per car-year, is determined through the function depicted in Figure 3-24. This function, when multiplied by the quality of facilities productivity multiplier, determines the maximum reasonable car productivity given the current quality of the fixed facili-

FIGURE 3-24
ASSUMED MAXIMUM REASONABLE CAR PRODUCTIVITY

Productivity Measured In Thousands Of Revenue Ton-Miles Per Car-Year



ties.¹ As is evident in the figure, the maximum reasonable car productivity function was estimated using data on past actual productivities. These productivities dipped in years when demand (and hence volume) dropped from its level in the previous year (i.e., 1967, 1970, and 1971), due to the short-run rigidity of the size of the car fleet. However, in spite of these demand-dependent dips, actual productivity was generally increasing due to the effects of increasing average car sizes and increasing average lengths of haul [2] on the maximum reasonable productivity of the cars. Hence, a maximum productivity function was "fitted" to the observed values, so that it would smoothly increase with time representing the effects of the demand-independent changes occurring in car sizes and lengths of haul.

The function depicted in Figure 3-24 lies above most of the observed actual values under the assumption that demand was less than capacity in most years. However, it also lies below several of the observed values, notably that of 1973. This was purposely done because there was a significant car shortage in 1973 resulting in abnormal operating policies being used to "squeeze" extra produc-

¹ It should be recalled from Section 3.4.2 that the quality of facilities multipliers are assumed to be 1.0 prior to 1974. Hence the function in Figure 3-24 alone determines car productivities during the validation period.

tivity out of the rolling stock. Inasmuch as this study is concerned with "how" the industry would normally function in the long run, it was decided to select a function which lay below 1973's abnormal productivity. Also, it was assumed that car sizes and average lengths of haul would reach some limit in the future, as they cannot increase indefinitely. The limit chosen was 110% of the estimated 1973 maximum reasonable productivity. This value is primarily based upon the past trends in the data, and is consistent in magnitude (but not identical) with the 115% limit assumed for TTGM (i.e., transportation) labor.¹ It was desirable to have similar limits for labor and rolling stock, as the long-run increases in both productivities are due to the same factors.

It should be noted that the model does allow volume to be a bit more than the normal capacity dictated by the function in Figure 3-24. Specifically, it was assumed that volume could be 4% above normal capacity, since years like 1973 (where the actual productivity was 2% above the functionally computed maximum), could happen again. However, all the rolling stock investment planning is centered around the normal productivity dictated by the func-

¹ The function which determines the assumed future course of TTGM labor productivity was depicted in Figure 3-2 (Section 3.1.2.1).

tion in Figure 3-24 (adjusted for quality effects), as abnormal operations are not something upon which the industry would likely base its investment decisions.

Locomotive productivity is determined by the product of the car productivity function in Figure 3-24 (adjusted for the quality of the facilities) and the planned car to locomotive ratio depicted earlier in Figure 3-22. The planned ratio, and not the actual ratio, is used because the planned ratio represents the operating policies in effect. The actual ratio might be different than the planned ratio for several reasons.¹ If the actual ratio is above the planned ratio, there is an excess of cars, and these cars do not add to the productivity

¹ In spite of the fact that the model's locomotive fleet planning equations discussed in the last section "ensure" that the actual ratio equals the planned ratio, these two ratios can diverge for several reasons. First of all, in the cases which analyze increased car productivity as the result of hypothetical yard time reductions in Chapter 5, the planned ratio of cars to locomotives suddenly becomes less than the actual ratio. This is because locomotive productivities are assumed not to be enhanced by yard time reductions, whereas car productivities are. The result is a sudden divergence between the actual and planned ratios, as the model finds itself with more cars than are necessary, given the number of locomotives on line and the operating policies in effect. Secondly, as mentioned in a footnote in Section 3.2.3.4, if investment funds for rolling stock became constrained, the actual ratio can differ somewhat from the planned ratio, as the model's equations ensure they are equal only when the desired investments are made.

of the locomotives given the operating policies which are implicit in the planned ratio. If the actual ratio is less than planned, cars, and not locomotives, are constraining the operating policies from achieving maximum throughput. The model takes both of these considerations into account in determining the capacity of the rolling stock, and hence of the system, as follows:

$$\text{car fleet capacity} = \text{car fleet size} \times (\text{quality adjusted}) \text{ maximum car productivity}$$

$$\text{locomotive fleet capacity} = \text{locomotive fleet size} \times (\text{quality adjusted}) \text{ maximum locomotive productivity}$$

$$= \text{locomotive fleet size} \times (\text{quality adjusted}) \text{ maximum car productivity}$$

$$\times \text{planned car to locomotive ratio}$$

$$\text{rolling stock capacity} = \text{minimum} (\text{car fleet capacity, locomotive fleet capacity})$$

That this is so can easily be seen by replacing "car fleet size" by "locomotive fleet size x actual car to locomotive ratio" in the first equation. When this re-

placement is made, it is evident that when the actual ratio is above the planned ratio, there are too many cars, and vice versa.

3.7 SUMMARY OF CHAPTER 3.

In this necessarily lengthy chapter, the structure of the model and the rationale behind this structure was discussed. The model can be conceptualized as consisting of six modules, all of which are either directly or indirectly interconnected, as was depicted in Figure 3-1. The Income Module is responsible for determining revenues, expenses, and income based upon the current state of the system described by the levels in the other modules. The Funds Flow And Finance Module is in charge of determining the sources and uses of funds, given the current state of the system and the investment/financing/liquidity policies embedded in its equations which guide its actions in light of the state of the system. The Fixed Assets And Debt Module is primarily in charge of balance sheet accounting, or the recording of the financial decisions made in the Funds Flow And Finance Module. It also keeps track of fixed charges and constraints on debt issuance. The Quality Of Facilities Module monitors the quality of the fixed facilities, and supplies the effects of quality on costs and productivities to other modules. It also determines the desired and minimum amounts of maintenance and investment in way that are used in the budgeting processes of other modules to determine the actual amounts spent. These actual amounts then "return" to this module

to supply quality to the system. The Equipment Needs Module keeps track of the amount of freight cars and locomotives on line, and is responsible for setting the desired rates of investment in each for use in the funds allocation process of the Funds Flow And Finance Module. Lastly, the Volume Determination Module, while the smallest and simplest of all the modules, is charged with the responsibility of determining volume, which is the prime driving force of the model.

The complexity and interactive nature of the model are indicative of the nature of the system being dealt with. Construction of the model forced the explicit identification of the existence and nature of the system components and interactions, and was a useful exercise in this respect alone. Furthermore, use of the model facilitates the study of the interconnected functioning of the entire system of interest. As was evident throughout this chapter, all system components are either directly or indirectly affected by all others. Constructing the model entailed prescribing simple, yet reasonable, rules about the relationship between directly interactive system components. However, many indirect relationships exist which are not apparent at first glance, due to the complexity of the system of interest. Hence, running the model is useful because it provides valuable insight into

the overall functioning of the system as caused by the interaction of the many simple rules which link the individual components.

As was apparent throughout this chapter, many simplifications were made in constructing the model. However, a model by its very nature is a simplification of reality. What is important in judging the model's structure is whether or not it captures the important aspects of the processes of interest. The descriptions of the model's components therefore also discussed why the model was structured as it was. Empirical evidence and any supporting "theory" used in constructing the model were presented in order to help clarify this point.

In the next chapter, the model's ability to match observed behavior over 1963-1973 is presented. Since the model's functions, parameters, and policies were derived by the analysis of data for this period, it is able to match this behavior quite well. However, both the accuracy of the calibration and the overall structure of the model had to be checked out by the validation process. This is further discussed in the next chapter.

3.8 NOTES ON CHAPTER 3.

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Chapter 4

MODEL VALIDITY

The validity of a model depends upon its ability to perform the tasks for which it was constructed. The interest in this study is to use the model as a comparative tool to analyze the relative effectiveness of various alternatives aimed at improving the long-run financial performance of the railroad industry. Hence the validity of the model is a function of its ability to predict the effects of these alternatives.

Model validity is typically tested by running the model through the past to see if it is capable of capturing the performance characteristics of the real system, hence promoting confidence in the model's structure and parameterization. The behavior of this model is influenced by its individual components and their interactions. Thus, the model was run through 1963-1973 in order to check on both these factors. Specifically, validation runs were made for three purposes, two of which are related to the validity of the individual model components.

4.1 ROLE OF VALIDATION IN THIS STUDY.

The three roles fulfilled by validation testing in

this study were:

- 1) To check the accuracy of the individual model components which were specified and calibrated on data from the 1963-1973 calibration/validation period.¹ In this case "validation" served as a test of the accuracy of the model's calibration.
- 2) To aid in the determination of those model policies which could not be "calibrated". Specifically, the liquidity policy and the investment policies of the Equipment Needs Module which dictate the desired investments in rolling stock could only be hypothesized prior to validation. Thus, validation served as a check on the structure and numerical validity of the equations representing these policies in the model.
- 3) To check on the overall structure of the model. While each individual model component was devised so as to approximate its real world counterpart, it could not be discerned prior to validation testing whether or not all the simplified model components, when interacting, would lead to behavior similar to that of the system of interest. Also it was pos-

¹Data sources used for calibration and validation were [1], [2], [3], and [4].

sible that some system component or interaction had been overlooked in constructing the model. Hence validation runs were used to check that all the important components were included, that all the interactions between these components had been specified, and that the components and interactions of the model as a whole would lead to system behavior similar to that observed in the past.

These three functions of validation in this study are inter-related, as the outputs of the validation runs (Section 4.2) allowed the checking of all the factors mentioned above. It should be noted that the first two roles of "validation" might typically be termed as calibration, as they involved the checking or specifying of parameters. Hence, it was the primary function of the validation process per se to check on the overall structure of the model, which is presented as the third role above.

Before presenting the comparisons of model to actual values over the validation period, two important points must be made.

First of all, the model is an abstraction of a complex system, with simple equations being used to represent the various components, rules, and human decision processes which drive this system. The model should therefore not be expected to precisely determine the state of the system or

the specific decisions made at any one point in time. However, it should be able to do so approximately, and over the long run. That is, the model should be able to capture the general trends in the behavior of the actual system. It is for this very reason that the model should be used as a comparative tool, and not as an absolute predictor.

Second, not all of the model's simple policy statements were formulated in an attempt to cause behavior completely similar to that observed in the past, although they could have been. For example, the model will reduce capital expenditures on way and structures from the levels observed in the past if net working capital is becoming too low, as was explained previously in Section 3.2.3.3. While this policy detracts somewhat from the model's ability to match the past,¹ it is a policy which will be used in the future cases analyzed because of its conservative nature. Also, it causes behavior only slightly different from that observed in the past, so it was used for both validation and future case analyses.

The above two points are important because they point out that whether or not the model's policies (or other equations) are designed to cause behavior similar to that ob-

¹This will be evident in the discussion of Figure 4-6 later in the chapter.

served in the past, they might not always do so accurately. This is because the model is but an abstraction of reality, with simplified rules governing its behavior. Given that these simple rules are easily understood, it will be possible to understand why various alternative tested in the model cause its performance to change. In any case, the rules of the model will either be invariant across alternatives or will change as part of an alternative to be tested. As the interest in this study is in the relative effectiveness of alternatives aimed at improving the financial performance of the industry, the results these alternatives have must be compared in light of the assumed rules in effect. That is, in the future cases analyzed, it is not that important if the model's rules lead to behavior slightly different than the "true" rules of the industry in a given situation. Rather, it is important that they do so consistently and understandably, as the model is to be used as a comparative tool, and not as an absolute predictor.

With the above points having been made about the model's policy (and other) equations, validation results can be presented. As is evident in the above discussion, the model is not expected to be able to replicate the past perfectly. Thus, in validating the model, it was sought to capture the general trends and magnitudes of system

variables, or to be able to explain why, if this did not occur. Due to the size of the model, validation results for each model component will not be discussed. Rather, the most important components, which represent the end results of the many processes occurring in the model, are presented.¹

4.2 VALIDATION RESULTS.

Figure 4-1 shows how model NROI and ordinary income compared to actual values over 1963-1973. The seemingly "poor" fits are incorrecible and do not invalidate the model, as these comparisons of actual to model values are primarily measures of how well the functions used to model operating expenses² fit the data points from which they were derived.

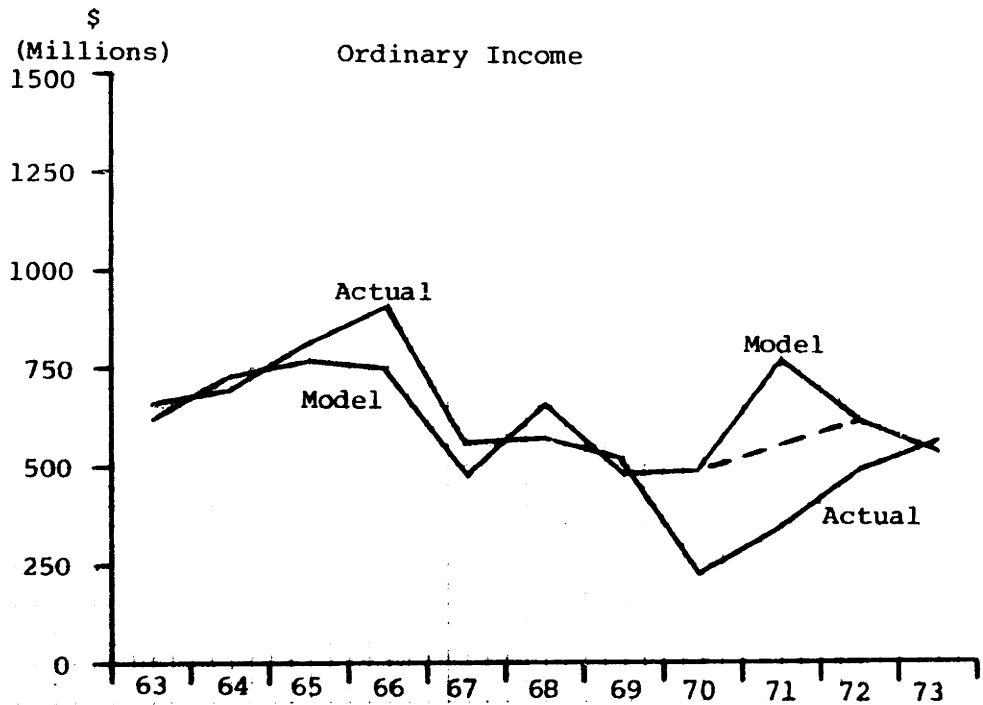
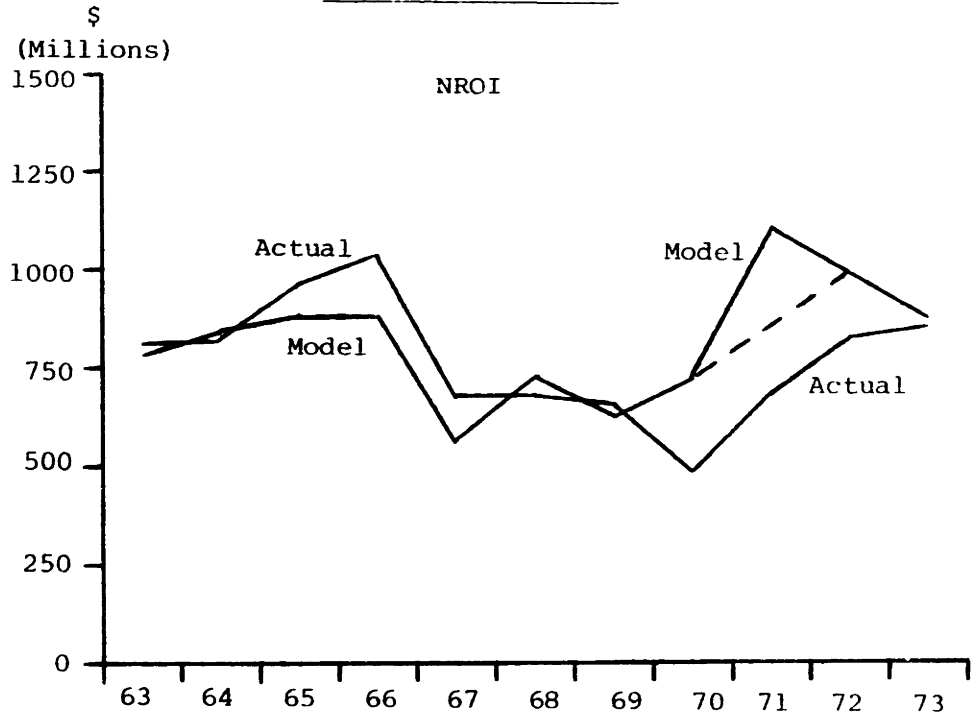
That is, because operating expenses enter into the model's computations of NROI and ordinary income, the variance in the actual data points about the model's cost functions translates into deviations between model and

¹All financial data presented is in terms of current (non-deflated) dollars.

²These functions, which were presented in Chapter 3, are derived in Appendix B.

FIGURE 4-1

VALIDATION RESULTS



actual NROI and ordinary income. It should be recalled from Sections 3.1 and 3.4 that the model determines most operating expenses as simple linear functions of volume in order to achieve a fair approximation to the long-run behavior of these costs. While they may be primarily volume-related in the long run, these costs can vary significantly in the short run, as many of these reported expenses are dependent upon management discretion in any one year, and can be manipulated or deferred in order to alter reported earnings. Furthermore, the model's functions are based upon industry data, while the costs being generated are the results of the operations and decisions of the various individual railroads. This further aggravates the variance in the total reported expenses in any one year, as significant changes may be occurring on the individual railroads, thus contributing to the overall deviations of industry costs, and hence industry earnings.

In Figure 4-1, a major deviation occurs between model and actual earnings in 1971, as all the various actual costs in that year were significantly above each of the functions used to estimate them. The dashed lines in Figure 4-1 join the model-computed values for 1970 and 1972 in an attempt to show how the model's values might compare to actual, had the actual 1971 costs not been so erratic.

It is important to realize that the comparisons of

actual to model values in Figure 4-1 are primarily indications of the model's ability to accurately predict operating expenses in any one year. The interest in this study is to have a fair approximation to these costs in the long run. As long as the model is approximately correct in predicting absolute values, it will be able to capture the significant trends caused by system changes, and thus it will be useful and hence valid as a comparative tool.

The plots in Figure 4-1 support the above argument. NROI, which is primarily determined by operating expenses and revenues, in actuality had a minor overall downward trend over 1963-1973, but the model failed to capture it due to the variance of actual costs about the functions used to approximate them. (Model revenues had nothing to do with this. The model was able to match actual volumes by its investing sufficiently in rolling stock to provide adequate capacity for these volumes. Hence, model revenues matched actual revenues, since actual revenue per ton-mile for each year over 1963-1973 was used in the model to compute freight revenues from volume, and all other revenues were exogenously supplied at their actual values.) The model is capable of providing good approximations to these costs, however, which is evident by the fact that model NROI is generally within \$200 million of actual NROI (i.e., total model expenses are generally within \$200 million of

total actual expenses), while the \$200 million model error is due to predicting expenses which are on the order of \$10 billion. The model is also capable of capturing major trends, in spite of its inability to accurately predict operating costs, as it succeeded in capturing the stronger downward trend in ordinary income that resulted (both in the model and in reality) from a significant increase in the level of fixed charges over the ten-year period. This, in turn, was due to the heavy reliance on debt financing of equipment purchases necessitated by the inadequate levels of cash flow and the associated inability to issue stock, as was discussed in Section 1.1.

As an indication that the model's cost functions provide a fair approximation to the long-run behavior of industry costs, Figures 4-1(a) and 4-1(b) present cumulative NROI and cumulative ordinary income over 1963-1973.¹ As is evident in these figures, the model captures the total earnings generated over the period quite well, as the deviations between model and actual earnings due to deviations in annual costs tend to even out in the long run. Furthermore, it is cumulative earnings which determine long-run financial viability, as short-term dips in

¹Model values include those computed by model for 1971, and not the dashed line surrogates of Figure 4-1.

FIGURE 4-1(a)
VALIDATION RESULTS

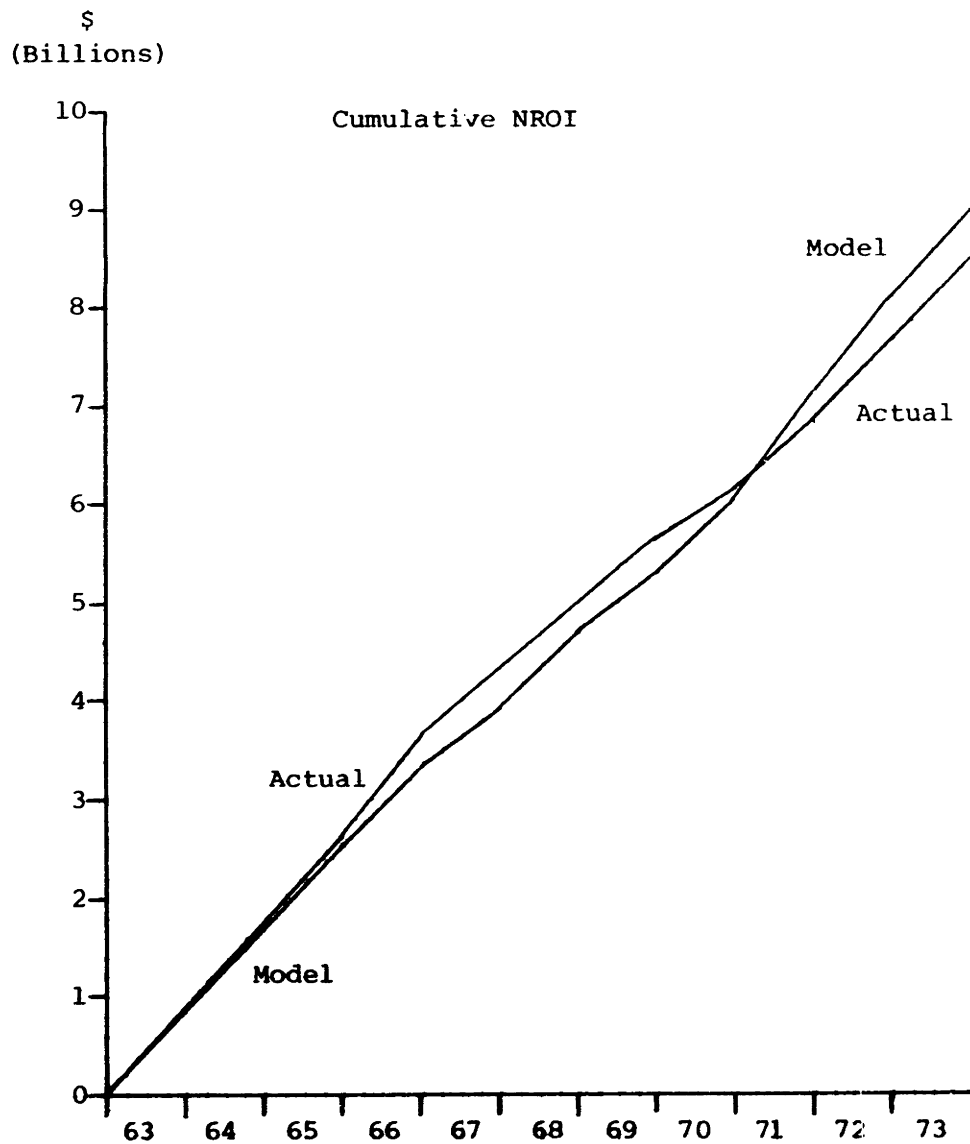
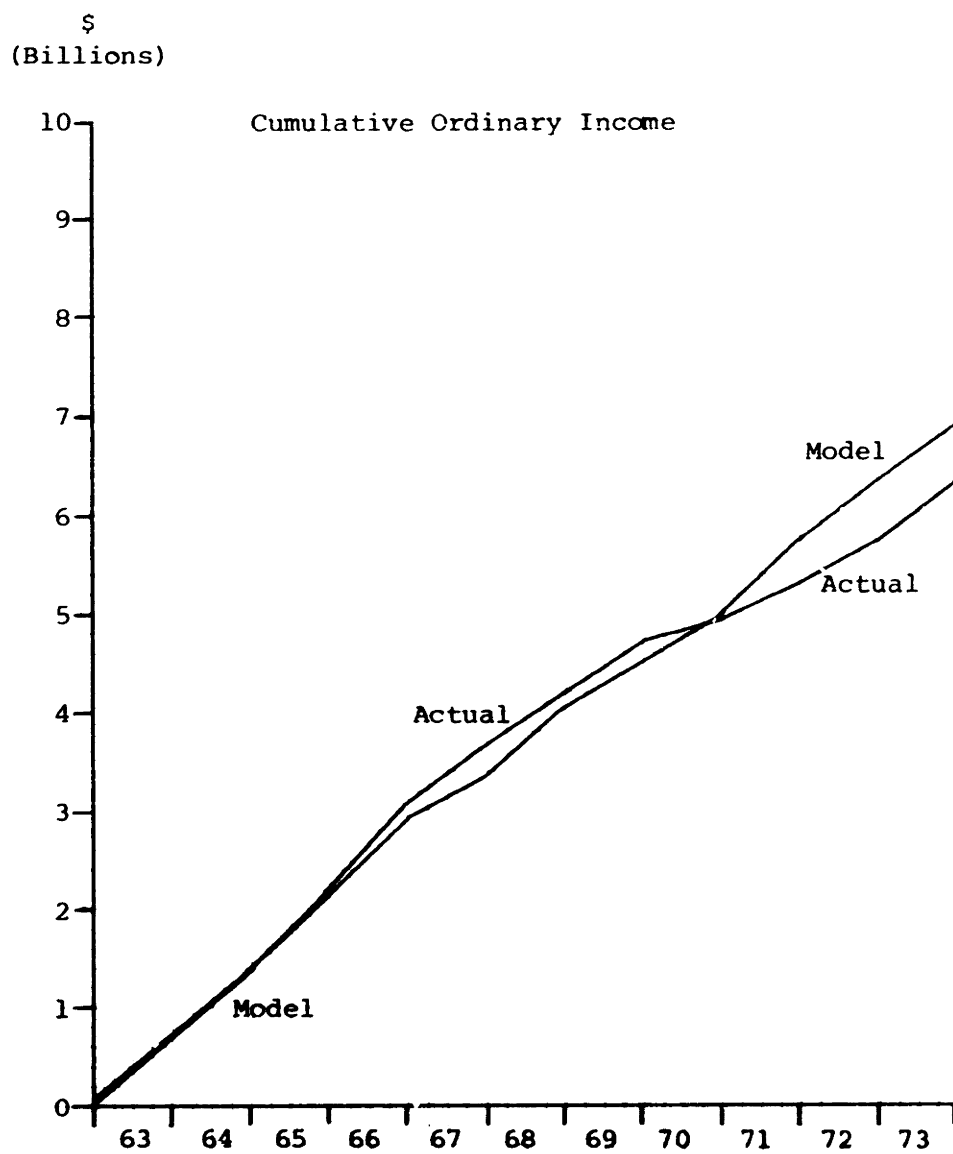


FIGURE 4-1(b)VALIDATION RESULTS

earnings can be accommodated by postponing some expenditures. Hence, the model can be useful as a comparative tool for studying the long-run financial performance of the industry, even though it cannot accurately predict earnings in any one year.

Figure 4-2 shows debt (long-term debt) and the associated fixed charges. The plots of model and actual debt are curtailed after 1970, as this was the last year for which information was readily available on the amount of outstanding debt. Both debt and fixed charges are determined within the model as the cumulative result of previous investment and financing decisions, interest rates prevailing at the time of debt issuance, and debt repayments. The model captured the overall effects of the dynamic interactions of these many factors fairly well, as the trends and magnitudes of both variables in the model are close to those that actually occurred.

Net working capital and net investment are depicted in Figure 4-3. Net working capital is affected by cash flow, debt issuance, cash supplied by asset disposals, debt repayments, dividends, and capital expenditures. The general trend has been one of declining net working capital due to the constant excess of uses of funds over sources, as was discussed in Chapter 3. Investment/financing/dividend/liquidity policies were built into the model

FIGURE 4-2

VALIDATION RESULTS

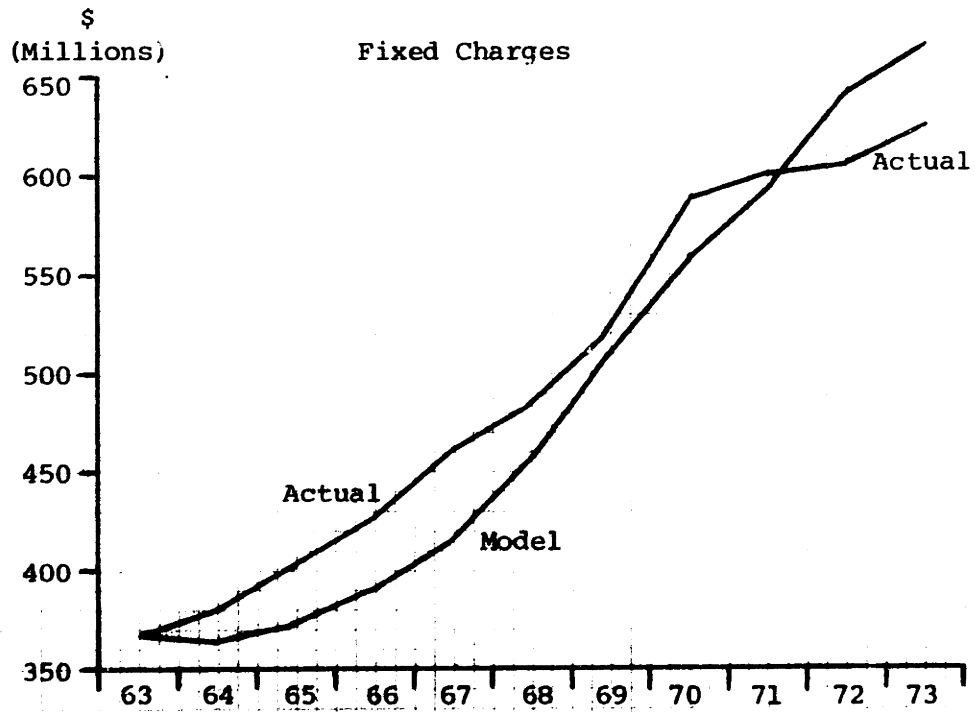
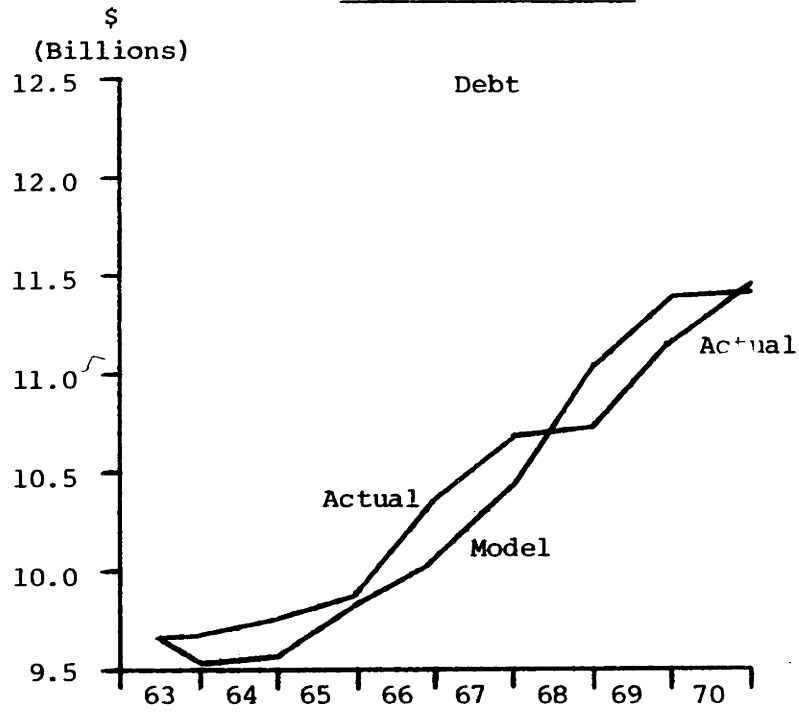
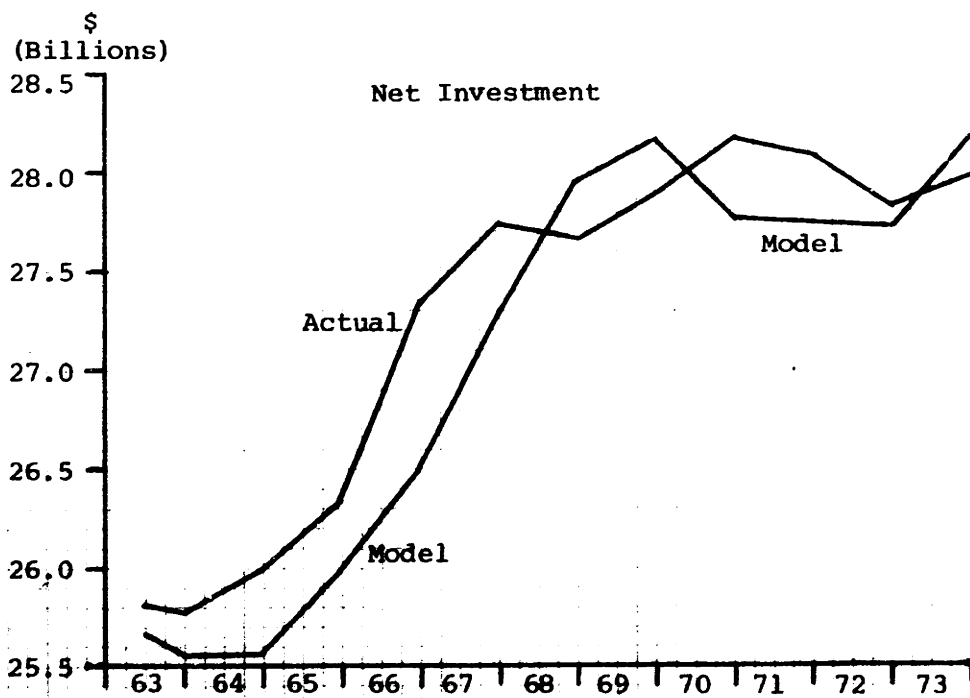
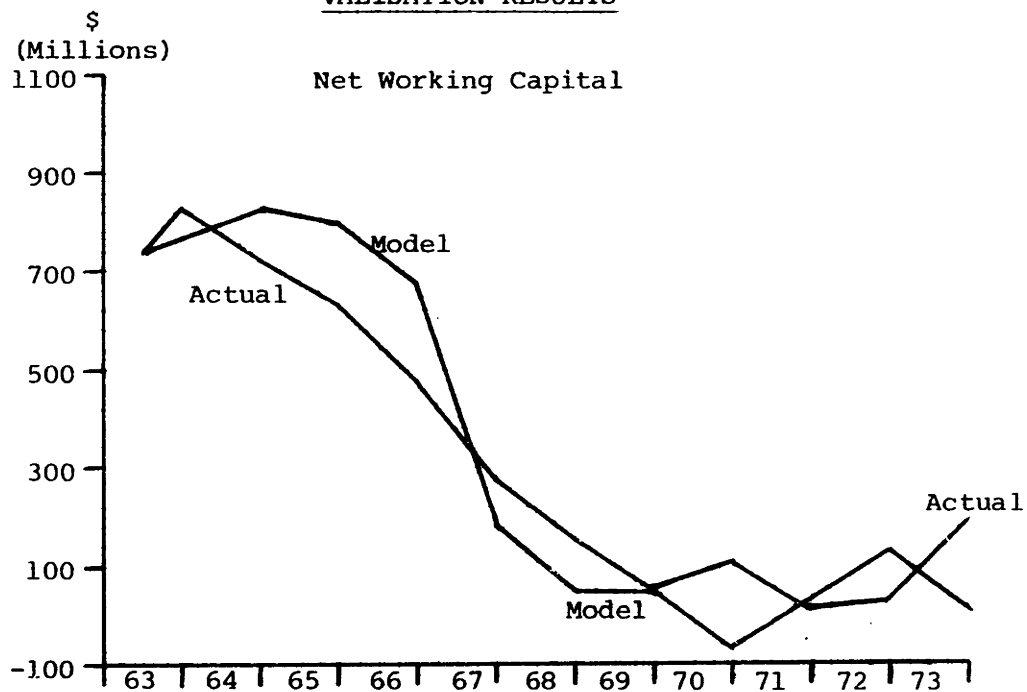


FIGURE 4-3

VALIDATION RESULTS

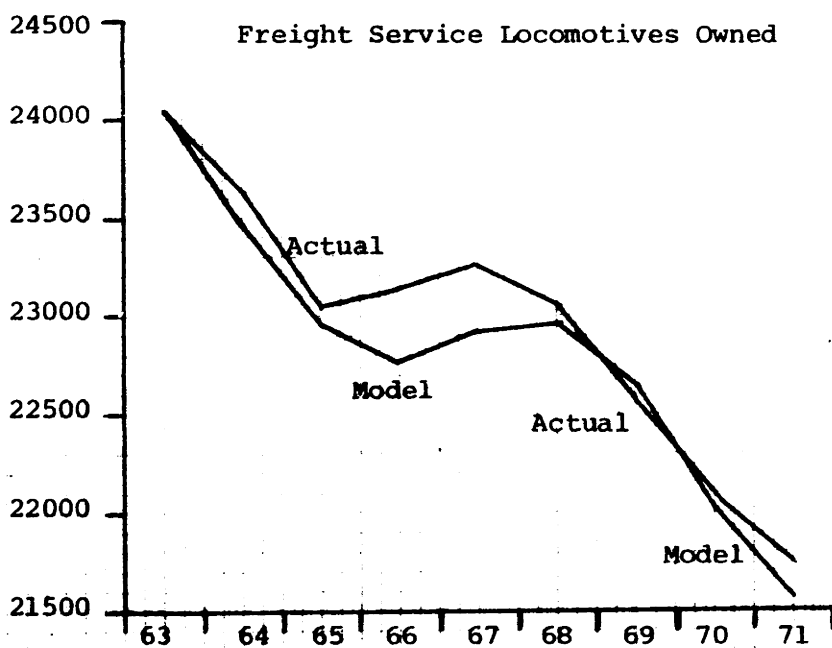
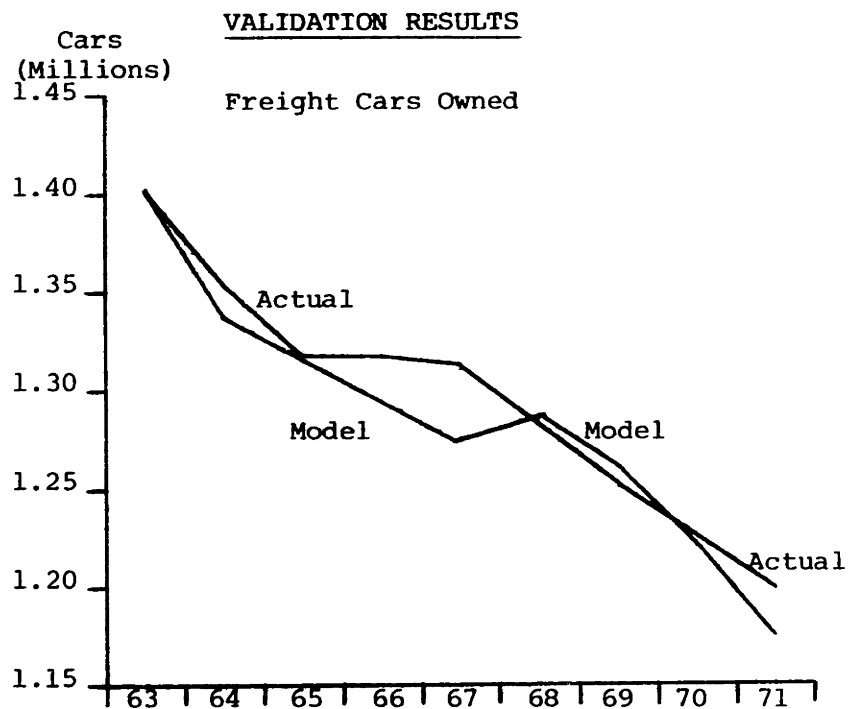
based upon those observed (which helped cause the decline in net working capital), resulting in the behavior of model net working capital being similar to that which actually occurred.

Net investment is based upon the net book values of railroad assets, and is affected by capital expenditures, asset write-offs, depreciation expense, and asset salvage values. Again, the model performed well in capturing the overall effect of these many factors. The rapid rise in net investment between 1963 and 1969, both in the model and in actuality, was primarily due to a similar trend in the net book value of railroad-owned cars.¹ This in turn was principally an effect of inflation of equipment costs, as the number of railroad-owned cars was decreasing during this interval.

In Figure 4-4, the model's performance in matching the trends in the numbers of freight cars and freight service locomotives owned by the industry is presented. In spite of the increasing volume of traffic handled (measured in revenue ton-miles), there has been a downward trend in both freight cars and locomotives owned. This was due to a combination of factors, such as: increasing

¹A discussion of this trend, and that in the number of railroad-owned cars, follows in the analyses of Figures 4-4 and 4-5.

FIGURE 4-4

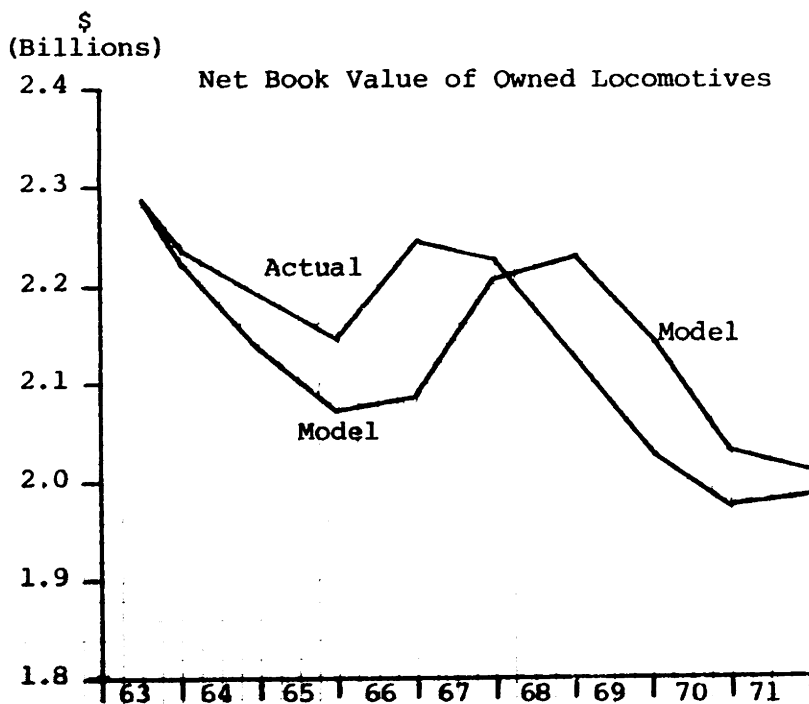
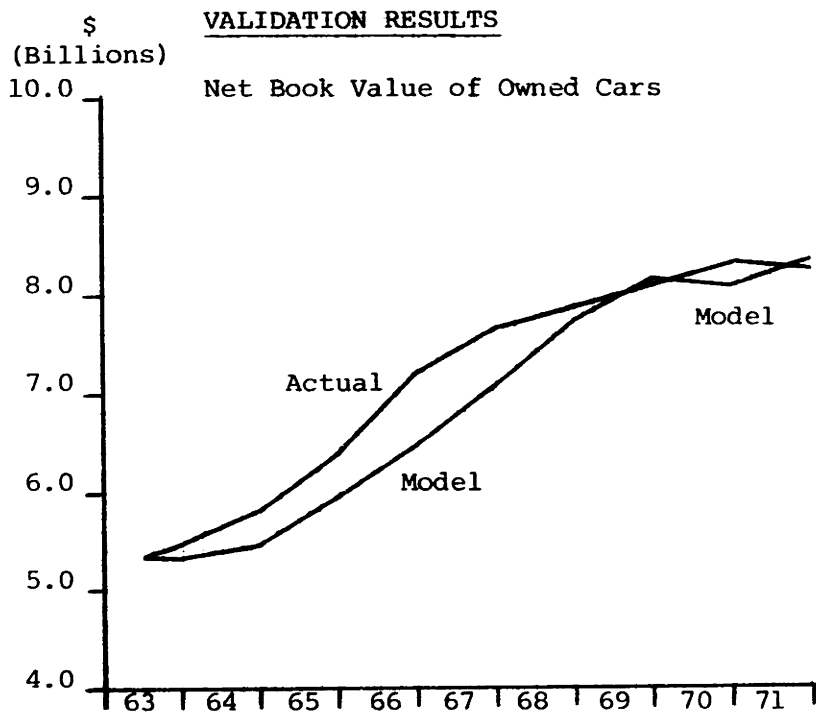


car capacities and longer average lengths of haul (both of which aid in increasing equipment productivity), and a growing reliance on the use of rented and leased equipment (particularly in the case of unprofitable railroads, who can neither service the debt associated with equipment purchases nor use depreciation and the investment tax credit to their advantage as means of reducing their federal income taxes).

Figure 4-4 presents the model and actual behavior for owned freight equipment through 1971 only, as this was the last year for which adequate data was available to allow the accurate determination of how much of the equipment in service was actually owned. These variables are determined primarily by the fleet planning process performed within the model, as described in Section 3.5.2, and by the number of retirements made each year. The model again performed well in capturing the magnitudes and trends in each case.

Figure 4-5 presents the model and actual behavior for the net book values of owned cars and locomotives, again only through 1971 due to data availability. Again the model performed well. As mentioned in Chapter 3, the values associated with passenger equipment were included in the levels that measure gross book values and accumulated depreciation for cars and locomotives (the differences

FIGURE 4-5



being net book values) in order to provide a better measure of net investment and to capture the effects of the cash flows associated with this equipment. The fact that the amount and net book value of passenger cars were both declining over 1963-1971¹ lends emphasis to the effect of freight car costs in determining the behavior of net book value over this period. In spite of the declining number of freight cars shown in Figure 4-4, net book value grows rapidly in Figure 4-5. Thus, the effect of inflation² on the measure of net investment can be seen to be rather pronounced.

In each of the preceding four figures, the behavior of the model tended to somewhat lag that which actually occurred, particularly through 1968. One of the major reasons for this is that model capital expenditures on equipment tended to lag those actually made during this same period, and fluctuated about the actual expenditures after 1968, as depicted in Figure 4-6. (The jump in model capital expenditures in 1973 is discussed below.)

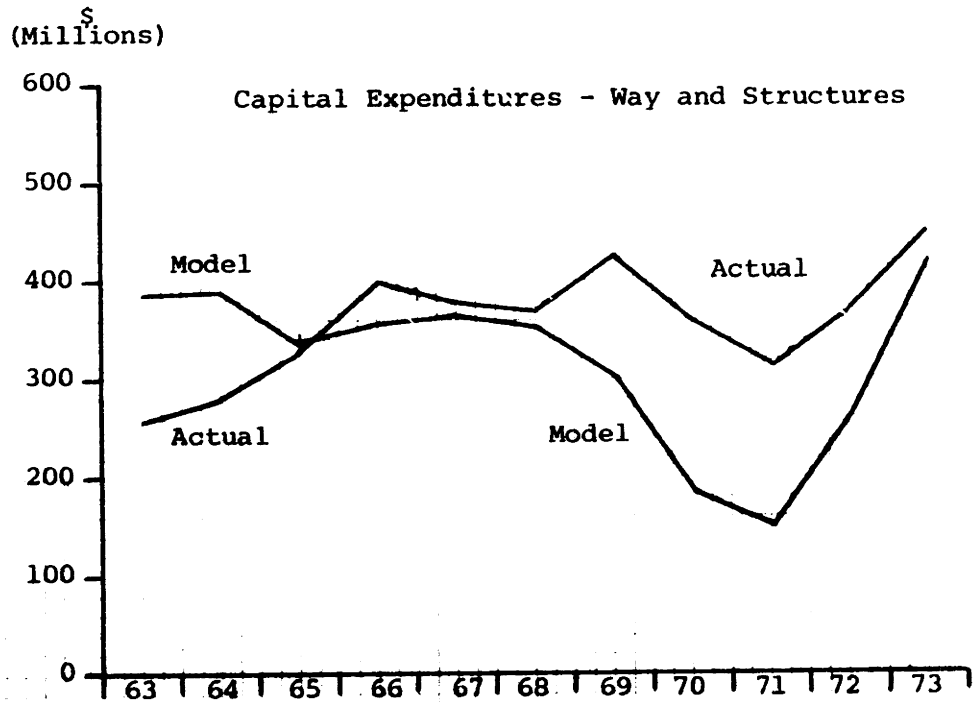
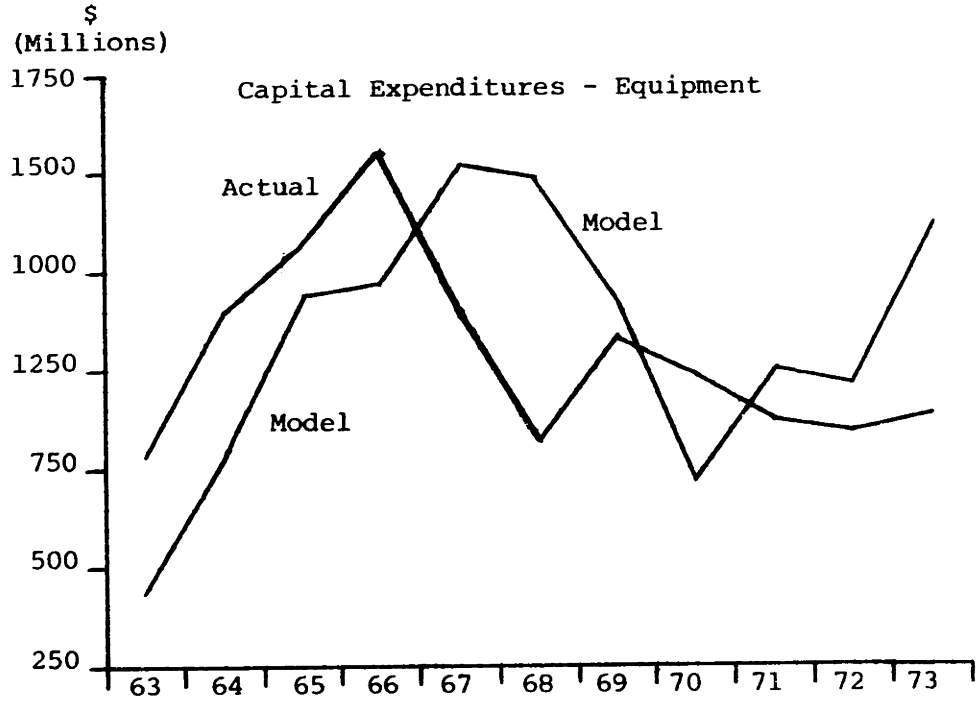
This lag is difficult to explain due to the many factors which interact in the model to determine capital ex-

¹ The interested reader is referred to [1] and [2] for the statistical bases of this statement.

² Of course, the increase in car costs was partially due to the increase in the sizes of cars purchased over this period of time.

FIGURE 4-6

VALIDATION RESULTS



penditures on equipment, but is most likely due to the joint effects of initialization "inertia" and the delays involved in the smoothing processes that affect the model's traffic and equipment needs forecasts.¹ However, the general pattern produced by the model was similar to that which actually occurred, and for similar reasons, as will now be discussed.

Principal factors affecting the rates of capital expenditures were traffic volume (and its associated forecasts), and the substitution of rented or leased equipment for purchased equipment. Table 4-1 presents the chronology of traffic volume and the number of "rented"² freight cars for the period 1963-1971. As demand and volume grew rapidly through 1966, so did the expected need for freight

¹ The model makes its forecasts by the process of exponential smoothing, which in effect delays information. The forecasting portion of the model was discussed in Section 3.5.2, and the code that performs the forecasting is available in Appendix A. For a discussion of the nature of exponential smoothing in a systems dynamics model, and its effect in delaying information, the reader is referred to Appendix E of [5].

² "Rented" freight cars is the name applied in this study to cars that the industry uses, but does not own. This category of cars is comprised of leased cars and cars supplied by car companies and shippers. The numbers of such cars, as presented in Table 4-1, was derived by subtracting the estimated average number of owned freight-carrying cars during a year (obtained by averaging the year-end counts of such cars, as available in [1]) from the average number of freight-carrying cars on line (available in [2]).

TABLE 4-1Traffic Volume And Rented Freight Cars1963 - 1971

<u>Year</u>	<u>Volume (billions of revenue ton-miles)</u>	<u>Rented Freight Cars (thousands)</u>
1963	622	297
1964	659	334
1965	698	334
1966	738	339
1967	719	354
1968	744	333
1969	768	342
1970	765	369
1971	740	397

cars. Rentals stayed fairly constant over 1964-1966, and the extra capacity was provided by an increasing number of purchases and rebuilds, which is evidenced by the slowing rate of decline in the number of owned freight cars over this period in Figure 4-4,¹ and by the simultaneous rapid increase in capital expenditures. Since the model's capital expenditures are determined in part by traffic forecasts (which were growing during this period due to the rapidly growing traffic), and are adjusted for exogenously supplied changes in the amounts of rented equipment,² it too "decided" upon rapidly increasing capital expenditures.

Over the period of 1967 through 1971, however, volume growth was much slower and more erratic, while at the same time the number of rented cars grew rapidly between 1968 and 1971. This was associated with lower rates of capital expenditures both in the model and in reality. Thus, overall, the model's process of determining equipment needs, while an abstraction of reality, acts upon the same

¹ In spite of the declining number of owned cars over this period, the number of cars installed or rebuilt per year rose from 61,000 in 1964 to 80,000 in 1966. [1].

² The reader is referred back to Section 3.5.2 for a discussion of the determination of equipment needs within the model. As is explained there, the model determines total (owned and rented) equipment needs, and then purchases whatever is not supplied by the exogenously determined increases in the sizes of the rented car and locomotive fleets.

basic logic as does the industry's: to serve a growing demand, more equipment is necessary. This simple logic, is indicative of the basic concepts that enter into the formation of the model structure. While the model might not accurately predict the exact rate of capital expenditures, it will increase this rate if demand is growing and if rented equipment cannot provide sufficient capacity for the increased traffic.

This leads to the explanation of the jump in model capital expenditures in 1973. As was discussed in Chapter 3, future cases will be analyzed under the assumption that all additional equipment is purchased after 1973. Due to the structure of the model's equations, the fact that the amounts of rented equipment will not change between 1973 and 1974 is "realized" in 1973, so the model's equipment purchases are increased accordingly at that time.

The behavior of model capital expenditures on equipment, therefore, can be seen to be based on a simple, yet realistic, set of ideas. Even though the model failed to accurately predict these expenditures in any one year,¹

¹ It should be noted that the accurate prediction of annual capital expenditures is extremely difficult, particularly due to the volatility inherent in freight car purchases. If, out of a fleet of over 1 million owned freight cars, the model's installations are different from actual by a mere 20,000 in any year, the deviation in capital expenditures would be over \$300 million.

it was able to capture the overall trends in these outlays. This ability, and its rational basis, lend credence to the validity of the model.

Also presented in Figure 4-6 is the behavior of model and actual capital expenditures on way and structures over 1963-1973. Overall, the model's behavior is similar to that which actually occurred, except that initially model expenditures are somewhat too high and the dip in expenditures that bottoms out in 1971 is more pronounced in the model. The initial excess in model capital expenditures is due to the model's constraint on debt financing allowing slightly more than was actually issued in 1963 and 1964, which enables the model to spend more than was actually the case. The more pronounced dip in model expenditures which bottom out in 1971 is due to the model's cutting back on investment in way and structures as a means of conserving funds, as net working capital was at rather dismal levels after 1968.

The above discussion of model behavior with respect to capital expenditures on way and structures, while explaining why the model performed as it did, also points out the fact (discussed at the start of this chapter) that the model sometimes computes system state and makes decisions somewhat differently than does the true system. As was also pointed out previously, since the model does so con-

sistently and understandably, it will still be useful as a comparative tool in spite of its differences with the "true" system of interest.

In this chapter, the role of validation in this study was discussed, and the more important validation results were presented. Furthermore, it was demonstrated that while the model cannot be expected to accurately predict system state, it can determine the major behavior patterns that did or would exist under various system conditions. This ability is attributable to a simplified, yet rational, model structure that will be useful in comparing alternatives aimed at improving the railroad industry's financial condition, and which can be useful in promoting a better understanding of the complex, dynamic interactions that are involved in determining this condition. In the next chapter, the model is put to use in comparing various means of improving the industry's long-term health.

4.3 NOTES ON CHAPTER 4

- [1] Bureau Of Accounts, Interstate Commerce Commission; "Transport Statistics In The United States, Part I"; for the years ended December 31, 1963 - December 31, 1971; published annually.
- [2] Economics And Finance Department, Association Of American Railroads; "Statistics Of Railroads Of Class I In The United States"; Statistical Summaries 48-58; published annually 1964-1974.
- [3] Economics And Finance Department, Association Of American Railroads; "Yearbook Of Railroad Facts, 1974 Edition."
- [4] Task Force On Railroad Productivity; "Improving Railroad Productivity, A Report To The National Commission On Productivity And The Council Of Economic Advisors"; Washington, D.C.; November 1973.
- [5] Forrester, J.W.; "Industrial Dynamics"; M.I.T. Press; 1961.

Chapter 5

MODEL APPLICATION

Thus far, the discussion has addressed the poor financial performance of the railroad industry and has introduced the modelling technique and philosophy to be followed in studying the dynamic nature of this performance. Also, the model developed for use in this research and a discussion of its validity as a tool for analyzing the problems of interest have been presented. In this chapter, the results of applying the model in various assumed future scenarios are presented and discussed. These results represent the "observations" associated with "experiments" performed on the railroad industry, and form the basis of the study conclusions.

The analyses in this chapter begin with several variants of a "base case", which represent hypothetical futures of the railroad industry resulting from the policies and parameters of the model derived from the 1963-1973 data period, in conjunction with various assumptions about the future that will remain in effect for the other cases to be analyzed. The other cases represent changes to the base cases, and the effectiveness of these changes are best judged by comparing the resultant financial performance to that of the appropriate base case. Since the as-

sumptions and simplifications of the model affect both the base cases and the changes to them, no one case should be used as an absolute predictor of the future, particularly since the model, which was structured and calibrated based upon 10 years of data, will be projected 35 years into the future in all cases. Rather, by comparing the outputs of the various cases which are all affected by the same simplifications and assumptions, the relative effectiveness of the various changes in altering model behavior may be discerned and used as a guide to evaluating the effectiveness of similar changes in the real system.

The existence of more than one base case is primarily due to uncertainty concerning the effects of quality of the fixed facilities on operating costs and productivities. Two sets of experiments are therefore analyzed here, one with "mild" quality effects and the other with "strong" quality effects, so that the sensitivity of the results to various assumptions about these interactions may be investigated. The assumed effects of quality on costs and productivity which were discussed in detail in Section 3.4.2 are presented again in Figures 5-1 and 5-2, and will be briefly re-explained.

The independent variable for each of these functions is the quality of facilities ratio, which is the quotient of current system quality to that of year end 1973. In

FIGURE 5-1
QUALITY COST MULTIPLIER

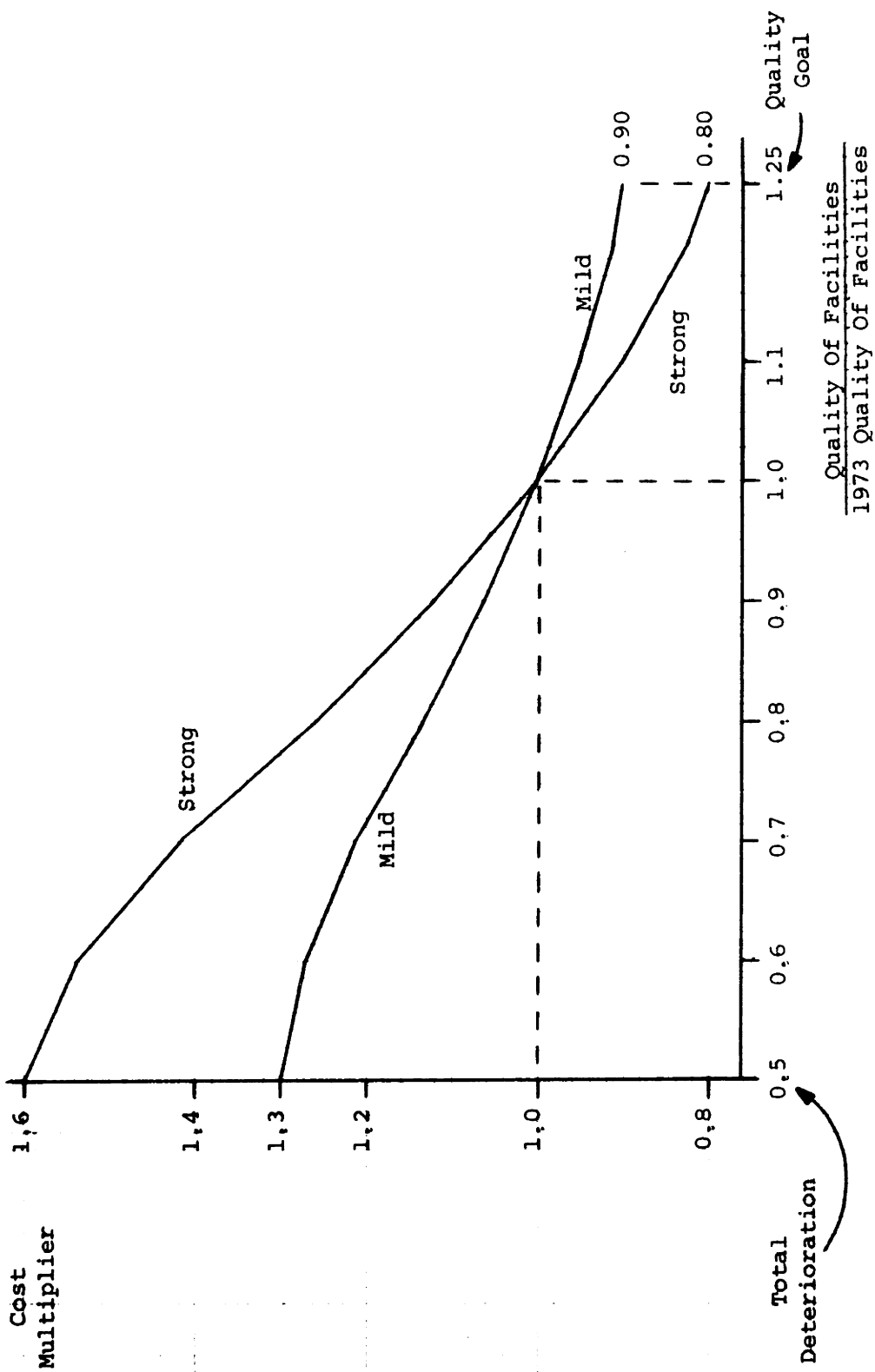
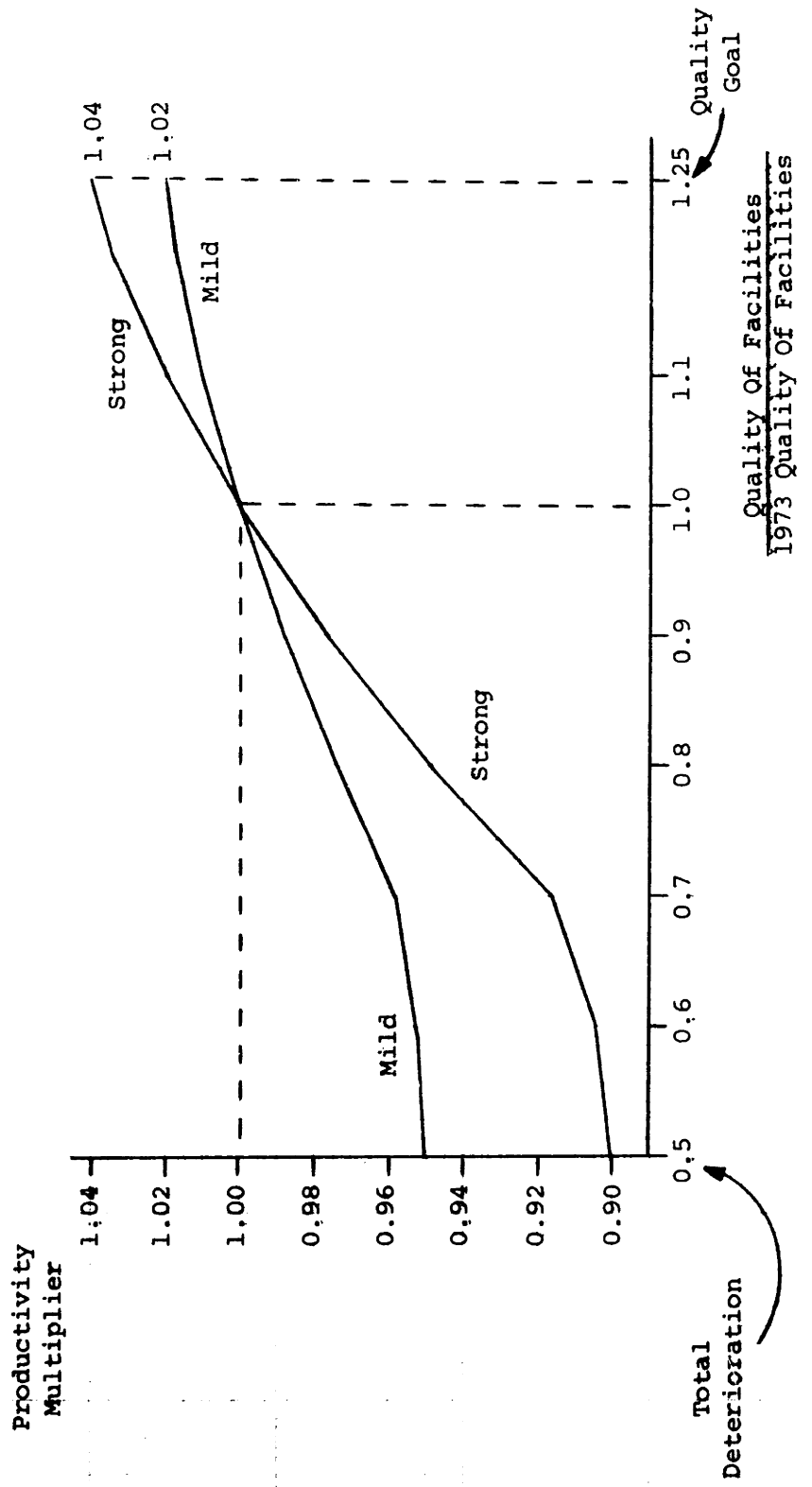


FIGURE 5-2
QUALITY PRODUCTIVITY MULTIPLIER



terms of (1967) constant quality dollars, quality at year end 1973 is computed to be \$32 billion within the model, and a quality goal of \$40 billion is assumed, indicating a maintenance backlog on the order of \$8 billion that is to be eliminated in the cases dealing with quality improvement programs. "Total deterioration" of the industry's fixed plant is assumed to be associated with a quality ratio of .5, indicating additional deferred maintenance of way on the order of \$16 billion. In Figures 5-1 and 5-2, with the assumed mild quality effects, this total deterioration is associated with a 30% increase in certain cost categories (fuel, TTGM other, maintenance of equipment, and maintenance of way) and a 5% decrease in TTGM labor productivity and the productivity of the rolling stock, for reasons cited in Chapter 3. In terms of the assumed strong quality effects, total deterioration has twice the effect, raising costs by 60% and reducing productivities by 10%.

It should be recalled from the discussion in Section 3.4.2 that TTGM labor costs (which are primarily transportation labor costs) are not affected by the quality cost multiplier of Figure 5-1. Rather, since the model determines TTGM labor requirements, and hence TTGM labor cost, for a given volume of traffic by means of TTGM labor pro-

ductivity,¹ these costs are affected (inversely) by the quality productivity multiplier of Figure 5-2. Furthermore, since equipment needs are determined within the model as a function of equipment productivity, the costs associated with equipment ownership (i.e., fixed charges and depreciation) are also affected by the productivity multiplier. The quality "cost" multiplier only affects costs which are not determined through productivity measures in the model, and which are assumed to be affected by system quality. Hence, this cost multiplier does not affect all costs, in spite of its name.

Quality improvement programs are dealt with in many of the cases analyzed in this chapter, with their result being the raising of quality to its desired level of \$40 billion, representing a 25% increase in system quality above its 1973 value. The assumed payoffs to such an improvement program are 10% cost reductions and 2% productivity increases with mild quality effects, and 20% cost reductions and 4% productivity increases with strong quality effects. It must be kept in mind that these percentage increases and decreases do not apply to total expenses, but only to portions of total expense, due to the dis-

¹ The reader is referred back to Section 3.1 for the explanation of how the model determines TTGM labor costs by means of TTGM labor productivity.

aggregation of the model's cost components. Thus, total expenses improve by less than these assumed percentages. Numerical examples of the effects on total expense will be given at appropriate points in the ensuing case analyses. It must also be kept in mind that sensitivity analyses are performed here on the numerical values of the quality cost and productivity multipliers, and not on their shapes. These shapes are assumed to be correct, and are based upon the economic theory of decreasing marginal returns (adjusted in the range of total system deterioration), as was discussed in Section 3.4.2. Furthermore, the ranges of numerical values that are being assumed for the purpose of sensitivity analyses have no theoretical or empirical justification. They were chosen to represent what the author considers to be a reasonable range of values to investigate.

The changes to the base cases to be tested with the model represent an important subset of the almost limitless alternatives possible. The base cases represent the future of the railroad industry with continuation of the general status quo (i.e., policies, cost relationships) based upon that observed over 1963-1973. In particular, they represent continued substandard maintenance and investment in way, and thus are indicative of the effect of further quality degradation. The changes to the base cases

center around a quality improvement program in which the enormous backlog of deferred maintenance of way is eliminated. In some of these cases, this program is undertaken in conjunction with improvements in labor productivity and freight car utilization (other than those resulting from a higher quality system). A quality improvement program was included in all the changes to the base cases because of the pressing need for such a program in actuality, and because the model itself indicates that further quality degradation can have serious financial implications for the industry. By analyzing the joint effects of such a program with improvements in labor or freight car productivities, the potential of these often discussed improvements in allowing the industry to finance such a program with minimal government aid is brought to light. Also, the implications of these changes on the long-run profitability of the industry can be evaluated. It should be noted that in Chapter 1, the industry was seen to be plagued by more than one problem. The cases analyzed here will show that there also seems to be no one solution to these many problems. That is, only those cases which have several improvements in effect (i.e., labor productivity, quality improvement, freight car productivity) indicate long-term health for the industry.

5.1 ASSUMPTIONS AND INTERPRETATION OF FUTURE CASES.

In each case analyzed, the specific numerical results are dependent upon the assumptions made which determine the future scenario. The major assumptions as to the future course of events (some of which have been previously discussed) which define the base cases, are as follows:¹

- i) General economic inflation at 7% per year.
- ii) If the quality of the fixed facilities remains at its year end 1973 value, then TTGM labor productivity will continue to increase and will approach 115% of its 1973 level in an exponentially decaying manner over time, as depicted earlier in Figure 3-2.
- iii) After year end 1974,² TTGM employees will always receive at least a cost of living (7% per year) pay increase. In years where productivity in-

¹ These assumptions, and all others made in this study, are indexed and discussed in Appendix D.

² Although the model was calibrated on data for the period 1963-1973, more data became available late in the research in the form of [1] and [2]. These data sources were used to update as many of the model's components as possible through 1974. Specifically, indices for labor, fuel, and material costs, as well as freight rates and demand are based upon 1974 values when inflated for the future. This has the effect of making the future scenarios somewhat more realistic, especially since the effect of the energy crisis on fuel costs is more adequately represented in the model.

creases over its previous highest value, they will also receive a pay increase proportional to this increase in productivity. (It should be recalled that employees' "pay" represents labor cost to the industry in the model, and includes fringe benefits as well as salaries or wages.) This assumption is perhaps rather pessimistic, as it implies the industry derives no benefits from increases in TTGM labor productivity.

- iv) After 1974, ME and MW personnel receive pay increases proportional to those of TTGM employees. (IF TTGM unit labor costs increase by X%, so do those of the ME and MW employees.)
- v) ME and MW material/labor ratios, which measure maintenance productivity in terms of constant dollars of material handled per man-year, will continue to increase and will approach 115% of their 1973 levels in an exponentially decaying manner over time, as depicted earlier in Figures 3-6 and 3-14.
- vi) Equipment costs inflate at 7% per year after 1973.
- vii) Material and fuel costs inflate at 7% per year after 1974.

- viii) Rental expense (equipment and facility rents) stays at its 1973 level, inflated at 7% per year thereafter. The number of rented cars and locomotive also stay at their 1973 levels, and all fleet additions are purchased after 1973.
- ix) Passenger expense, passenger revenues, state and local taxes, miscellaneous revenues, and other income stay at their 1973 levels, inflated at 7% per year thereafter. Other income is adjusted for interest earned/paid for deviations in net working capital about its 1973 year end value, at the prevailing interest rate for long-term debt (assumed to be the same for short-term investments).
- x) The effective federal income tax rate for the industry remains at 20%, approximately its average value over 1963-1973 due to the use of accelerated depreciation for tax purposes, the investment tax credit, and in part due to some railroads operating at a loss. (It should be noted that the average tax rate was somewhat lower in the mid-sixties before the collapse of the Penn Central, indicating that the effect of unprofitable roads in determining this rate

can be counter-intuitive: since railroads operating in the red lower aggregate net income before tax without reducing the taxes paid by the profitable roads, it is possible that the effective tax rate would be lower if all railroads were profitable.)

- xi) The dividend payout ratio never exceeds 25% of ordinary income after 1974, and varies linearly between 25% and 0 as net working capital varies between +100 million and -100 million constant 1967 dollars. This dividend policy is more conservative than that actually followed between 1963-1973,¹ and is assumed here due to its more conservative nature with respect to cash use.
- xii) Minimal maintenance of way and structures will continue unless financial statement considerations allow more. Minimal maintenance is based upon wear and tear rate and the historical percentage of expenditures charged to expense, and represents the functional relationship between maintenance and volume observed over 1963-1973. (The process by which maintenance

¹ Dividend payout ratios were constantly above 50% over 1963-1973, and exceeded 100% on several occasions [3].

is determined was discussed in detail in Chapter 3.)

- xiii) Minimal investment in way and structure will continue unless cash flow/debt availability allows more. Minimal investment is based upon the wear and tear rate, the historical percentage of expenditures capitalized, and on the level of net working capital. The minimal amount of investment in way is linearly reduced to zero from its "usual" value as net working capital falls from +100 million to -100 million constant 1967 dollars, in the same manner as is the dividend payout ratio. This policy is used as another means of conserving net working capital when it is becoming low.
- xiv) At least 15%¹ of the desired investment in rolling stock will always be done and must be cash financed (i.e., rebuilds, cash purchases, down payments on equipment trusts necessary before the debt can be issued). If there is suf-

¹ Over 1963-1970, the average percentage of "cash" (non-equipment debt) financing of rolling stock acquisitions was 34%, as computed from the data in [3], which only extends through 1970. Based upon the marked decrease in rebuilds over 1970-1974 [1], and as a means of bolstering model net working capital, 15% was used as a more conservative estimate of this lower bound on cash expenditures for the future cases.

ficient cash flow, more than this percentage will be cash financed. Again, if net working capital is becoming too low, this percentage is linearly reduced to zero as a means of conserving funds. These Necessary Cash Expenditures on Rolling Stock (NCERS) were explained in detail in Section 3.2.3.3.

- xv) Both unsecured and equipment debt are constrained in availability/desirability according to the interest coverage constraints discussed in Section 3.3.4.
- xvi) Quality of the fixed facilities affects costs and productivities according to the "mild" or "strong" quality effect functions presented earlier in this chapter, beginning in 1974.
- xvii) Demand for rail service grows at 2% per year after 1974. As was discussed in Chapter 1, demand is assumed to be completely insensitive to freight rates and service quality, as competition from other modes is not included in the model. Thus, this assumed demand growth occurs regardless of the state of the industry.
- xviii) The railroad industry follows a volume growth policy subject to financial constraints on cash and equipment debt; Capacity will be adjusted

to the demand forecast as long as there are sufficient funds to do so.

- xix) Interest rates on long-term debt reach 10% in 1975, and remain at this level, consistent with a 7% inflation rate and a 3% assumed true time value of money. (The interest rate will be lowered to 8% in several cases, but unless otherwise stated, it is 10%.)
- xx) Traffic mix does not significantly change, and all freight rates inflate at 7% per year. Thus average revenue per ton-mile increases at 7% per year above its 1974 level. This assumption is related to that of demand inelasticity discussed above.
- xxi) Freight car (maximum reasonable) productivity continues to grow due to increasing lengths of haul and increasing average car capacity, and approach 110% of its 1973 value on exponentially decaying manner over time, as depicted earlier in Figure 3-24.
- xxii) The planned car to locomotive ratio in the system, which is used to determine locomotive requirements based upon freight car requirements, continues to decline and approaches 92.5% of its 1973 value in an exponentially

decaying manner over time. This ratio is also used to determine locomotive productivity from that of freight cars, and was depicted earlier in Figure 3-22.

The multiplicity of the above assumptions is indicative of the complexity of the system being dealt with, and further emphasizes the irrationality of trying to accurately predict the future with a model. Besides the simplifications necessary in the model itself, assumptions must be made about the many factors that affect the system being modelled in order to achieve a forecast of the future. Inasmuch as the simplifications of the model and the assumptions made affect the exact numerical values of the model's outputs, conclusions should not be based upon the numerical values of the outputs of any one case. For example, if the model computes NROI of \$3 billion in 1990 as the result of some change in labor productivity, it cannot be concluded that this change will have that effect by 1990, as this specific numerical value depends on the model's simplifications and the assumptions made. Rather, given the model and the future assumptions (which are made for the purpose of producing reasonable and "realistic" numerical values), conclusions are sought about the effectiveness of this change in labor productivity as compared to

other possibilities. Hence, the usefulness of the model as a comparative tool is again emphasized.

Besides the above assumptions, there are two important aspects about how the model is applied which require discussion. These items play an important role in determining the outputs of many of the cases presented in this chapter, and in the interpretation of these outputs.

First, in most of the cases presented, equipment debt is assumed to be constrained in availability according to the interest-coverage constraint explained in Section 3.3.4. This constraint, while not necessarily the "true" constraint on equipment debt availability/desirability, is indicative of the fact that at some poor level of interest coverage, this form of debt financing must become more difficult to obtain, or less desirable to have, as there would be difficulty in meeting debt repayments and interest payments.

This constraint can lead to volume growth being less than demand growth, as it can prevent the capacity of the rolling stock fleet from being adequately increased to meet all of the demand for rail service. The question arises as to whether the industry, as a common carrier, would be "allowed" by the government to forego growth on the basis of its inability or lack of desire to increase the amount of debt in its capital structure. It is most likely that

the federal government would intervene in the situation in some manner, either guaranteeing or supplying the loans if they were not available in the capital markets, or by forcing the railroads to grow, and in either event supplying some sort of financial aid (either by a change in regulation, or by a direct infusion of funds) that would keep the industry solvent while it served the demand for its service.

However, any form of intervention by the federal government is by itself one of many alternatives aimed at improving the financial condition of the industry. Of interest here, and in the industry and government, is how the industry can profitably grow with the demands for its service with minimal government aid. Thus, most cases are analyzed with this constraint on equipment debt in effect to indicate how the industry might fare if left alone. Of course, this is an extremely hypothetical situation, as the railroads, being common carriers, could never forego growth if the economy required it. Furthermore, the recent formation of Conrail with the aid of large amounts of federal funds makes this situation even more hypothetical. However, this treatment of the industry's growth process provides very useful comparative outputs from the model. Various changes to the current system, which are internal to the industry, are compared as means of allowing

the industry to meet its growth "obligation" to society on its own, while at the same time achieving a better financial position. In addition, several cases of "forced" growth are presented in order to allow the analysis of their financial impact, and thus to indicate the extent of federal, or other external, aid implied.

Thus, cases in which capacity, and hence volume, is restricted due to the inability of the industry to cover its capital costs are not necessarily "realistic" future scenarios. Rather, they indicate how the industry might fare of its own accord. The interest here is in industry profitability and growth, and in the relative effectiveness of internal options open to the industry that would allow them to meet their objectives and the needs of society. Any alternative tested can promote either or both goals, so the ability of an alternative in furthering either objective can be interpreted as an improvement. Due to the structure of the model, volume growth is a higher "priority" goal than is improved profitability (although the latter promotes the former within the model), based upon the assumed need for rail services in the economy, and the industry's tendency to seek growth. Thus, any helpful change to the system will first of all promote volume growth, and secondly will lead to better financial performance if the change causes a major improvement.

Second, in several of the cases analyzed, net working capital takes on large negative values, but the model has the industry stay in business in spite of this. Furthermore, continued operation in this obviously bankrupt situation often makes it worse. It is therefore important to interpret these large negative values of net working capital for what they are. They are not predictions of the future, as measures not accounted for in the model's assumed future scenario (i.e., reorganization, policy changes within the industry, changes in regulation, etc.) would most likely be undertaken if this situation ever arose in actuality. In fact, measures not accounted for in the model's assumed future scenario would most likely be undertaken to prevent such a situation from occurring. These model outputs (and all the model's outputs) represent what could occur given the assumed future scenario. As such, they are only useful in a comparative sense, as these future scenarios are hypothetical. Hence, it is again emphasized that the model is best used as a comparative tool, and not as an absolute predictor.

In a comparative sense, the extent of negativity in net working capital provides valuable information when interpreted in light of how it comes about in the model. As was explained in Section 3.2.2, repayments of long-term debt, and other uses of funds, are treated as direct reduc-

tions in net working capital, even if net working capital is negative. However, further reductions in net working capital when it is negative cost the industry the prevailing interest rate on long-term debt, which is assumed to be the same for short-term debt. Thus, a reduction in net working capital when it is negative can be given several interpretations. First of all, it might be interpreted as debt in default being treated as a current liability and costing the prevailing interest rate rather than the rate associated with the original debt issue. This might also be interpreted as the creditors' having granted renewable short-term extensions on the obligations that could not be met when they became due. Finally, it can be interpreted as the industry having obtained renewable short-term loans from elsewhere that allow them to meet their other current liabilities or long-term debt repayments.

Whatever the interpretation, negative net working capital represents a cost to the industry associated with money being owed to someone who has not yet been paid. If the model manages to raise net working capital back to a positive level, it indicates the ability on the part of the industry to repay these obligations under the conditions or alternatives in effect in the model. In this situation, the maximum extent of negative net working capital may be interpreted as the amount of loans necessary from

any external source to see the industry through a temporary funds shortage.

If net working capital becomes more and more negative, however, it indicates insolvency under the assumed conditions. Since the model does not "allow" the industry to go out of business, the indicated extent of insolvency can be misleading, as it is caused by continued operation under the assumed conditions. In actuality, something would be done (i.e., reorganization) that is not accounted for in the assumed model scenario. Therefore, when net working capital becomes hopelessly negative under a given set of assumptions, it indicates the extent of the need for either federal intervention or some other type of alternative that would arise if the industry were to continue operations in the assumed scenario.

Now that the basic assumptions and important aspects of output interpretation have been outlined, the results of the various cases can be presented and discussed.

5.2 CASE ANALYSES.

There were 15 cases analyzed in this study, each representing the hypothetical future of the railroad industry through the year 2010 under various assumed scenarios. This section will present the output values of NROI, ordin-

ary income, fixed charges, net working capital, and volume for each case, as these variables represent the important end results of the many processes occurring in the model. The discussion of each case will also deal with the other factors in the model that are causing the observed results. All monetary outputs presented are in constant 1967 dollars,¹ and all discussions of monetary items (such as investment rates, quality of the fixed facilities, debt issuance, etc.) will be in terms of constant 1967 dollars, unless otherwise stated.

As was mentioned earlier in this chapter, the analyses begin with several variants of a "base case" and then address changes to these base cases. The base cases are defined by the base assumptions listed earlier in Section 5.1, and thus the changes to the base cases represent changes in assumptions. Specifically, changes in the base assumptions about maintenance (and investment) in way policies, transportation labor requirements, freight car productivity, equipment debt availability, and interest rates are made. The particular assumptions made about each of these factors, in addition to the assumed degree of quality effects (i.e., mild or strong), define each of the 15 cases to be analyzed in this chapter, as presented in Table 5-1.

¹ The deflator used is the consumer price index, inflated at 7% per year after 1974.

TABLE 5-1

CASE SCENARIOS

<u>CASE</u>	<u>MW POLICY</u>	<u>QUALITY EFFECTS</u>	<u>TRANSPORTATION EMPLOYEES</u>	<u>FREIGHT CAR PRODUCTIVITY</u>	<u>EQUIPMENT DEBT</u>	<u>INTEREST RATE</u>
I	Base	None	Base	Base	Constrained	10%
II	Base	Mild	Base	Base	Constrained	10%
III	Base	Strong	Base	Base	Constrained	10%
IV	Base	Mild	Base	Base	<u>Unconstrained</u>	<u>8%</u>
V	Base	Mild	<u>Base - 40%</u>	Base	Constrained	10%

TABLE 5-1 (continued)

CASE SCENARIOS

<u>CASE</u>	<u>MW POLICY</u>	<u>QUALITY EFFECTS</u>	<u>TRANSPORTATION EMPLOYEES</u>	<u>FREIGHT CAR PRODUCTIVITY</u>	<u>EQUIPMENT DEBT</u>	<u>INTEREST RATE</u>
VI	<u>Quality Improvement</u>	Mild	Base	Base	Constrained	10%
VII	<u>Quality Improvement</u>	Strong	Base	Base	Constrained	10%
VIII	<u>Quality Improvement</u>	Mild	Base	Base	<u>Unconstrained</u>	<u>8%</u>
IX	<u>Quality Improvement</u>	Strong	Base	Base	<u>Unconstrained</u>	<u>8%</u>

TABLE 5-1 (continued)

CASE SCENARIOS

<u>CASE</u>	<u>MW POLICY</u>	<u>QUALITY EFFECTS</u>	<u>TRANSPORTATION EMPLOYEES</u>	<u>FREIGHT CAR PRODUCTIVITY</u>	<u>EQUIPMENT DEBT</u>	<u>INTEREST RATE</u>
X	<u>Quality Improvement</u>	Mild	<u>Base - 20%</u>	Base	Constrained	10%
XI	<u>Quality Improvement</u>	Mild	Base	<u>Base + 25%</u>	Constrained	10%
XII	<u>Quality Improvement</u>	Mild	<u>Base - 20%</u>	<u>Base + 25%</u>	Constrained	10%
XIII	<u>Quality Improvement</u>	Strong	<u>Base - 20%</u>	Base	Constrained	10%
XIV	<u>Quality Improvement</u>	Strong	Base	<u>Base + 25%</u>	Constrained	10%
XV	<u>Quality Improvement</u>	Strong	<u>Base - 20%</u>	<u>Base + 25%</u>	Constrained	10%

For each case, the assumptions that are different than the base assumptions presented earlier are underlined so that the major changes in effect may be easily discerned.

Several aspects of these cases deserve mention at this point. First, Case I is listed as having "no" quality effects. This case is presented to show the behavior generated by all the base assumptions in the "absence" of quality effects on costs and productivities. That is, the quality cost and productivity multipliers are assumed to equal 1.0 regardless of system quality. Since this case has the base maintenance and investment in way policy (referred to as MW policy in Table 5-1), it tends to generate inadequate expenditures on way and structures, but because of the absence of quality effects, the declining system quality caused by this policy has no effect on earnings. The next two cases also have the base MW policy, as well as mild or strong (as opposed to no) quality effects. In these cases, inadequate expenditures on way will affect earnings and many other aspects of system behavior. Hence, Case I is presented so that the changes in system behavior caused by the introduction of varying degrees of quality effects may be seen.

Second, Cases I through IV are all referred to as base cases in this chapter, even though Case IV does not

include the base assumptions as to equipment debt availability and interest rates. Case IV is included in the "base" category because its operating costs and MW policy are defined by the base assumptions, and it is operating costs and MW policy that will be the focus of most of the changes analyzed in this study.

Third, the percentage changes in transportation labor requirements and car productivity represent arbitrarily¹ chosen values which may or may not be feasible in light of current restrictions on such changes in the industry. These values were chosen merely for the sake of presentation.

Fourth, as is evident in the format of Table 5-1, there is a "structure" to the chosen set of cases. Cases I through V are presented on the same page because they all have the base MW policy. Cases VI through IX all appear together because they represent quality improvement programs without any changes in labor requirements or car productivity. Also, Cases X through XV appear on the same page because they represent quality improvement programs with various combinations of changes in labor requirements and car productivity assumptions.

¹ These values are not completely arbitrary, as there is some relationship between them. This will be apparent as the cases are presented.

The relationships between the cases are apparent in the "tree" diagrams presented in Figures 5-3 and 5-4. In both figures, the assumptions in effect for any case are found by tracing a path from the "root" of the "tree" at the left of the figure rightward to the appropriate case. Any assumption not listed for a case is a base assumption. Figures 5-3 and 5-4 are useful reference tools in reading this rather long chapter, and it will be helpful for the reader to refer back to them at the start of each case discussion in order to place the cases in perspective.

Figure 5-4 will be particularly useful, as it includes 10 out of the 15 cases analyzed. It should be noted that the cases in Figure 5-4 fall into two similar groups of 5, the only difference between the groups being the degree of quality effects assumed (i.e., mild or strong). Thus, it will be useful to compare similar cases in the two groups so that the impacts of different quality effect assumptions on the model's outputs can be seen. It will also be useful to compare cases within each group so that the effectiveness of the alternative(s) tested in each case can be compared under similar quality effect assumptions. Lastly, it will be extremely useful to compare cases in each group by moving from left to right in Figure 5-4, as this will greatly facilitate understanding the additional

FIGURE 5-3
RELATIONSHIP BETWEEN CASES WITH BASE MW POLICY

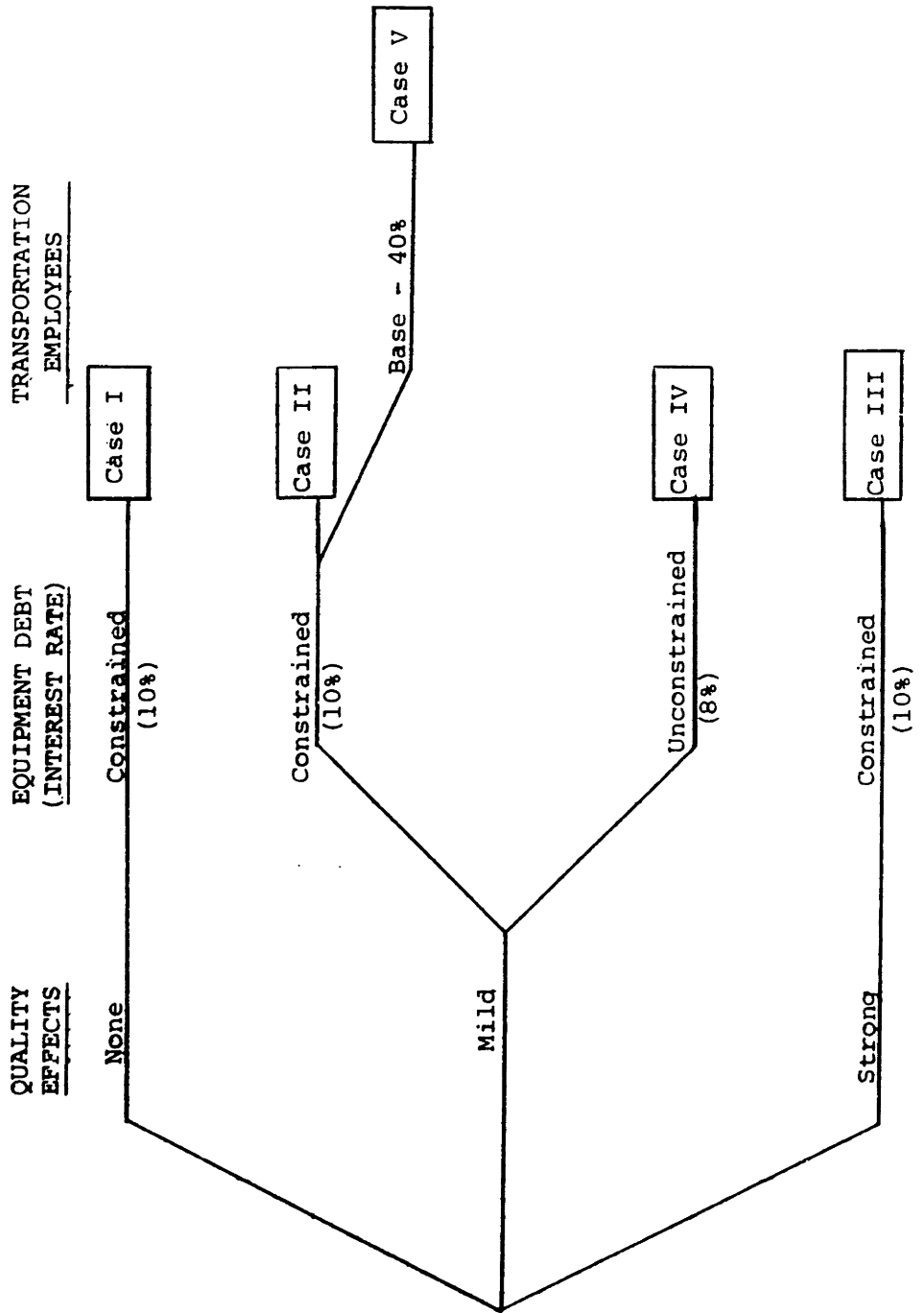
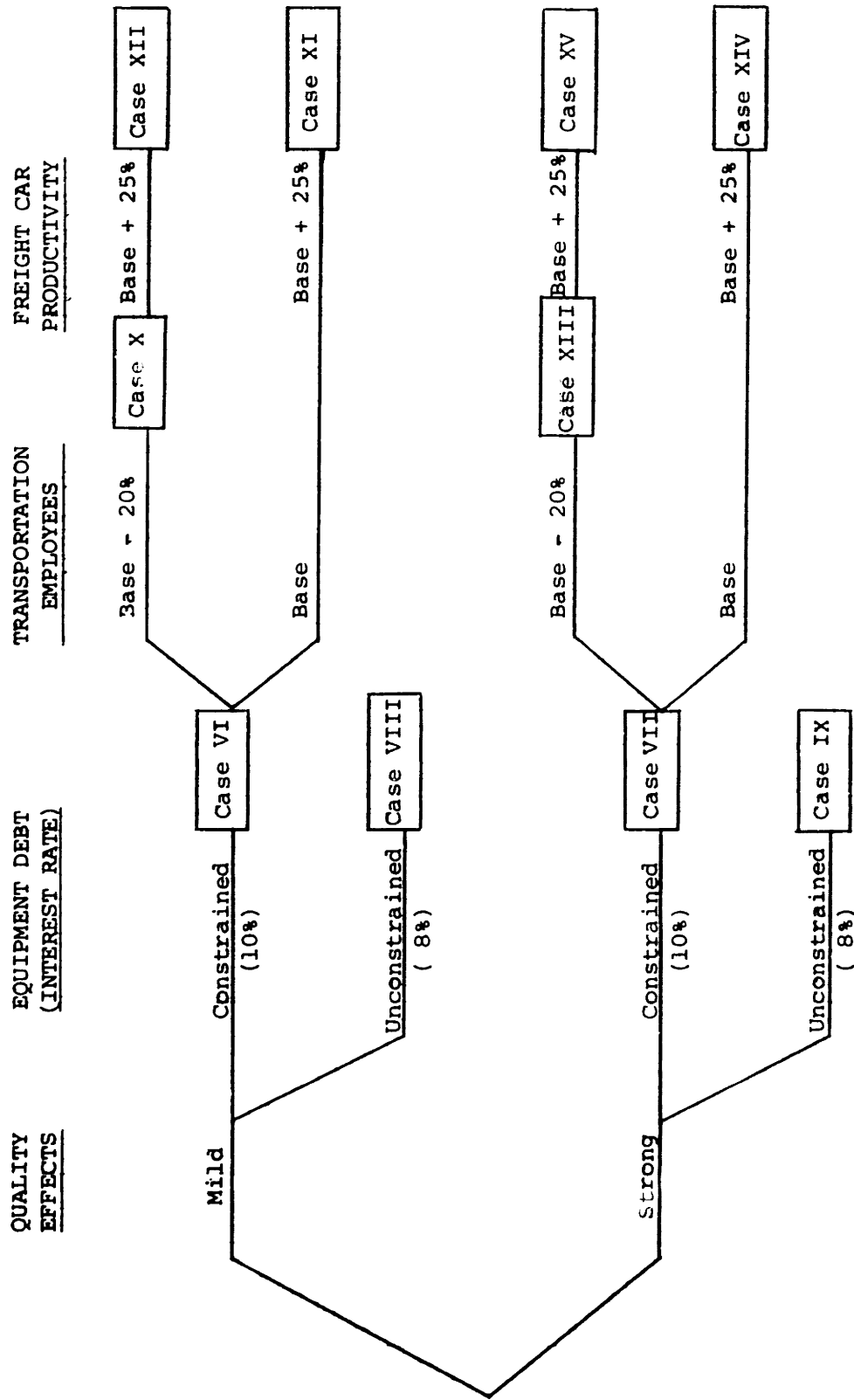


FIGURE 5-4
RELATIONSHIP BETWEEN QUALITY IMPROVEMENT CASES



impact of each additional base assumption changed.

The cases are presented in numerical order, Case I being first, and Case XV being last. Throughout, as many comparisons as necessary to highlight the important aspects of one case relative to others will be discussed. However, for the sake of brevity, not all comparisons will be detailed. Again, it is suggested that the reader refer back to Figures 5-3 and 5-4 at the start of each case discussion in order to place the cases in perspective. Also, as mentioned previously, all monetary items discussed will be in terms of constant 1967 dollars, unless otherwise stated.

5.2.1 Case I: Base Case - No Quality Effects.

This case is presented to show the system behavior resulting from the base assumptions, and in particular the behavior resulting from the aggregation of the operating cost assumptions, in the absence of quality effects. It must be noted that the base maintenance and investment in way policy is in effect, and that this policy leads to inadequate expenditures and hence declining quality. However, the quality multipliers are assumed to equal 1.0 for all values of quality, so the dynamic effects of quality degradation on costs are not manifested in the model outputs.

The results of this case are presented in Figures 5-5 and 5-6, and basically indicate a continuation of the past marginal financial performance of the industry.

Volume grows slowly, at an average annual rate of 1%, whereas demand is increasing at 2% per year. This discrepancy is due to the industry's poor interest coverage and insufficient cash flow not allowing them to generate enough external or internal funds to expand the rolling stock fleet so as to serve all the demand for rail service. This slow growth in volume leads to similar behavior in NROI, which increases from \$935 million in 1975 to about \$1.3 billion by 2010. The effects of the linear operating cost functions in conjunction with the "fixed" costs of passenger service, state and local taxes, rental expense, and the fixed passenger and other revenues, lead to industry total expenses (before fixed charges) and revenues being roughly proportional to freight volume, hence NROI and volume both grow by 37% between 1975 and 2010. This behavior is probably pessimistic, as one would expect NROI to grow somewhat more than proportionally to volume, and is most likely due to the nature of the operating cost functions used. While the numerical accuracy of this behavior can be questioned, its general nature, which is most important, is correct: NROI increases with volume in the absence of quality effects on costs and pro-

FIGURE 5-5

BASE CASE - NO QUALITY EFFECTS

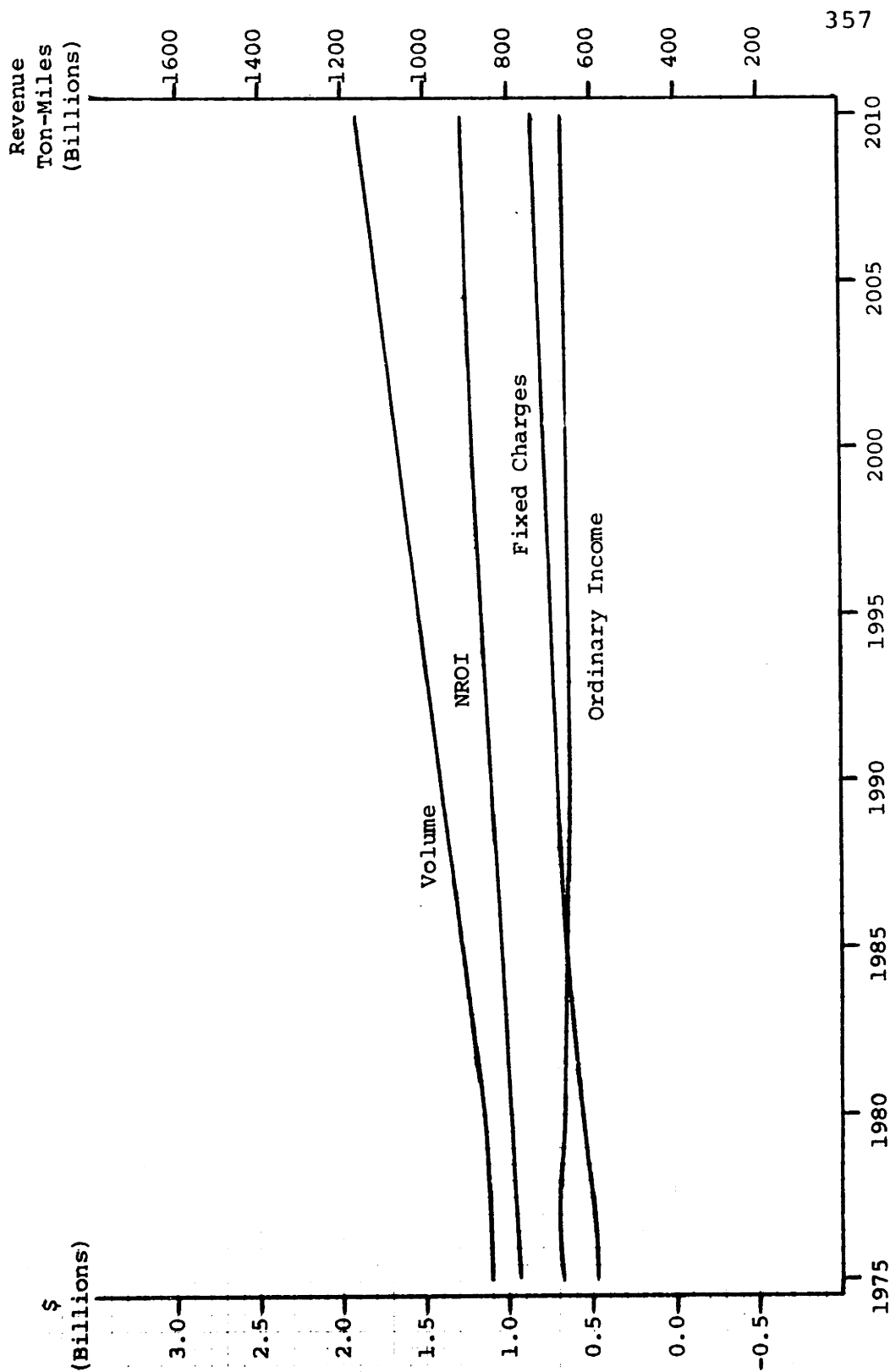
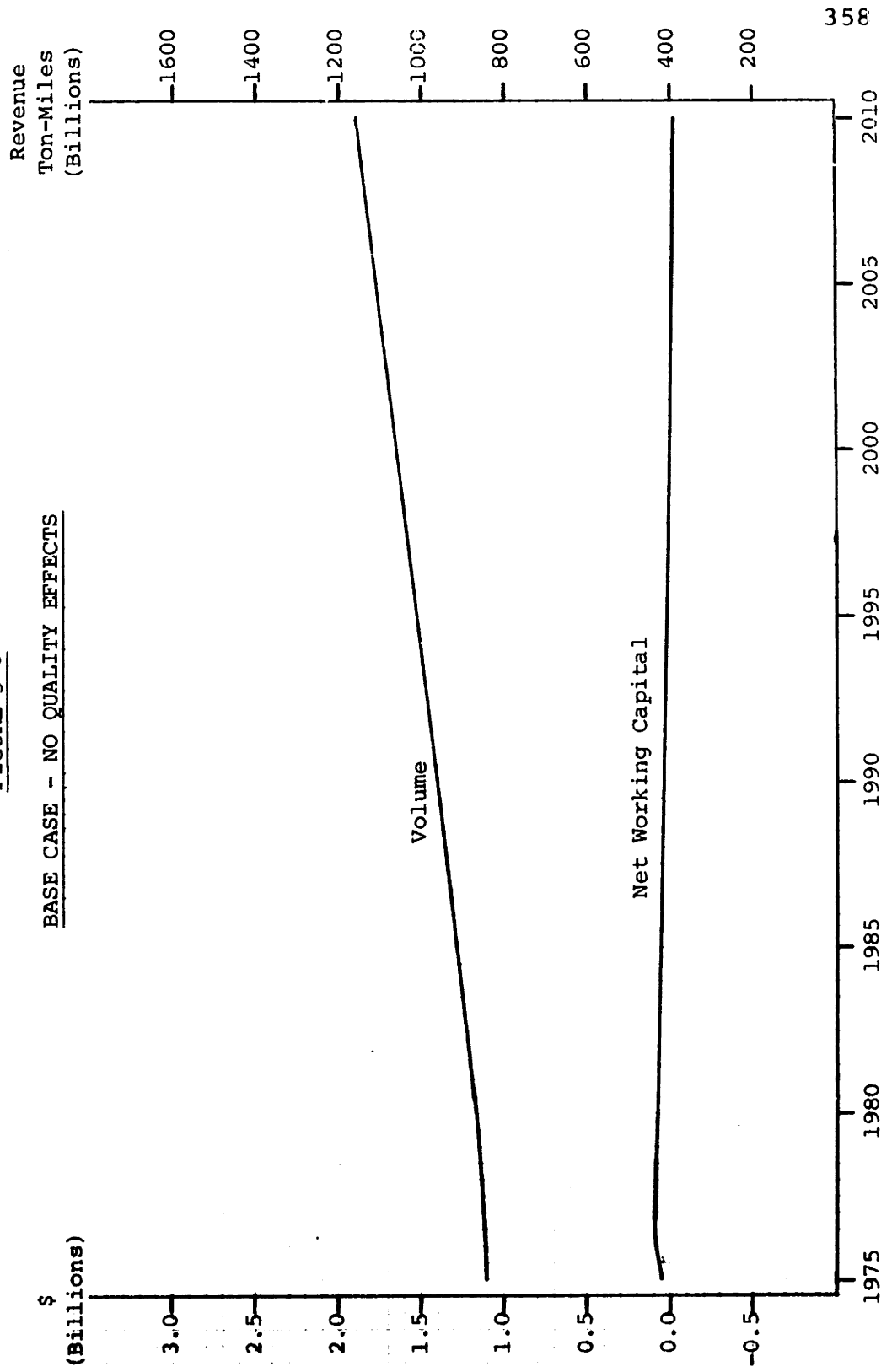


FIGURE 5-6

BASE CASE - NO QUALITY EFFECTS



ductivities, given the assumption of inflationary rate increases.

It should be noted that while the size of the rolling stock fleet only increases sufficiently to allow a 37% increase in volume, fixed charges, which are primarily affected by equipment debt, as zero unsecured debt is available, rise from \$480 million to \$850 million, representing an increase of about 75%. This greater increase in fixed charges is due to the replacement of old equipment obligations at low interest rates by newer ones which (by assumption) cost 10% per year. Since NROI and fixed charges both increase by about \$350 million, and since net working capital hardly changes (and thus neither does other income), ordinary income stays fairly constant throughout, dipping somewhat initially as the effects of the increased interest rates on fixed charges occur primarily before 1985.

Thus, the observed cost functions and policies, together with the assumptions made about the future, lead to a continuing poor performance on the part of the industry not too unlike that actually observed over 1963-1973. The major difference between actual performance over 1963-1973 and that of this future scenario is that constant dollar NROI grows with volume and time in the future, while it declined over the past decade. Partially responsible

for this difference is the assumption of inflationary rate increases, which did not occur in timely fashion in the past. However, the dynamic effects of the quality degradation resulting from the continuation of substandard maintenance of way (which was the nature of MW expense in this case) have been ignored. These effects now become the focus of attention.

5.2.2 Case II: Base Case - Mild Quality Effects.

The introduction of the dynamic effects of quality degradation resulting from the inadequate maintenance of way assumed in the base cases has a fairly dramatic effect on the model outputs, as will be evidenced in Figures 5-7 and 5-8. It should be noted that mild quality effects are assumed here, as depicted in Figures 5-1 and 5-2.

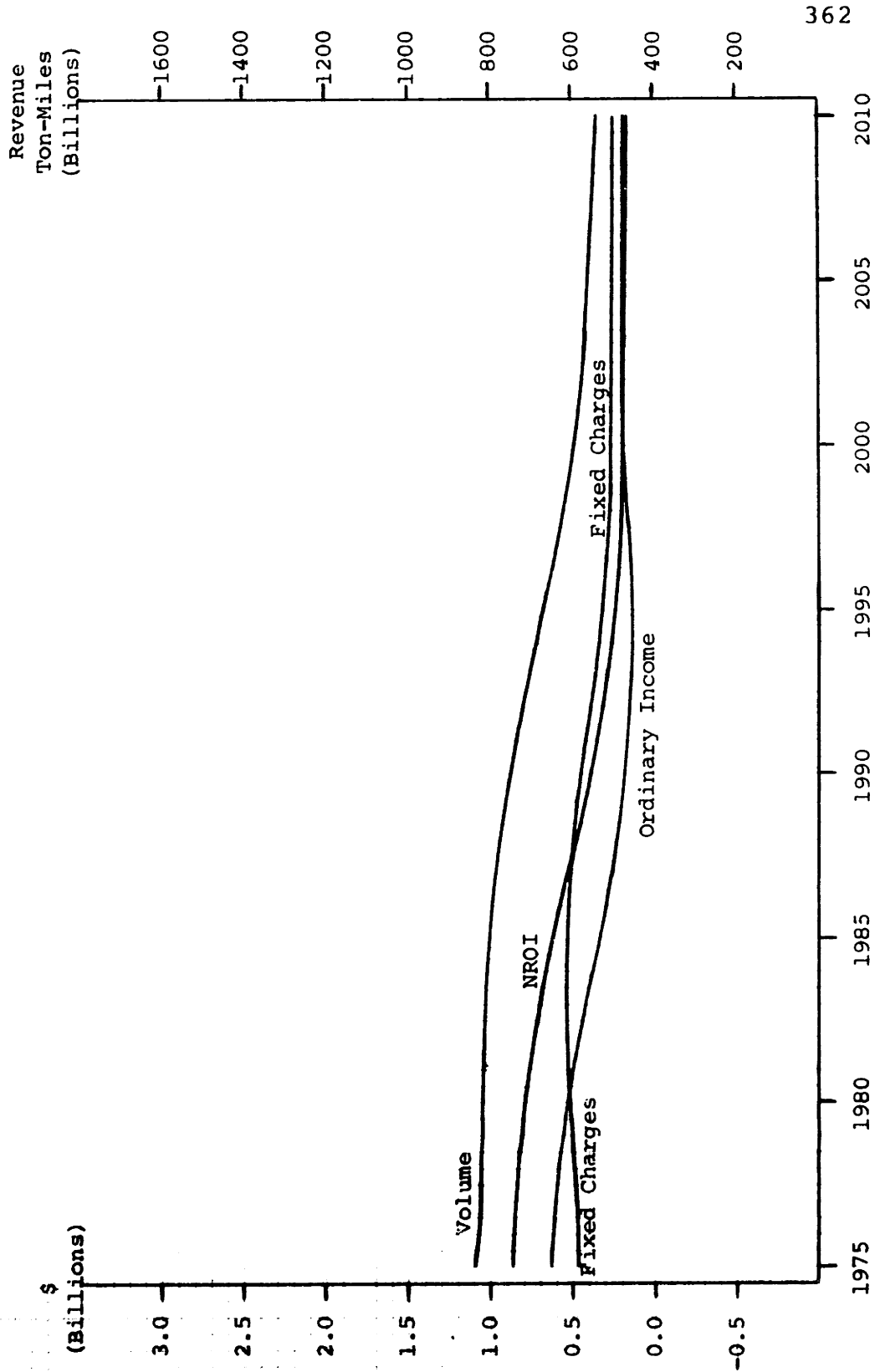
Quality of the fixed facilities is assumed to affect fuel usage, TTGM other costs (such as loss and damage, damage to property, non-labor costs of clearing wrecks, etc.), maintenance of equipment, and maintenance of way, as well as equipment and transportation employees' productivities and hence the costs affected by these productivities. Furthermore, the effects of quality degradation are rather minor, with fuel, TTGM other, and the maintenance costs increasing by a maximum of 30% due to additional

deferred maintenance of way above its 1973 level on the order of \$16 billion, and productivities only falling by 5% as a result of this same huge increase in the maintenance backlog.

In dollar terms, as computed by the model for 1975, TTGM other, fuel, and maintenance costs represented \$7.7 billion (current dollars) out of total expenses (including fixed charges, but before income taxes) of \$17 billion (current dollars). Thus a 30% increase in these costs at 1975 traffic levels, would entail an additional \$2.3 billion (current dollars) of expense. The expenses affected by productivity changes are depreciation on rolling stock, fixed charges on equipment debt, and TTGM labor costs. Inasmuch as depreciation on rolling stock represents about 75% of total depreciation expense, if it is assumed this same split applies to fixed charges, then the total 1975 costs affected by productivity changes would be \$6.7 billion (current dollars). A 5% increase in these costs would cause an additional \$335 million (current dollars) of expense at 1975 traffic levels.

Thus, if model volume stayed at its 1975 level of 840 billion revenue ton-miles, the effects of a massive increase in the maintenance backlog would be an increase in expenses before income tax of about \$2.6 billion (current dollars) or 15%. At lower traffic volumes, such as those

FIGURE 5-7
BASE CASE - MILD QUALITY EFFECTS



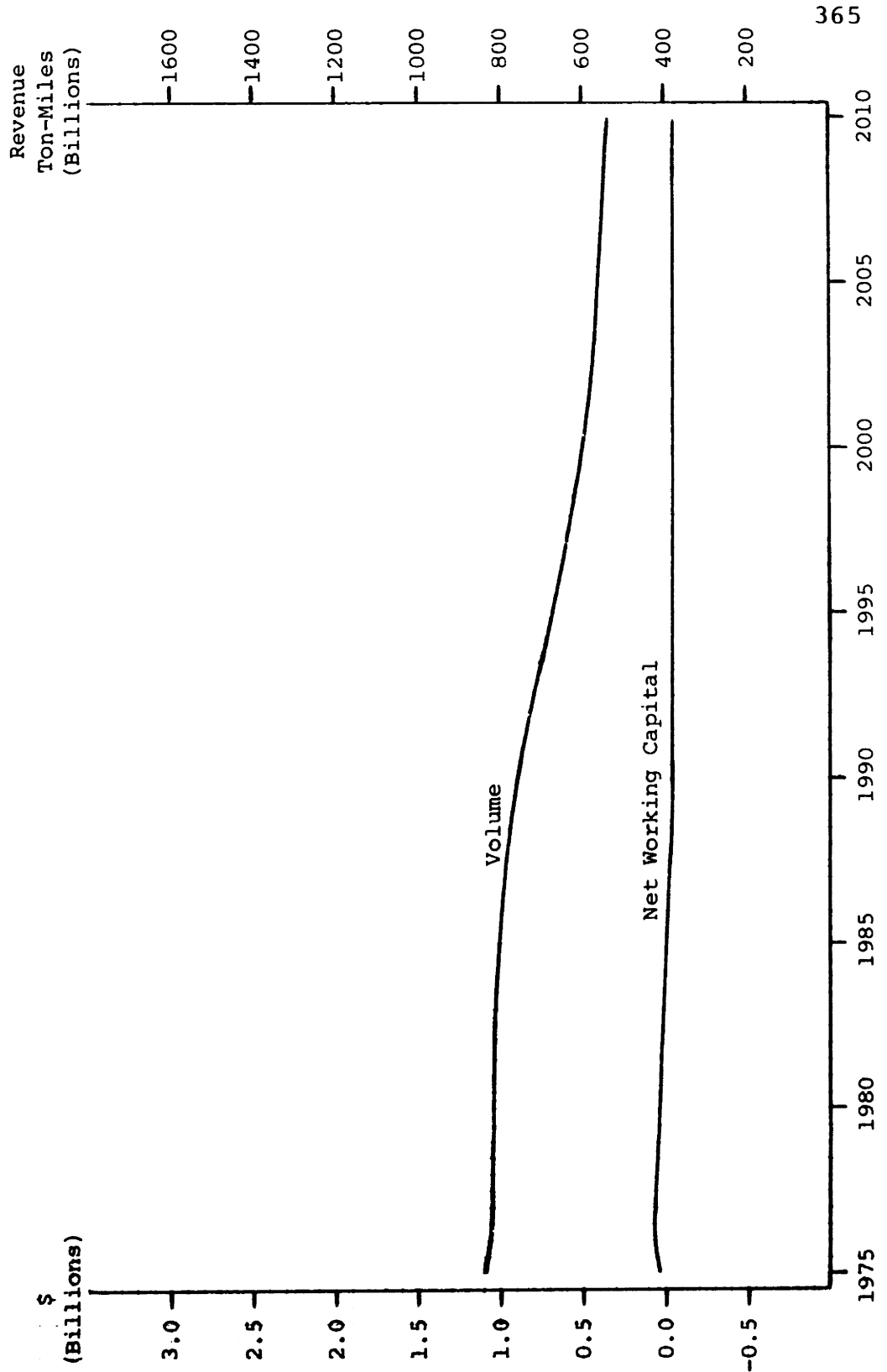
that occur by the year 2010, when the maintenance backlog has increased by about \$16 billion in this future case, the overall increase in costs is a lesser percentage of the total, due to the presence of the "fixed" costs of state and local taxes, passenger expense, and rentals. It is therefore evident that the "mild" quality effects are indeed mild, as only a minor increase in total expenses is caused by an increase in the amount of deferred maintenance of way on the order of \$16 billion (approximately \$20 billion in terms of 1975 dollars). In spite of this minor effect, the results are striking.

Referring to Figure 5-7, over the period of 1975-1985, net revenues before fixed charges are insufficient to allow enough equipment debt issuance to expand capacity. Therefore, capacity and volume slowly fall through 1985 due to equipment installations being slightly less than retirements. In spite of the "low" rate of debt issuance during this period, fixed charges rise somewhat due to the higher interest rates on the new debt issued. At the same time, the slowly declining volume reduces revenues slightly while decreasing quality keeps the expenses that affect NROI (all expenses except fixed charges, and before income tax) fairly constant, leading to a slow decline in NROI. Falling NROI and rising fixed charges in turn cause a more pronounced decline in ordinary income.

Around 1985, falling NROI coupled with fairly constant fixed charges leads to a worsening of the interest coverage situation. The rate of equipment debt issuance is thus further reduced (no unsecured debt is available throughout most of these cases), causing a decline in fixed charges. The reduced rate of debt issuance and the associated reduced rate of investment in rolling stock causes capacity to decline more quickly, leading to a rapid decline in volume between 1985 and 1995. This volume decline, coupled with rising unit costs due to declining quality, in turn causes a rapid decline in NROI.

About 1993, quality of the fixed facilities has sufficiently declined that its effects on costs and productivities begin to "top out" or reach the declining slope portion of the quality effect curves depicted earlier. This slows the rate of decline in NROI to approximately that of fixed charges, so that ordinary income achieves a fairly constant level after 1993, in spite of the decline in NROI. The rate of decline in NROI eventually approaches zero as volume and quality effects on costs achieve constant levels. Volume levels off after 1995 due to a sort of equilibrium being achieved between the levels of fixed charges and net revenues, causing debt issuance and investment in rolling stock to remain at constant levels, as measured in 1967 dollars. Quality effects also stop increasing due to sys-

FIGURE 5-8
BASE CASE - MILD QUALITY EFFECTS



tem quality approaching the state of total deterioration, as depicted previously in Figures 5-1 and 5-2.

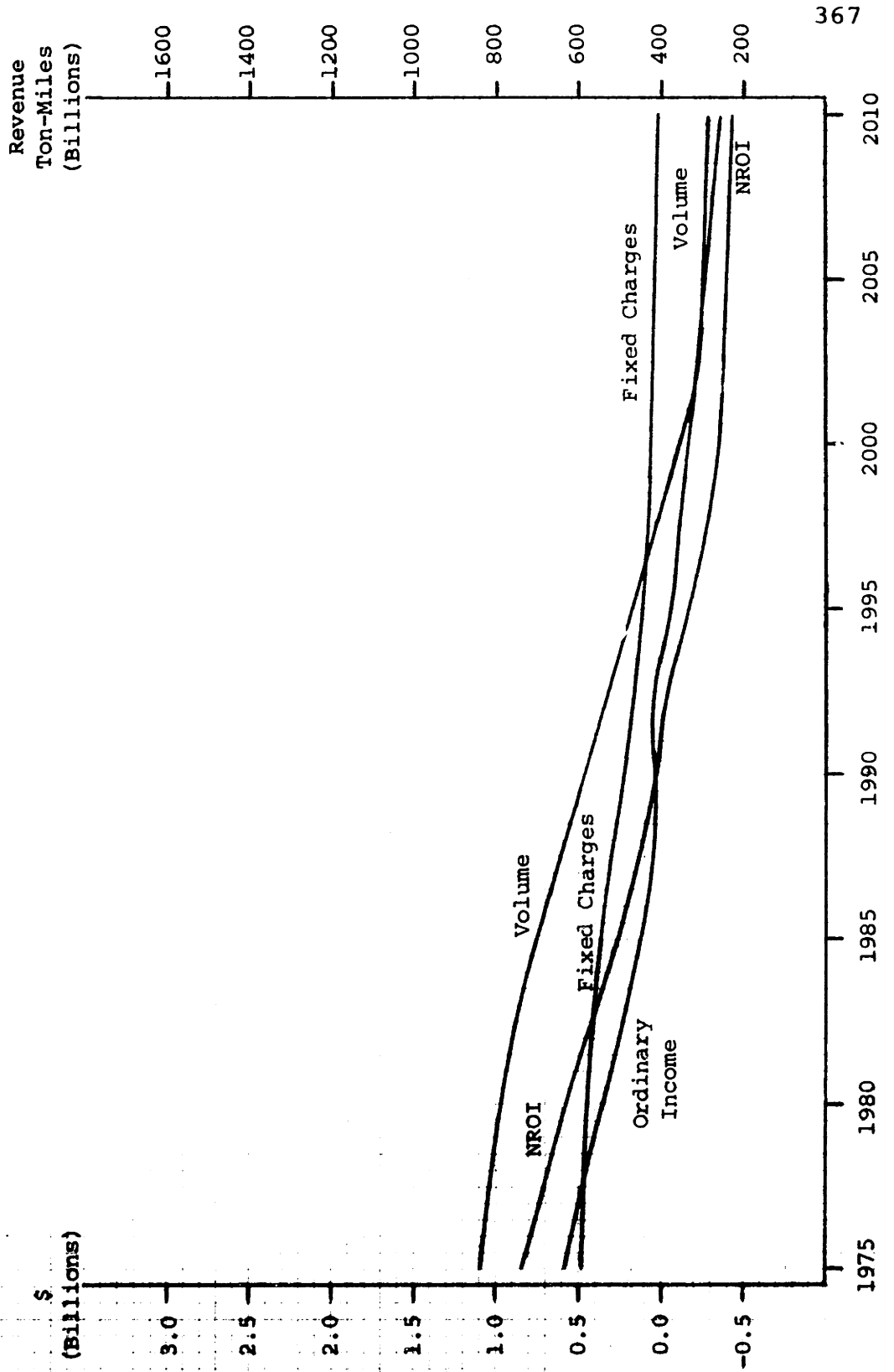
Due to the assumed dividend, investment, and financing policies, which reduce uses of internal funds if net working capital is falling within the range of \$±100 million, conditions must become rather dismal in order to cause insolvency. Due to the mild nature of the quality effects assumed here, and because the industry is allowed to reduce investments in rolling stock if their interest coverage situation is worsening, conditions do not become so bad as to cause a significant decline in net working capital, as Figure 5-8 indicates. Thus, other income, which is affected by the interest earned/paid on increasing/decreasing net working capital, stays fairly constant through 2010 and has no noticeable effect on ordinary income.

In the next two cases, where stronger quality effects are assumed and investment cutbacks in rolling stock are not allowed, the behavior of net working capital is much different.

5.2.3 Case III: Base Case - Strong Quality Effects.

This case, which assumes strong quality effects, has similar, but more pronounced results than the previous case. Again, inadequate maintenance of way is assumed.

FIGURE 5-9
BASE CASE - STRONG QUALITY EFFECTS



Due to a doubling of the quality effects at any level of system deterioration, the effects of increasing the maintenance backlog by \$16 billion would be a 30% increase in total pretax expense if volume stayed at its 1975 level. The results for this case are given in Figures 5-9 and 5-10.

In comparison to the previous case, NROI is falling more rapidly here between 1975 and 1980 as a result of the stronger effects of declining quality on operating costs. This rapidly declining NROI causes poorer interest coverage to occur sooner, so debt issuance is lower than in the previous case. Thus, fixed charges decline from the start in this case, and the associated lower rate of investment in rolling stock causes capacity and hence volume to decline more rapidly, further aggravating the decline in NROI.

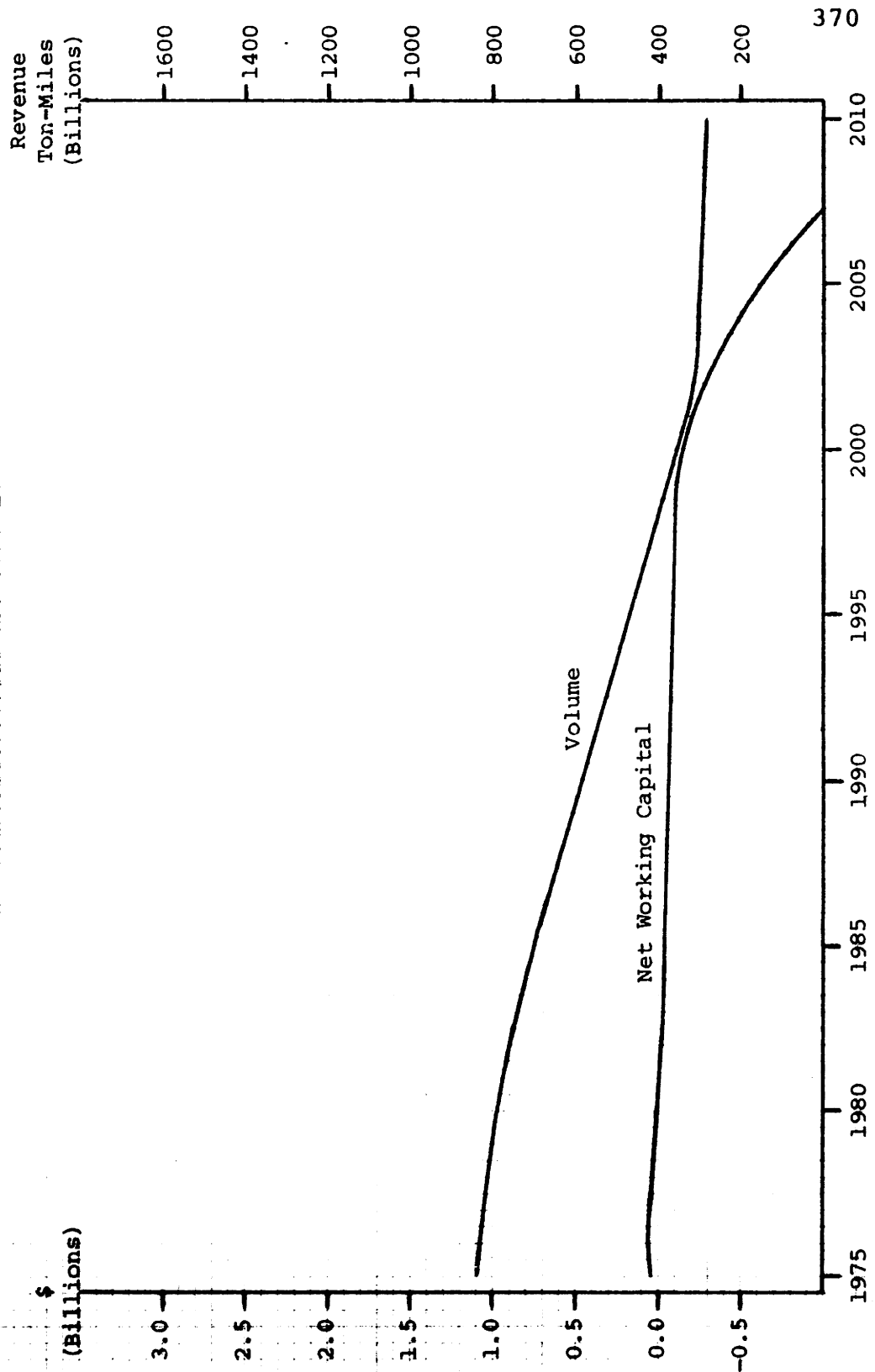
Between 1980 and 1990, rising unit costs due to the declining quality, and declining volume cause NROI to rapidly fall and to hit zero by 1990. At this time, the quality of facilities cost multiplier, shown in Figure 5-1, has only reached 1.34 giving a 34% increase in the cost categories it affects, while productivities have only fallen 7%. Thus, these "strong" effects can be seen to cause significant earnings decay, in spite of the fact that they do not represent excessive changes in the costs they affect.

After 1990, NROI continues to decline, but in a decel-

erating manner due to a slowing of the dynamic increases in costs caused by quality degradation. These effects are slowing down due to a slower rate of quality decline associated with lower volumes and due to the quality being low enough so that the left-hand lower sloped portions of the quality effect curves are being traversed. Volume reduction also prevents NROI from becoming extremely negative, as average NROI expense is greater than average revenue per ton-mile when NROI is negative, so lower volumes give a lower total loss.

The rapid fall in NROI through 1990 caused increasingly worse interest coverage, because fixed charges could not be reduced as quickly due to the terms of the associated debt. This led to reduced rates of investment in rolling stock and therefore falling volume. After 1990, negative NROI detracts from other income's ability to cover fixed charges (other income remains fairly constant at about \$230 million through 1998, and then is reduced by the interest charged on the rapidly declining net working capital), and investment in rolling stock is thus continuously reduced till it hits zero by about the year 2000. This causes further volume reductions after 2000, as equipment is retired while none is installed, and leads to fixed charges approaching zero due to the absence of new debt issues after 2000 and due to the low rates of debt issu-

FIGURE 5-10
BASE CASE - STRONG QUALITY EFFECTS



ance between 1990 and 2000.

As in the previous case, net working capital slowly declines through the year 2000. However, after 2000, worsening negative ordinary income combines with remaining debt obligations to cause an outflow of funds in excess of the sources available from the dwindling depreciation and cash supplied by asset disposals (both are declining due to the falling amount of rolling stock). This causes a drain on net working capital, and it therefore becomes very negative after the year 2000. This drop in net working capital further aggravates the decline in ordinary income which is helping to cause it, as the industry is charged 10% per year on declining net working capital, and this shows up as a reduction in other income, and hence in ordinary income.

Thus, the sensitivity of the overall behavior patterns to the assumed quality effect functions is rather minor. Both this and the previous case exhibited similar aspects of decay, although the rates and extent of the decay depended on the quality functions in effect. One noticeable difference between the two cases was that with strong quality effects, financial conditions became bad enough so as to overcome the "stickiness" of the zero net working capital range, and led to insolvency. However, this result is in part dependent upon the assumption of fixed network size.

If volume was indeed reduced to 300 billion revenue ton-miles from its current level of about 850 billion, the industry would undoubtedly be attempting to rationalize its network. These abandonments, were they allowed by the agencies which regulate the railroad industry, would reduce property taxes and would provide more cash from asset disposal than is captured by the model. Thus it is possible that the situation would not be as dismal as the output indicates.

In both this case and the preceding one, the constraint on equipment debt allowed the industry to reduce its capital expenditures on equipment if their interest coverage was such that additional fixed charges could be detrimental to income. This in turn led to falling capacity and volume, and interacted with increasing costs to cause rapid declines in NROI. The question arises as to how things might differ if volume were allowed to grow, so that volume decay would not further the effects of increasing costs in pulling NROI down. The next case deals with this issue.

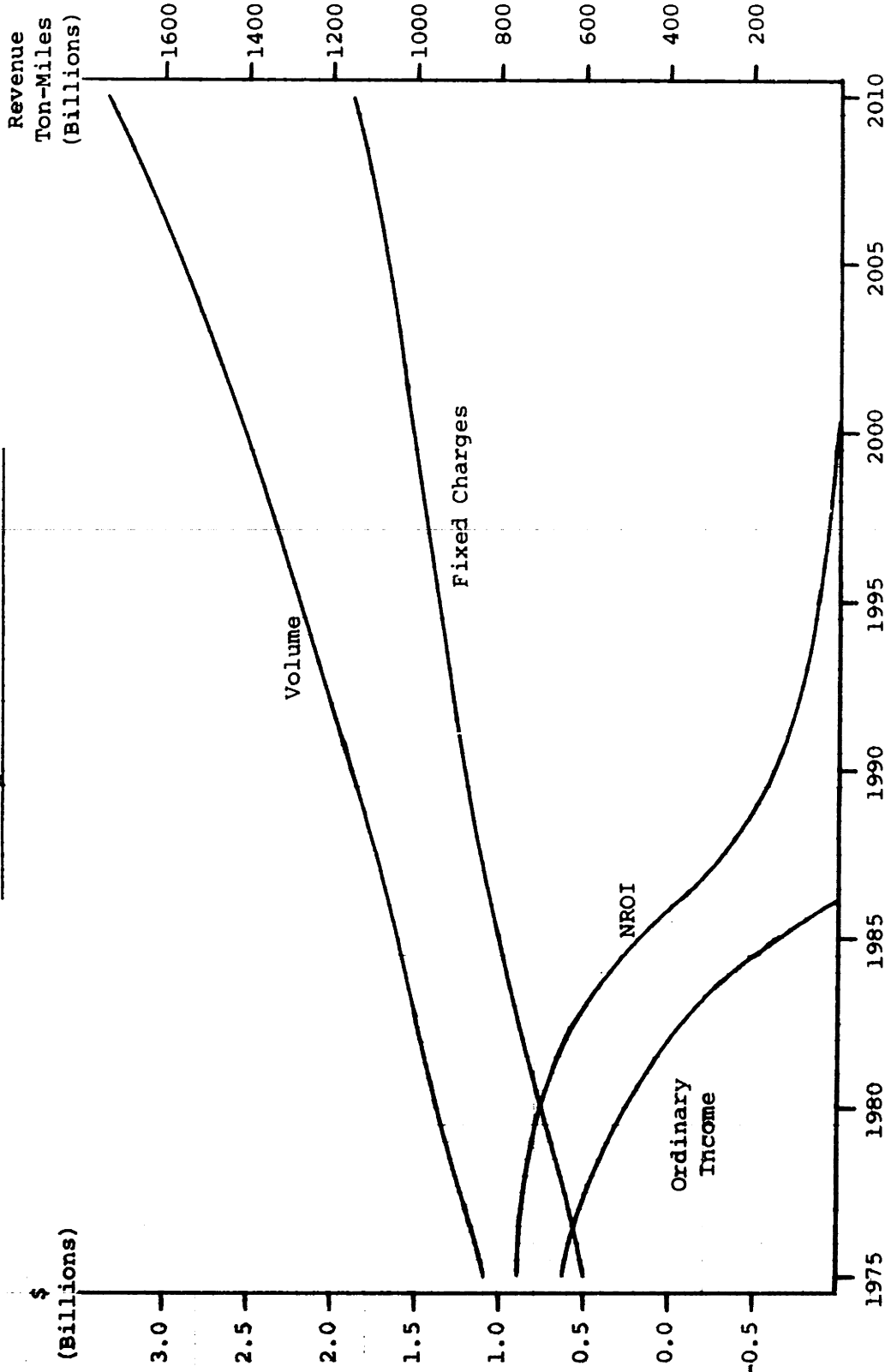
5.2.4 Case IV: Base Case - Mild Quality Effects, 8% Interest Rate, and No Equipment Debt Constraint.

In this case, both the constraint on equipment debt is relaxed and the interest rate on new debt issues is reduced

from 10% to 8%, beginning January 1, 1976. The debt constraint was relaxed so that the joint effects of volume growth and quality decline could be studied. The interest rate was reduced in an attempt to make volume growth more profitable, as the previous cases exhibited difficulty in maintaining adequate interest coverage. Judging by the behavior previously exhibited in Figure 5-7, where the equipment debt constraint was in effect and interest rates were at 10%, initial expectations as to the outcome of this case might be along the lines of growth with some degree of profitability. However, as is evident in Figures 5-11 and 5-12, the financial results of this case are extremely dismal, in spite of the mild quality effects assumed. The results would be worse with strong quality effects, so a case similar to this one with strong quality effects need not be presented.

The observed results in this case are partially due to the specification of the maintenance policy in the model, and their explanation yields some interesting ideas. The model's minimal maintenance policy is stated in terms of performing a certain percentage of wear and tear on the system. Since wear and tear increases with volume, under this type of policy the amount of maintenance deferred per year increases with volume. Thus quality falls faster and unit costs increase more rapidly if volume grows quickly.

FIGURE 5-11
BASE CASE - MILD QUALITY EFFECTS, 8% INTEREST RATE,
AND NO EQUIPMENT DEBT CONSTRAINT



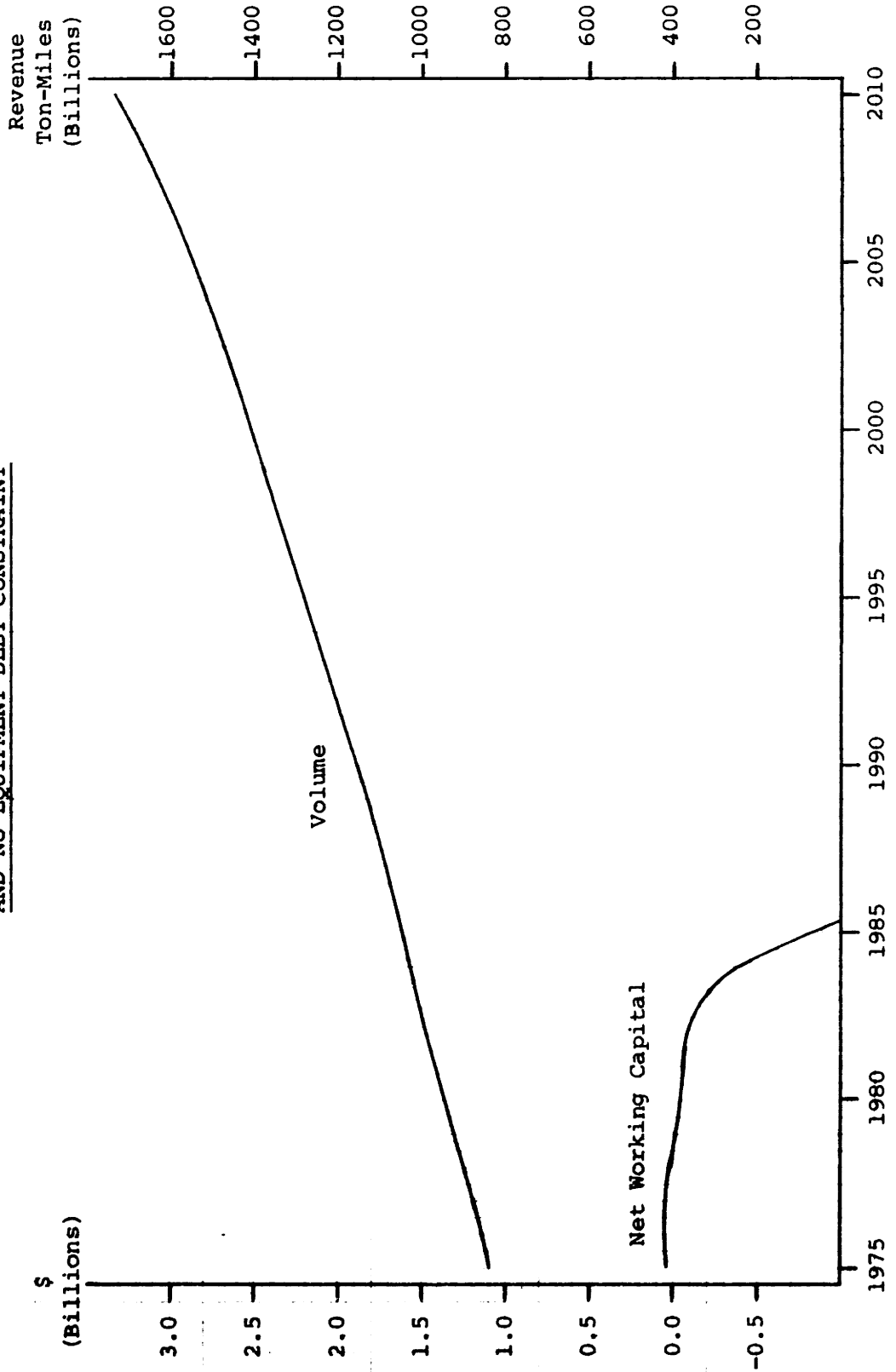
This occurred in this case, and "total deterioration" of the system quality occurred by 1990, whereas this was delayed until 2010 in Case II. Thus, in situations where a certain percentage of necessary maintenance is deferred each year, the result will be quicker quality degradation and unit cost escalation if the volume of traffic is growing.

Another important factor leading to the observed results is that quality of the fixed facilities has its biggest impact on operating costs, which are highly variable. Since variable costs comprise a larger fraction of total cost as volume grows, a percentage increase in these costs due to quality degradation means a larger absolute increase in total cost at higher volumes.

Thus, the rapid decline in NROI in Figure 5-11 can be attributed to faster quality degradation and cost escalation resulting from a "percentage rule" maintenance policy coupled with growing volume as well as to the fact that declining quality has a greater absolute impact on costs in a high volume situation. In other words, the model indicates that more traffic can cause decreased profitability if expenditures on way and structures are inadequate, and particularly if they are determined by a "percentage rule" policy.

The fact that declining quality has a greater absolute

FIGURE 5-12
BASE CASE - MILD QUALITY EFFECTS, 8% INTEREST RATE,
AND NO EQUIPMENT DEBT CONSTRAINT



impact on costs in a high volume situation is especially important in considering continued maintenance deferral in the light of the growing needs for rail service. It is also important in considering quality upgrading, as the benefits associated with a higher quality system will also increase with volume, due to the dependence of variable costs on system quality.

Also of interest is the behavior of ordinary income and net working capital. Ordinary income falls more quickly than NROI due to the increase in fixed charges associated with the unconstrained issuance of debt. This declining income, coupled with the increasing debt repayments necessitated by the high rate of investment in rolling stock,¹ leads to massive insolvency by 1985, as net working capital approaches \$-1 billion, and is accelerating downward, never to turn up again.

Thus, in dealing with the financial performance of the railroads if left alone to decide their actions under the assumed future conditions, the equipment debt constraint can be seen as a built-in control mechanism that prevents insolvency and bankruptcy. It is also realistic, as it

¹ It should be recalled from Section 3.3.3 that new debt issues in the model entail annual repayments beginning as soon as the debt is issued, in correspondence with the general nature of actual equipment debt instruments such as equipment trusts.

would be impossible for the industry, if generally insolvent, to issue further equipment debt without government aid of some sort. Inasmuch as alternatives which are internal to the industry are of primary interest here, the equipment debt constraint will remain in effect for most of the cases analyzed. Those changes which will foster profitable volume growth in the model, in spite of the constraint, are the ones being sought.

The preceding cases indicated that even with mild quality effects, continuing quality degradation can have serious effects on the financial future of the industry, given the assumed future scenario. The next case is presented as further evidence of the importance of system quality in determining long-run profitability.

5.2.5 Case V: Drastic Improvement In Labor Productivity - Mild Quality Effects.

The previous four cases all operated with the same basic assumptions about the future, and all led to continuing poor performance on the part of the industry. This continued poor performance was due in part to the assumed industry cost structure, and was strongly influenced by the effects of continued quality degradation on costs. In this case, a drastic change is made in the nature of industry costs, and the long-term effects of quality degradation

again have an important impact on the industry's financial performance. This further emphasizes the role of system quality in determining the long-run health of the industry, and sets the stage for all the remaining cases, in which a quality improvement program is one of the system changes considered throughout.

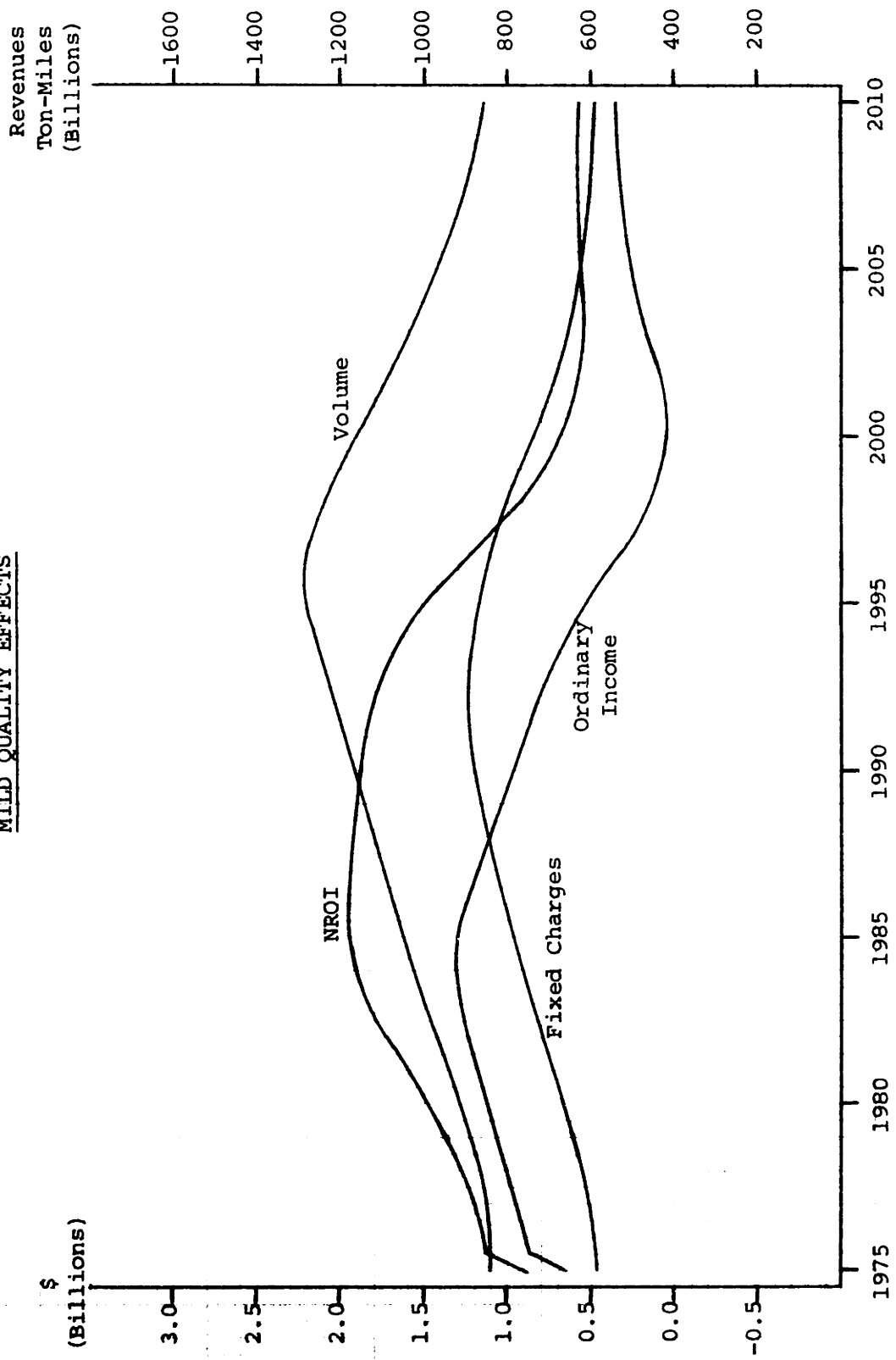
The major change made to the industry cost structure here has to do with TTGM labor productivity. Beginning in 1976, the number of TTGM employees required at any level of volume is reduced to 75% of what it would normally be, indicating a 33-1/3% increase in the productivity of these employees. Furthermore, a productivity-related pay increase is not given to the remaining employees due to this work force reduction. Rather, they continue to receive cost of living raises and "normal" productivity raises that would have accrued without the work force reduction. (These normal productivity raises are tied to the TTGM labor productivity function presented in Figure 3-2, which interacts with the quality of the fixed facilities through the mild productivity multiplier depicted in Figure 5-2 to determine the dynamic course of normal labor productivity.)

This 25% reduction in TTGM employees corresponds to a 40% reduction in transportation employees, based upon the 1973 composition of TTGM employees, as computed in Appendix B. Thus, this reduction might be achieved by a 67% in-

crease in transportation labor productivity, possibly effected by drastic changes in the work rules that tend to promote low utilization of the labor resources involved in operating the trains and yards of the industry. While such a major change is unlikely due to its severity (approximately 72,000 men would be laid off at current volume levels), it is considered here because of the financial impact it could have. It is assumed that the industry does not compensate any employees laid off. Thus, this work force reduction represents a major cost reduction for the industry and a variable cost reduction, as the savings grow with volume.

To indicate the magnitude of the savings possible, model-computed TTGM labor cost (which includes fringe benefits) for the year 1975 is approximately \$5.55 billion (current dollars). Ignoring inflation and normal changes in labor productivity, if volume remained the same in 1976, the saving would be 25% of \$5.55 billion, or roughly \$1.4 billion current dollars (approximately 900 million 1967 dollars) per year, and the saving would increase approximately proportionally with volume. In spite of this drastic saving, the financial future of the railroad industry, as presented in Figures 5-13 and 5-14, is surprisingly poor in the long run. The major reason for the ultimate failure of this cost change in promoting long-term profitable growth

FIGURE 5-13
DRASTIC IMPROVEMENT IN LABOR PRODUCTIVITY -
MILD QUALITY EFFECTS



is that quality of the fixed facilities is again allowed to deteriorate, and even with the mild quality effects assumed here, this deterioration escalates costs enough to eventually overcome the benefits of the high labor productivity increase. In other words, the effect of the labor savings is to merely postpone the decay evident in the previous cases, given a similar maintenance policy.

With regard to Figure 5-13, NROI jumps by about \$250 million in 1976 as the labor productivity improvement takes effect. The total labor cost savings in that year are \$900 million, but this saving is used to increase maintenance of way by \$550 million, leading to a before-tax income increase of \$350 million, of which about \$100 million goes to additional income tax. So maintenance of way is increased initially in spite of the "minimal" maintenance policy in effect. This is due to the nature of the maintenance policy built into the model. If revenues and costs before maintenance of way are such that more than minimal maintenance can be performed and still lead to a return on investment (NROI divided by net investment) equal to the average interest rate on the outstanding debt, then this additional maintenance is carried out. This policy, while not necessarily realistic in terms of its definition, is however representative of a concern for current reported earnings in planning MW expense, as is not uncommon in the

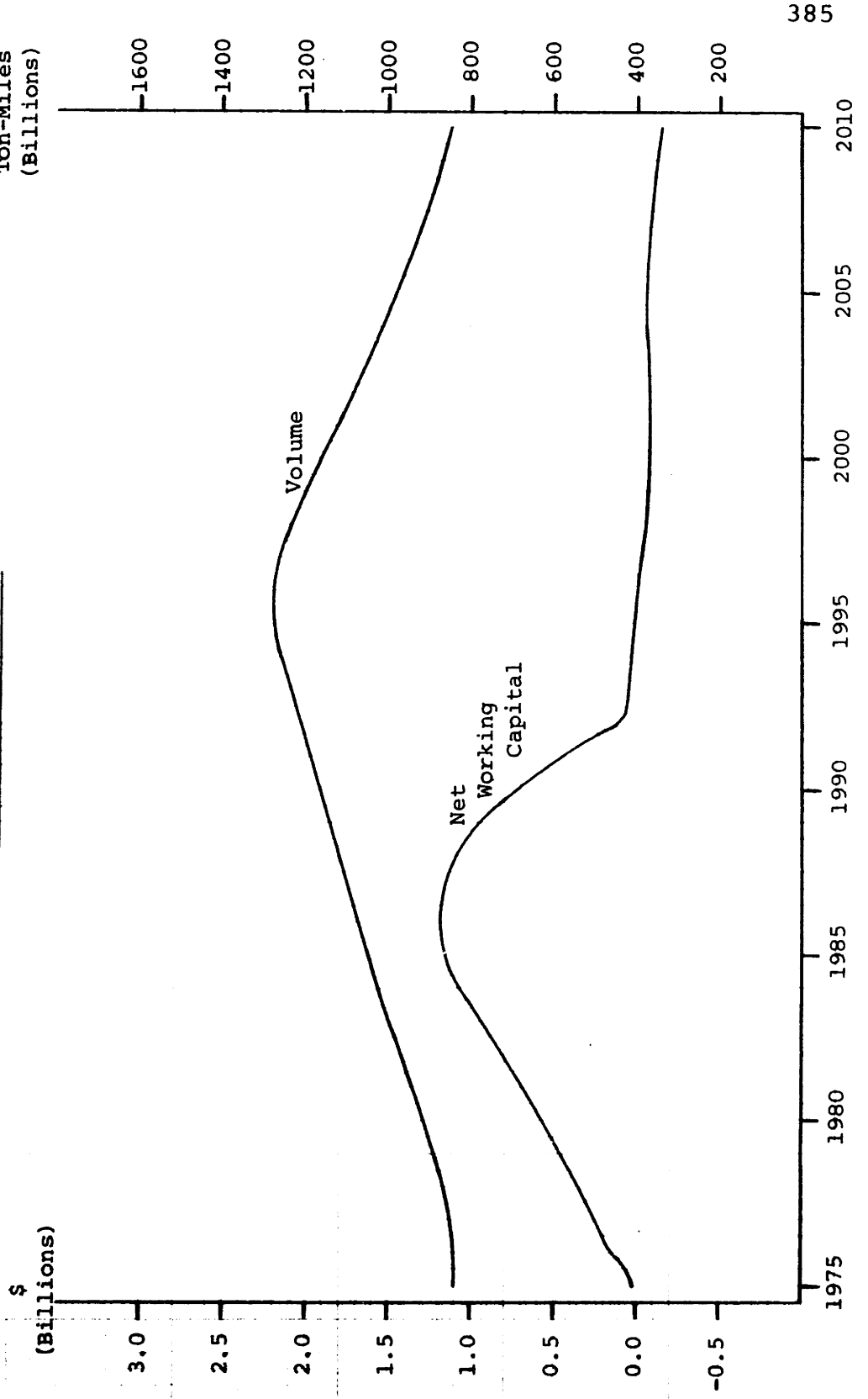
industry today [3]. That is, the maintenance policy built into the model is representative of the fact that MW expense in actuality is often cut back or deferred as a means of raising reported earnings in the short-run, in spite of the long-term consequences of these deferrals. Thus, in this case, although more than "minimal" maintenance is performed initially, a long-range maintenance policy is not in effect. Rather, MW expense is determined on the basis of the minimum necessary (as dictated by the wear and tear rate), plus any "slack" that exists in the present financial statements. As will be evident in the ensuing discussion, this policy again leads to quality decay and finally to poor financial performance.

The initial jump in earnings in 1976 improves the interest coverage situation, so more equipment debt is available and is used. Thus, capacity, volume, and fixed charges grow through 1985, with capacity catching up to demand by 1983. The growing volume aids in promoting a faster increase in NROI, which increases from \$1130 million in 1977 to \$1950 million in 1985, a 73% increase in spite of a 25% increase in volume over this period. The marked increase in NROI is partially due to the variability inherent in the labor savings; as these savings grow with volume. However, this increase also results from the behavior of maintenance of way expense through 1985.

In spite of the increasing volume, maintenance of way remains at a constant level of about \$2 billion per year. This is caused by the short-term return on investment policy governing MW over this period. Due to rapid increases in net investment caused by the influx of a lot of new equipment (which has little accumulated depreciation on it), and due to the quick rise in the average interest rate on outstanding debt caused by the issuance of a lot of debt (at 10%) to finance these equipment purchases, the amount of additional MW that can be supported (besides that dictated by the wear and tear rate and the minimum expenditure percentage) declines over this period. Thus maintenance of way remains at a constant level, allowing return on investment to rise with the average interest rate on outstanding debt through 1985.

By 1985, volume has sufficiently increased so that the minimum amount of maintenance of way associated with the wear and tear rate surpasses the \$2 billion per year level maintained through this time, and thus becomes the determining factor in maintenance outlays. Whereas the additional outlays on maintenance prior to 1985 led to a minor improvement in system quality, and thus aided somewhat in the growth of NROI through the associated reductions in costs, after 1985 quality begins to fall as maintenance and investment in way are again less than neces-

FIGURE 5-14
DRASTIC IMPROVEMENT IN LABOR PRODUCTIVITY -
MILD QUALITY EFFECTS



sary to maintain constant quality. The associated increases in costs become evident as NROI is slowly declining over 1985-1990 in spite of growing volume over this period.

Examining Figure 5-14, net working capital is seen to grow to a healthy \$1.2 billion by 1985. This is the result of the maintenance policy in effect, as the concern for current reported return on investment causes some, but not enough, of the labor savings to be allocated to quality improvement. A lot of the labor savings therefore end up as increased cash flow, which helps to raise net working capital up from its dismal 1975 level. This is another example of the emphasis placed on short-term profitability, as the benefits accruing from the labor savings are used to raise interim profits and are channelled into short-term investments (earning 10% per year) that raise the level of net working capital, rather than being used for long-term "investments" in way.

Thus, the enormous savings in labor costs coupled with the assumed maintenance of way policy lead to impressive financial performance in the short run. After about ten years however this emphasis on short-term profitability begins to take its toll. Quality begins to decline after 1985, leading to increasing unit operating costs and thus slowly declining NROI through 1990, in spite of

increasing volume. Over this same period, fixed charges are rising (and thus ordinary income is falling) as interest coverage is still adequate enough to allow debt issuance and capacity expansion commensurate with demand growth. However, falling ordinary income detracts from the industry's ability to meet its debt obligations and simultaneously keep net working capital growing. Thus, by 1990, net working capital has begun its decline back down towards the zero level.

By 1993, quality has sufficiently declined that the quality multiplier for costs has increased the costs it affects by 10%, while productivities have fallen by 2%, and these effects are accelerating with time due to the rapidly deteriorating system quality. Thus NROI begins to fall rapidly, worsening the interest coverage situation. Debt issuance is therefore reduced, and fixed charges begin to fall. Soon thereafter, the decreasing rates of equipment installations are surpassed by the high rates of retirements occasioned by the past high rates of installations. Volume therefore begins to decline after 1995 due to decreasing capacity, and this falling volume combines with increasing unit costs (due to declining quality) to further the decline in NROI. Rapidly declining NROI over 1995-2000 causes ordinary income to approach zero, as the "fixedness" of fixed charges prevents them from falling as

quickly as NROI.

Around the year 2000, total system deterioration has occurred, with productivities down by the maximum 5% and other quality-affected operating costs up by the maximum 30%. Due to the deceleration of quality effects towards their ultimate levels, as caused by the shapes of the functions in Figures 5-1 and 5-2, NROI decelerates in its descent just prior to 2000, allowing ordinary income to bottom out at zero.

After the year 2000, volume continues to decline, but NROI is fairly constant. This strange phenomenon is due to the nature of the wear and tear function, which for volumes over 500 billion revenue ton-miles allows maintenance of way to decrease more than proportionately to volume, due to its convex shape. Since the poor system quality has increased the slope of this function, this effect is more pronounced, and leads to costs and revenues falling at the same rate, and hence to constant NROI with falling volume in this case. Constant NROI in turn combines with falling fixed charges to allow a slight rebound in ordinary income after the year 2000.

This case has some rather important implications, as it shows the importance of system quality on the long-term performance of the industry, and indicates how policies concerned with current earnings can detract from long-term

financial health. In spite of a rather unrealistic improvement in labor productivity, the industry ends up worse off in 2010 than they are now, as volume and fixed charges in 2010 are again at their 1975 levels, but earnings are lower. The industry did not achieve long-run health even though the effects of quality degradation were assumed to be mild in this case. (A similar case was run with strong quality effects, and the results were the same, only more pronounced. Thus this case will not be presented.)

The importance of system quality in determining long-term financial health, and the need for policies that have long-run perspectives as a means of maintaining or improving system quality is apparent. The following cases are therefore centered around a quality improvement program. Such a program, while reducing reported earnings in the near-term due to increased maintenance of way expense, can strengthen the long-term performance of the industry. This is the exact opposite of the results of maintenance policies which are concerned with short-term profitability and is due to the fact that such maintenance policies act in accordance with the earnings deterioration cycle associated with maintenance deferral, responding to it by deferring maintenance to raise reported earnings, and thus feeding it by the resultant increases in operating costs.

A quality improvement program, on the other hand, ignores the level of current earnings for the sake of long-term health, and can reverse the deterioration cycle, causing earnings growth and long-term health.

5.2.6 Case VI: Quality Improvement Program - Mild Quality Effects.

This, and subsequent cases, are concerned with the improvement of the quality of the industry's fixed facilities. Due to continuous maintenance and investment deferrals in the past, the quality of these facilities has declined to a level that is substandard in terms of the age, condition, and type (i.e., rail weight) of the assets used to provide right-of-way [5]. The improvement program dealt with here is aimed at bringing the fixed facilities up to "standard", through the elimination of these previously deferred expenditures.

It is estimated that the present (1975) industry-wide backlog of deferred maintenance of way is on the order of \$10 billion (current dollars).¹ As discussed in [5], this estimate possibly overstates the amount of deferred maintenance that would actually be considered in a quality up-

¹ This discussion of the estimated actual maintenance backlog and annual underspending is drawn from [4] and [5].

grading program, though, as it includes the deferrals associated with lightly used branch lines which might be abandoned or left at their current quality. However, this estimate is felt to be indicative of the total expenditures (including improvements which are accounted for as investments) necessary to raise the quality of those fixed facilities which receive reasonable usage up to the standards required by today's heavier and more track-demanding loads. Furthermore, it is estimated that the annual maintenance (i.e., expenditure, if the above qualifications are taken into account) budget shortfall could be as high as \$1 billion (current dollars).

The magnitude of the quality improvement program modelled is similar to that indicated by the above (approximate) numbers in order to achieve a fair degree of realism. In the model, the expenditure (maintenance and investment) backlog is computed to be on the order of \$12.5 billion (current dollars) at the end of 1975, with annual maintenance and investment expenditures for way and structures being about \$500 million (current dollars) too low to maintain current quality. While these model figures are not exactly the same as the above estimates, they are close enough to approximate the "true" (unknown) values indicated by these estimates.

In terms of the 1967 dollars which will be discussed

in the case analyses, the model must eliminate a backlog of about \$8 billion and increase annual expenditures by approximately \$300 million (at current volume levels) in order to prevent further deferrals from accumulating. As explained in Section 3.4.3, the quality gap associated with the deferral backlog will be closed at the rate of 10% per year, so that the expenditure backlog will be eliminated in an exponentially decaying manner. That is, of the \$8 billion to be made up, \$800 million will be taken care of in the first year of the program (1976), leaving \$7.2 billion of previously deferred expenditures at the end of 1976. In 1977, therefore, 10% of the remainder, or \$720 million of the backlog will be eliminated, etc. In this manner, the total backlog is almost completely eliminated by the year 2000. (It is never completely eliminated due to the exponentially decaying manner in which the backlog is made up. However, by 2000, 90% of the backlog is eliminated, and quality has been raised to \$39.2 billion from its 1973 value of \$32 billion.) Besides eliminating the previously accumulated backlog of deferred expenditures, the quality improvement program must raise annual expenditures on way and structures from what they would be under the base maintenance policy, as this policy allows additional deferrals of expenditures each year. In 1976, the increase necessary to prevent further deferrals of expendi-

tures from occurring in that year is \$300 million, so that in total, an additional \$1.1 billion will be spent in 1976 to start off the quality improvement program. It is assumed that approximately 80% of this will be charged to expense, based on the historical split between maintenance and investment outlays, so that approximately \$880 million will appear as maintenance of way expense on the income statement. Given the assumed 20% tax rate, after-tax earnings will therefore drop by about \$700 million in the first year of the program.

Mild quality effects are assumed in this case. Hence, as system quality approaches its desired level (i.e., as the backlog of deferred expenditures approaches zero) there would be approximately a 10% reduction in the costs affected by the quality cost multiplier of Figure 5-1. (Because the backlog is never completely eliminated, a 10% reduction is never achieved, but is approached asymptotically. However, the reduction is approximately 10% as the backlog approaches zero.) That is, as system quality approaches its desired level of \$40 billion, there would be approximately a 10% reduction in fuel usage, TTGM other costs, and maintenance of equipment. There would also be approximately a 10% reduction in the wear and tear rate, and hence in necessary MW expense (other than the expense associated with eliminating past deferrals, which is approximately

zero once the backlog is substantially reduced). Also, TTGM labor and rolling stock productivities would increase by about 2% if system quality approached its desired level, as depicted in Figure 5-2. Hence, the costs affected by these productivities, specifically TTGM labor costs, fixed charges, and depreciation, would fall by about 2%.

Relative to a case in which MW expense was only raised sufficiently to keep quality at its 1975 level (i.e., one in which past deferrals would not be made up, but MW expense would be at the "necessary" level dictated by the wear and tear rate), a total annual savings of about \$600 million would be eventually achieved. That is, based upon model computations for 1975 costs, the (approximate) 10% reductions in fuel usage, TTGM other costs, maintenance of equipment and necessary maintenance of way would cause savings of about \$500 million per year, and the productivity-related costs would be reduced by about 2%, or \$100 million per year. This total annual savings of \$600 million accrues at 1975 traffic levels, and will be greater if volume exceeds its current levels due to the long-run variability of all the costs affected by the quality of the fixed facilities.

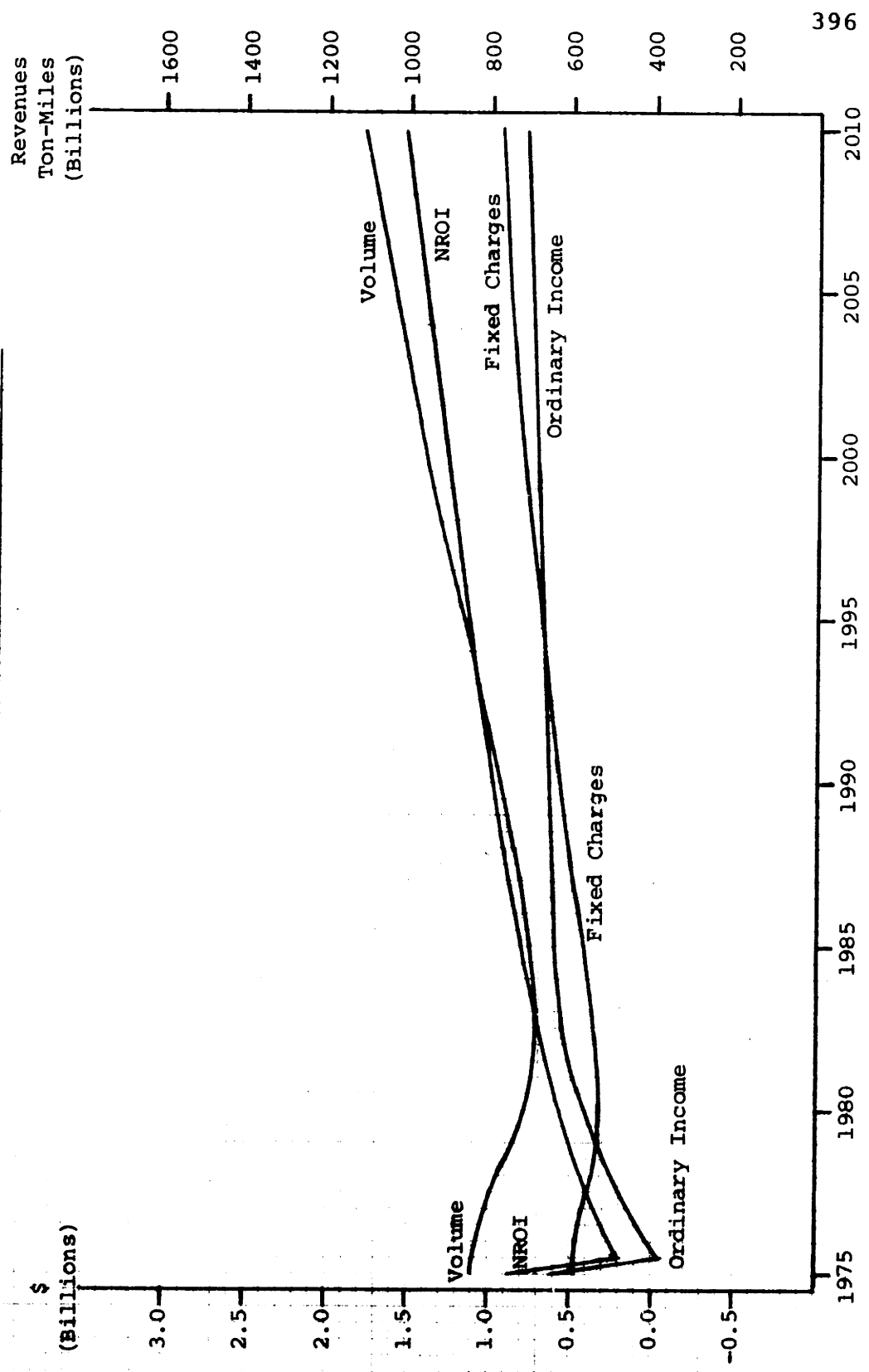
As in most of the previous cases, the constraint on equipment debt is in effect as a means of preventing the industry from borrowing itself into insolvency. This con-

straint will be relaxed in Cases VIII and IX to indicate the impacts of a quality improvement program undertaken simultaneously with volume growth.

The results of this case are presented in Figures 5-15 and 5-16. As previously explained, NROI and ordinary income both initially drop by \$700 million as a result of that portion of the 1976 additional maintenance outlays charged to expense. The drop in NROI causes extremely poor interest coverage, resulting in almost zero equipment debt issuance through 1978. Thus capacity, volume, and fixed charges begin to fall. In spite of the falling volume, earnings quickly rebound and grow. This is partially due to the reductions in unit operating costs caused by improving quality. However, the initial growth in NROI is primarily due to the exponential decay in those MW expenses which are associated with the 10% per year elimination of the maintenance backlog.

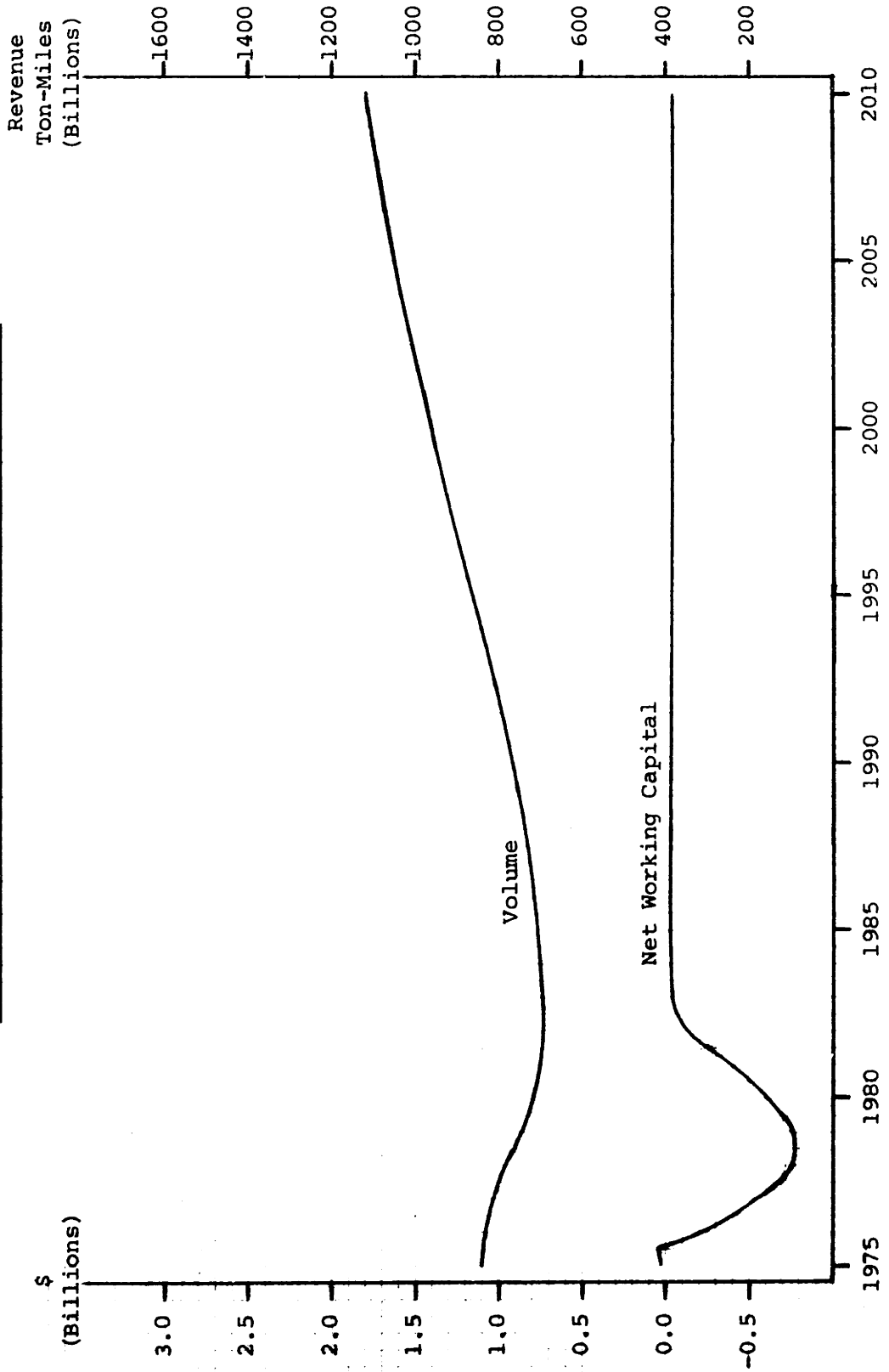
During the first five years of the quality improvement program, the additional MW expense outweighs the cost savings it causes enough to dictate a continual decline in fixed charges. However, as cost savings become more pronounced and fixed charges are reduced to an appropriate level, the capital costs of more equipment can be covered by the growing earnings. Thus, around 1981 fixed charges begin to grow, soon followed by capacity and volume.

FIGURE 5-15
QUALITY IMPROVEMENT PROGRAM - MILD QUALITY EFFECTS



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FIGURE 5-16
QUALITY IMPROVEMENT PROGRAM - MILD QUALITY EFFECTS



The initial behavior of net working capital is very interesting. Net working capital dips as the quality improvement program begins. This is because the program must be entirely financed by internal funds, as no unsecured debt is available. As soon as net working capital hits \$-100 million, dividends and cash expenditures on rolling stock are curtailed as a means of conserving funds, but the enormous outlays on way and structures cause total cash outflow (expenses, capital expenditures on way and structures, and debt repayments) to exceed inflows (revenues, other income, depreciation, and cash from asset disposals), thus net working capital continues to decline. About 1978, however, the reduced rate of debt repayments and fixed charges caused by the minimal debt issuance since 1976, coupled with reduced expenditures on way and structures (as the quality gap is closed), and decreasing unit costs, leads to a rebound in net working capital.

The interpretation and plausibility of the dip in net working capital perhaps requires some discussion. If in actuality the industry had \$800 million in unmet current liabilities, there might be widespread declarations of bankruptcy. The model does not explicitly deal with this problem, as was previously discussed. Rather, the industry is assumed to always stay in business, either by obtaining renewable short-term extensions on long-term debt obliga-

tions that cannot be met in the year they become due, or by obtaining renewable short-term loans (probably from the government) that allow them to meet all their other current liabilities. Additional long-term debt is ruled out as a possibility for supplying short-term cash needs. In any event, the industry is charged the prevailing interest rate (usually 10%) on negative net working capital, indicating that money is owed to someone, and has not yet been paid. Thus, negative net working capital is a measure of the industry's inability to meet its current obligations. In this case, the extent of this inability was on the order of \$800 million. Given the assumed future scenario, it may be interpreted that this amount of external aid was necessary in this case to see the industry through its temporary period of funds shortage.

The long-term effects of this quality improvement program are not impressive. Capacity is only expended to handle about 1100 billion of the 1700 billion revenue ton-miles of demand that exist in 2010. In spite of the 70% increase in NROI achieved with this 33% volume growth over 1975-2010, ordinary income only grows by 25%, and net working capital remains at approximately zero, as the change in the situation did not allow enough of an improvement to cause a better liquidity position. These specific long-run results are in part due to the model's policies and

parameterization, and do not necessarily represent the "true" future of the industry if it were to undertake a quality improvement program on its own. Rather, they represent the future, given the assumptions made. These assumptions will also be in effect for other cases to be analyzed, so the importance of comparing the outcomes of this case to those of the others is again emphasized.

The general nature of the outcome of this case is important, however. Compared to the base cases previously analyzed, which all led to industry decline due to the assumed maintenance policies, this case represents a striking reversal, as fairly profitable growth occurs. In this case, short-term concerns are ignored for the sake of quality improvement, and the result is an improved cost structure that is (somewhat) conducive to growth and capable of covering fixed charges. Due to the mild quality effects assumed, the "payoff" to quality improvement was not that striking monetarily, but it is still impressive directionally, compared to the decay evident in the previous cases.

5.2.7 Case VII: Quality Improvement Program - Strong Quality Effects.

The scenario for this case is identical to that of the previous case, except that strong quality effects are assumed. Thus, each dollar spent on improving the physical

plant has twice the marginal impact it had in Case VI. In terms of constant 1967 dollars, at current traffic levels, the ultimate annual savings resulting from a complete elimination of the maintenance backlog would therefore be on the order of \$1.2 billion relative to a case in which quality was kept at its current level. Again, the annual savings grow with volume due to the variable nature of the quality-affected costs.

The results of the quality improvement program with strong quality effects are depicted in Figures 5-17 and 5-18. Comparing these results to those of the previous case, it is seen that the behavior patterns here are similar to those previously discussed, and these patterns result again for the same reasons. However, in this case, NROI, volume, and fixed charges all rebound a bit more quickly and reach larger final magnitudes than in the previous case due to the additional cost savings achieved through quality improvement. The more pronounced reductions in unit costs achieved by quality improvement in this case put operating expenses more in line with fixed charges and revenues, so that interest coverage is better at any level of volume. Thus more equipment debt is available here, and capacity expansion proceeds rapidly, with capacity catching up to demand by 2005.

The effects of the quality improvement program on earn-

FIGURE 5-17
QUALITY IMPROVEMENT PROGRAM - STRONG QUALITY EFFECTS

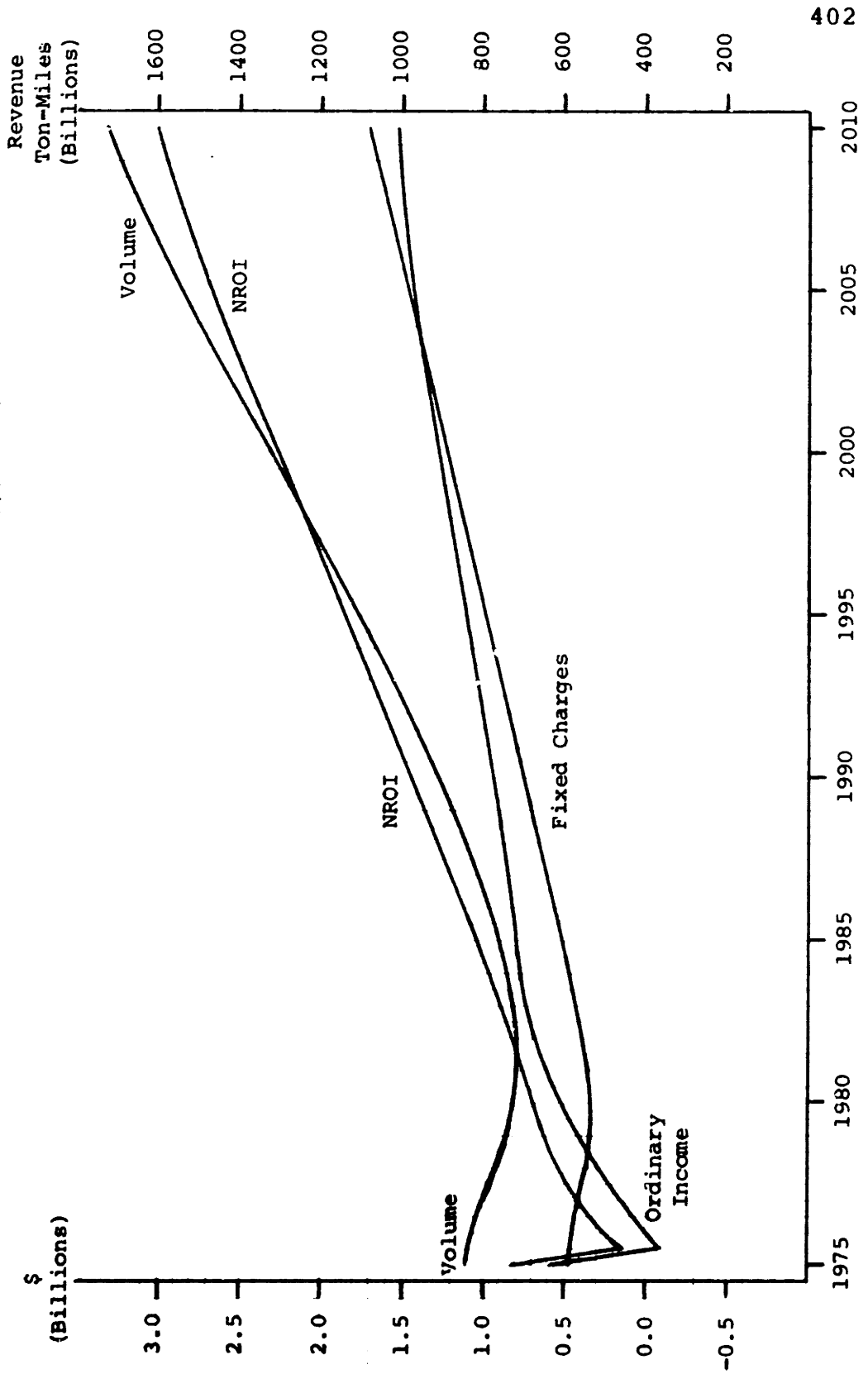
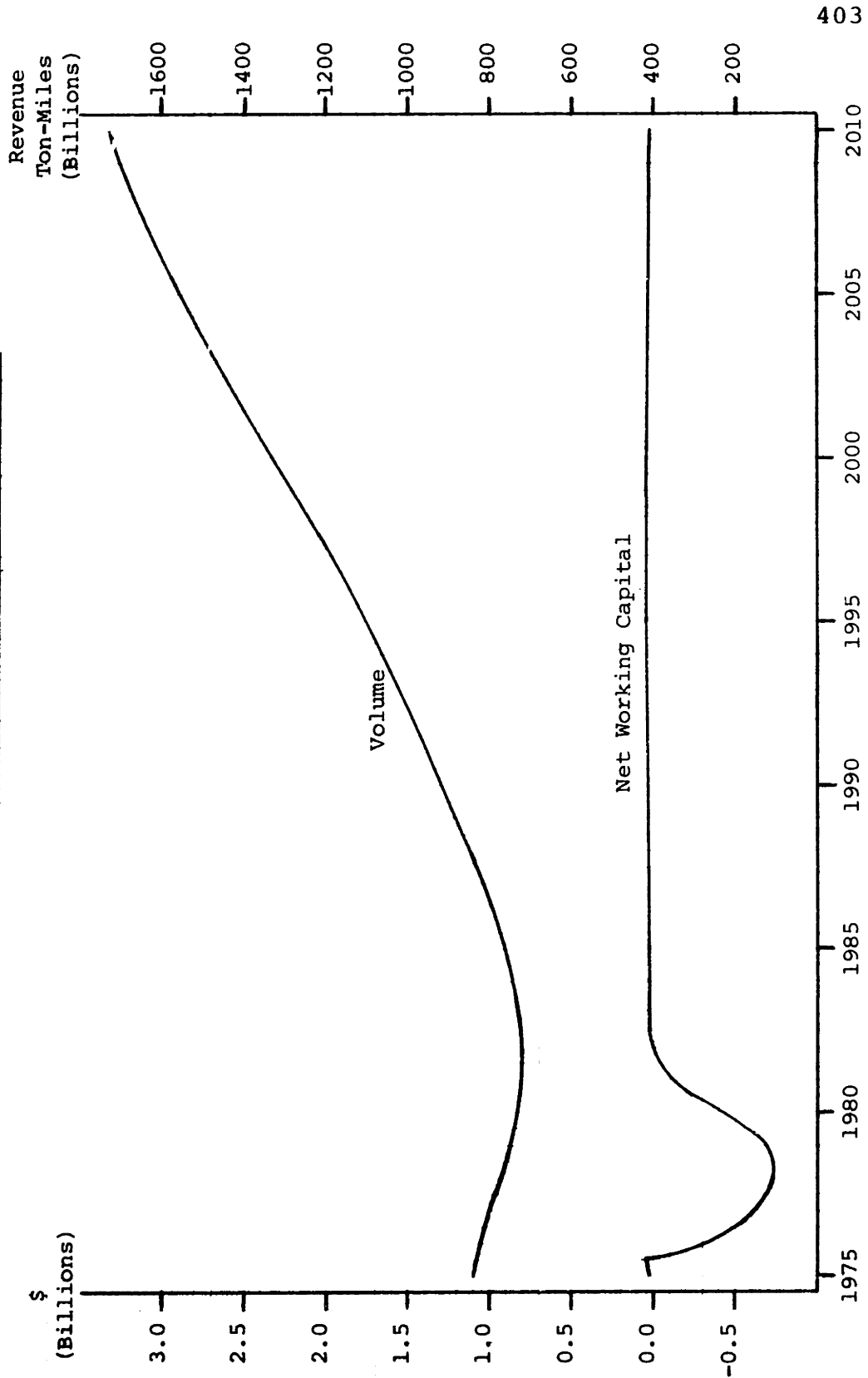


FIGURE 5-18
QUALITY IMPROVEMENT PROGRAM - STRONG QUALITY EFFECTS



ings are fairly dramatic, as a 105% increase in volume between 1975 and 2010 is accompanied by a 260% increase in NROI and a 160% increase in ordinary income. However, net working capital remains near the zero level after its initial dip down to \$-800 million. The similarity in the initial behavior of net working capital to that of the previous case is rather striking, as it falls to the same level in this case, and rebounds to zero only about one year sooner. This similarity is due to the minor effects that the slightly improved quality has on costs in the first few years of the improvement program, so that cash inflows in the two cases are about the same initially, as are cash outflows.

The poor long-run performance of net working capital in spite of the dramatic growth in earnings seems counter-intuitive. However, this behavior is in fact a result of the processes that are causing the earnings growth. Due to the priority given to volume growth in the model, the savings achieved by the reductions in operating costs are used to service the debt and fixed charges associated with the additional rolling stock required for the extra volume and earnings. It turns out that these savings are not sufficient to perform this task while simultaneously improving the liquidity situation. Thus, due to the policies and assumptions of the model, improved performance in this case

is manifested by more volume and profits and a continuing marginal level of net working capital. In some of the subsequent cases, alternatives will be tested that can further improve upon the results achieved here. Specifically, alternatives are sought that can promote growth, profitability, and a decent level of net working capital.

5.2.8 Case VIII: Quality Improvement Program - Mild Quality Effects, 8% Interest Rate, and No Equipment Debt Constraint.

Before turning to the analyses of quality improvement programs in conjunction with labor and equipment productivity improvements which complement the effects of higher system quality, the implications of unconstrained volume growth during a quality improvement program will be discussed. In the previous two cases, net working capital initially fell as the result of the "internal" financing of the quality improvement program, but quickly rebounded due to improved NROI and the decreased debt repayments and fixed charges caused by capacity contraction during the early years of the program. In this and the following case, the constraint on equipment debt is relaxed, beginning in 1976, in an attempt to study the tradeoff between more NROI and more debt and fixed charges, both of which are associated with the higher volumes possible without the con-

straint in effect. The tradeoff affects net working capital, as additional NROI adds to it, while additional fixed charges and debt repayments reduce it.

Due to the difficulty observed in the base cases with respect to maintaining adequate interest coverage with the assumed cost/rate structure, and since immediate cost changes due to quality improvement are small, an 8% interest rate is assumed here in an attempt to reduce the adverse effects that the equipment costs might have initially. This assumption might be representative of government-supplied or guaranteed loans aimed at aiding volume growth in the early stages of the quality improvement program, as the industry shunned such growth in the two previous cases where it was left alone to decide on its capacity expansion. (Again, it is emphasized that those cases represented hypothetical situations, since the industry most likely cannot legally forego growth.) As will become evident, this type of government aid is not sufficient if the industry is to simultaneously upgrade its physical plant and serve all the demand for its service, as a severe funds shortage will occur.

The outputs for this case are presented in Figures 5-19 and 5-20. Volume grows with demand through 2010, increasing to 1730 billion revenue ton-miles. Accompanying this 105% increase in traffic above its 1975 level is a

FIGURE 5-19
QUALITY IMPROVEMENT PROGRAM - MILD QUALITY EFFECTS,
8% INTEREST RATE, AND NO EQUIPMENT DEBT CONSTRAINT

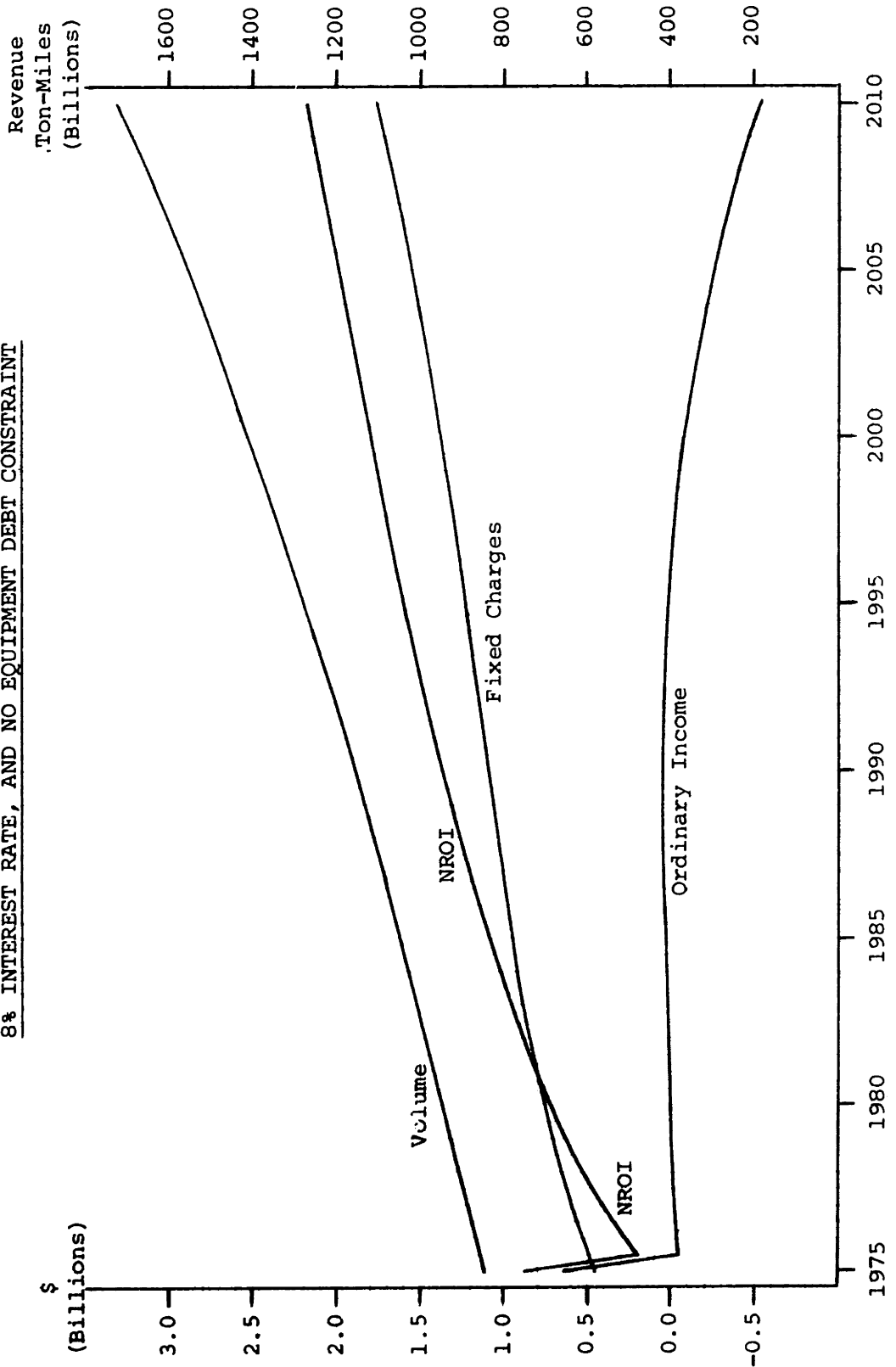
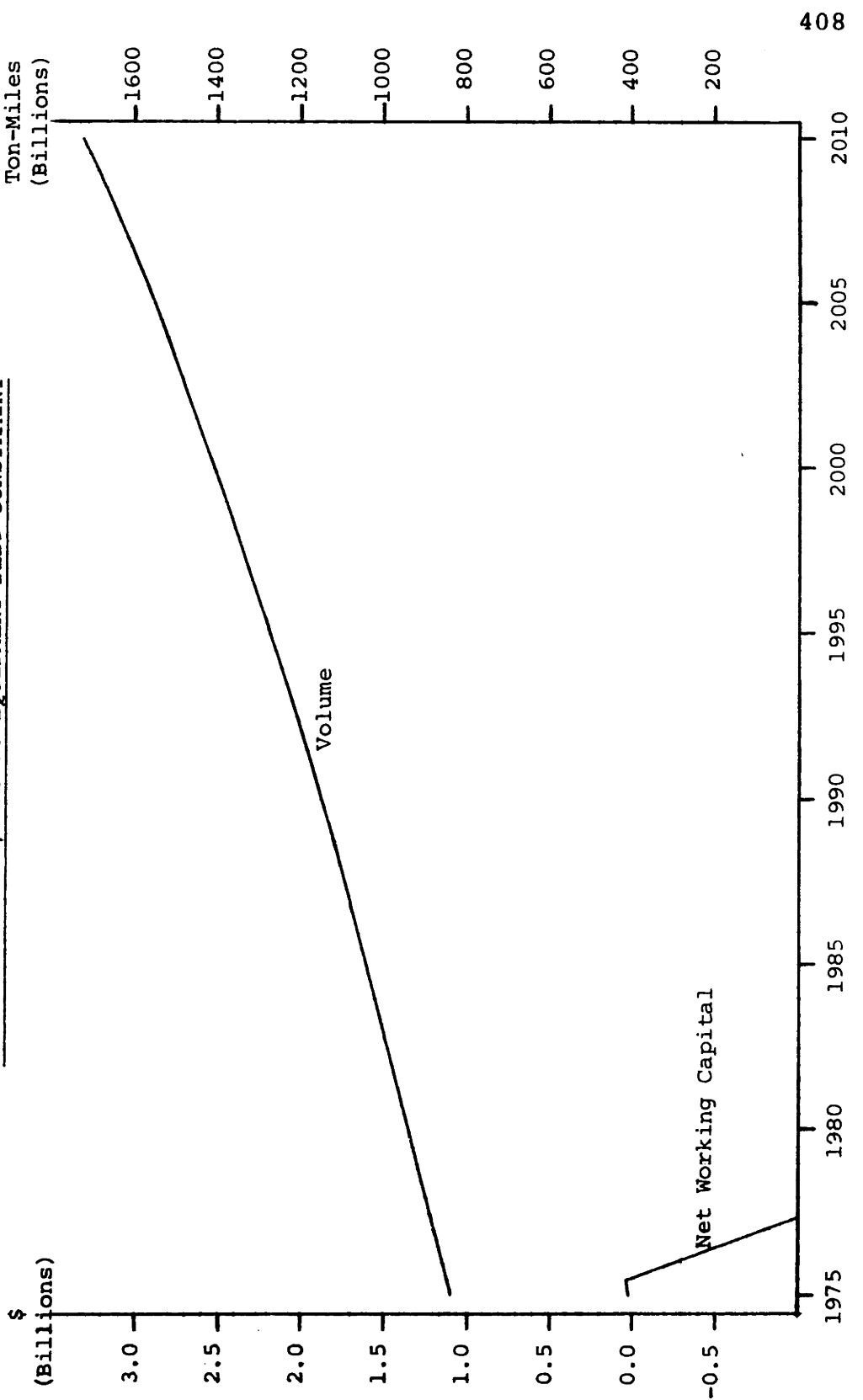


FIGURE 5-20
QUALITY IMPROVEMENT PROGRAM - MILD QUALITY EFFECTS,
8% INTEREST RATE, AND NO EQUIPMENT DEBT CONSTRAINT



145% increase in NROI due to the reduced operating costs associated with quality improvement. Even though NROI grows somewhat more quickly here in the early years of the quality improvement program than it did in Case VI (Figure 5-15), due to the additional volume, ordinary income does not rebound after 1976 as it did in that case due to the more rapid growth in fixed charges which accompanies the volume growth.

This failure of ordinary income to rebound quickly combines with the increasing debt repayments due to the additional equipment debt issued to increase the strain on net working capital already caused by the internal financing of the quality improvement program. Thus, the initial decline in net working capital that occurred in Figure 5-16 is worsened by reduced cash flow and increasing debt repayments in this case. Furthermore, the increasing ordinary income and declining debt payments that aided in halting the decline in net working capital in Figure 5-16 are non-existent in this case. Rather, ordinary income remains about constant through 1980 while debt repayments are mounting. The result is hopelessly declining net working capital, which continues to fall at a rapid pace through 2010. The interest charged (8% per year) on the massive declining net working capital reduces other income, thus causing the long-run behavior of ordinary income

in Figure 5-19.

The results of this case are not too surprising. The industry, which as a whole is currently having trouble making ends meet, attempts to internally finance a massive quality improvement program while simultaneously investing heavily in equipment. Furthermore, the debt instruments used to finance the equipment purchases require immediate annual principal repayments rather than a lump sum repayment far off in the future. Thus, given their limited revenues, they commit themselves to too many uses of funds in the near term, while the payoffs to these expenditures are much further out in the future and are not significantly large (i.e., the payoffs to investments in rolling stock also depend on the mild effects of the quality of the facilities, as the profitability of the equipment depends on the net revenues they generate, which in turn depend on unit operating costs). The result is "bankruptcy." In other words, unless massive federal aid is received (or some other changes are made, as in ensuing cases), the industry would not be able to meet all its contractual obligations if it were to attempt a quality improvement program while at the same time serving all the demands for its service.

In this case, mild quality effects were assumed, and thus it is possible that the results of simultaneous expan-

sion and quality improvement are not as bleak as they appear here. In the next case, the scenario is the exact same, except that strong quality effects are assumed, so that the "return" on the investments made is greater.

5.2.9 Case IX: Quality Improvement Program - Strong Quality Effects, 8% Interest Rate, and No Equipment Debt Constraint.

By doubling the return associated with fixed plant improvement, the results change drastically, as evident in Figures 5-21 and 5-22. The more rapid increase in NROI caused by the larger payoffs to fixed plant rehabilitation better offsets the initial increase in fixed charges, allowing ordinary income to grow from the start. By 1985, ordinary income has sufficiently increased, such that its contribution to cash flow outweighs the effects of the increased debt repayments and the internally financed quality improvement program on net working capital. Thus, in 1985 net working capital "bottoms out" at \$-2.8 billion, and starts a slow recovery back to zero.

Again external aid would be necessary in keeping the industry solvent. The \$2.8 billion dip in net working capital can be interpreted as \$2.8 billion in loans at 8% issued to keep the industry alive during its period of cash shortage. Thus, the "internally-financed" quality improve-

FIGURE 5-21
QUALITY IMPROVEMENT PROGRAM - STRONG QUALITY EFFECTS,
8% INTEREST RATE, AND NO EQUIPMENT DEBT CONSTRAINT

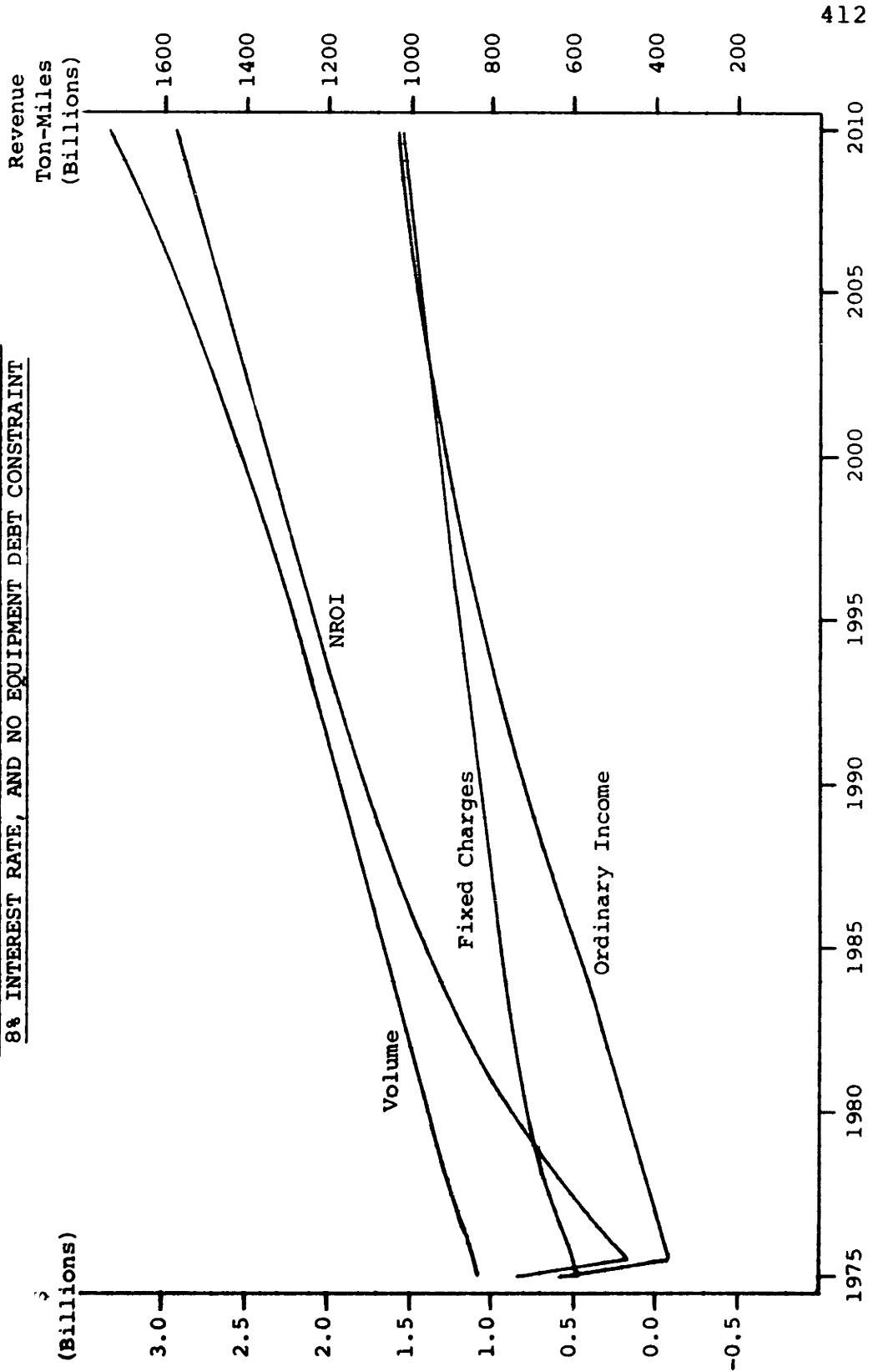
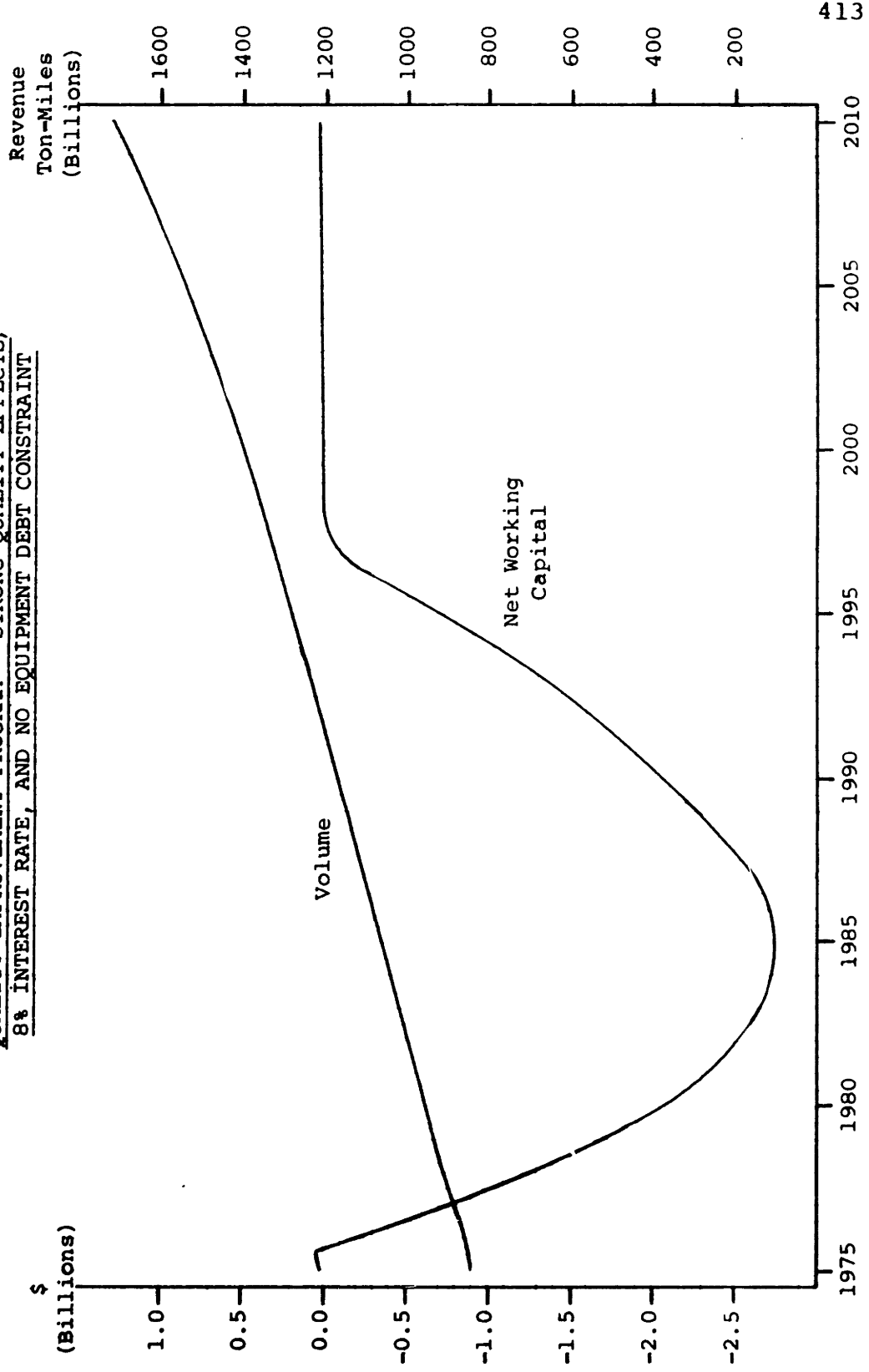


FIGURE 5-22
QUALITY IMPROVEMENT PROGRAM - STRONG QUALITY EFFECTS,
8% INTEREST RATE, AND NO EQUIPMENT DEBT CONSTRAINT



ment program actually depends rather heavily on external funds, quite possibly supplied by the government. However, in this case, unlike the other two cases (Cases IV and VIII) in which the equipment debt constraint was ignored, net working capital eventually rises to zero, implying the paying off of the loans necessary to keep the industry solvent.

In spite of the industry's ability to pay off the interim loans necessary to keep it solvent in this case, it is again evident, as it was in Cases IV and VIII, that ignoring the equipment debt constraint can lead to permanent or temporary insolvency without external aid or government intervention, under the assumptions about the future that are made here. Also, these three cases of forced volume growth indicated that a good deal of external funds could be injected into the railroads to support this growth, never to be repaid unless a significant cost change is effected within the industry. Furthermore, Case V highlighted the importance of system quality, while Cases VI and VII showed the potential that a quality improvement program has in causing growth rather than decay.

As a means of studying the potential that the industry has for achieving profitability, growth, and quality improvement with minimal external aid, the following cases will therefore focus on a quality improvement program

coupled with the constraint on equipment debt as a means of avoiding government intervention or other types of external aid. Changes in labor and equipment productivities will be tested in conjunction with the quality improvement program, so that the potential the industry has for the internal promotion of profitable growth can be analyzed, as these additional changes will weaken the effect of the equipment debt constraint in retarding growth and will add to profitability.

5.2.10 Case X: Quality Improvement Program - Mild Quality Effects With 20% Reduction In Transportation Employees.

This is the first of three cases dealing with modifications to the quality improvement program with mild quality effects of Case VI. Thus, Case VI and its results (depicted in Figures 5-15 and 5-16) represents the "base case" against which these three cases will be compared. Subsequently the same three cases will be analyzed with strong quality effects to test the sensitivity of the outcomes to the quality effect assumptions. For all six of these cases, the equipment debt constraint is in effect and the interest rate is assumed to be 10%.

The modification to the quality improvement program that is of interest here is a 20% reduction in the number of transportation employees involved in freight service at

any level of volume. Thus, the results achieved are representative of what could occur if one out of five train, yard and other transportation jobs were eliminated at any traffic level. The work force reduction is assumed to occur instantaneously in 1976, the same year that the quality improvement program begins, at no cost to the industry related to compensating employees laid off. This is implemented in the model by a 12.5% decrease in TTGM employees, based upon the 1973 ratio of transportation to total TTGM employees, and therefore represents a 14% increase in the productivity of TTGM labor and may also be interpreted as such rather than as a 20% reduction in transportation employees. As in Case V, the remaining employees do not receive additional pay as a result of this "abnormal" productivity increase.

This reduction in employees is exactly one half of the "drastic" reduction made in Case V, and implies the immediate elimination of about 36,000 out of 290,000 jobs that currently exist for TTGM freight service. Whether such a change could actually be effected in the light of union opposition is an issue that will not be explicitly addressed at this point. Also, the issue about compensating employees who lose their jobs initially will not be addressed at this point. The interest here is in the effectiveness of such a change, if it were to be implemented. It should

be noted, however, that this less drastic work force reduction is more plausible than that considered in Case V, and thus it was chosen as the labor option to be studied.

To indicate the magnitude of the savings possible from this labor force reduction, 1975 TTGM labor cost, as computed in the model, is about \$5.55 billion (current dollars), so a 12.5% reduction implies annual savings of \$700 million (current dollars) at current volumes. This saving, which is equivalent to \$450 million (constant 1967 dollars), will add about \$350 million (again 1967 dollars) to after-tax earnings in the first year of the quality improvement program. These savings will grow with volume since the same productivity increase applies at all levels of traffic.

The results of this case are presented in Figures 5-23 and 5-24. In order to appreciate the impacts of this improvement in labor productivity, these results should be compared to those of Case VI (Figures 5-15 and 5-16), which represents the "base" quality improvement program here.

As the quality improvement program begins, earnings now only dip by about \$350 million, as compared to \$700 million in Case VI. The additional \$350 million is the after-tax result of the work force reduction, as previously explained. This smaller dip in earnings leads to better initial interest coverage in this case, so more equipment

FIGURE 5-23
QUALITY IMPROVEMENT PROGRAM - MILD QUALITY EFFECTS
WITH 20% REDUCTION IN TRANSPORTATION EMPLOYEES

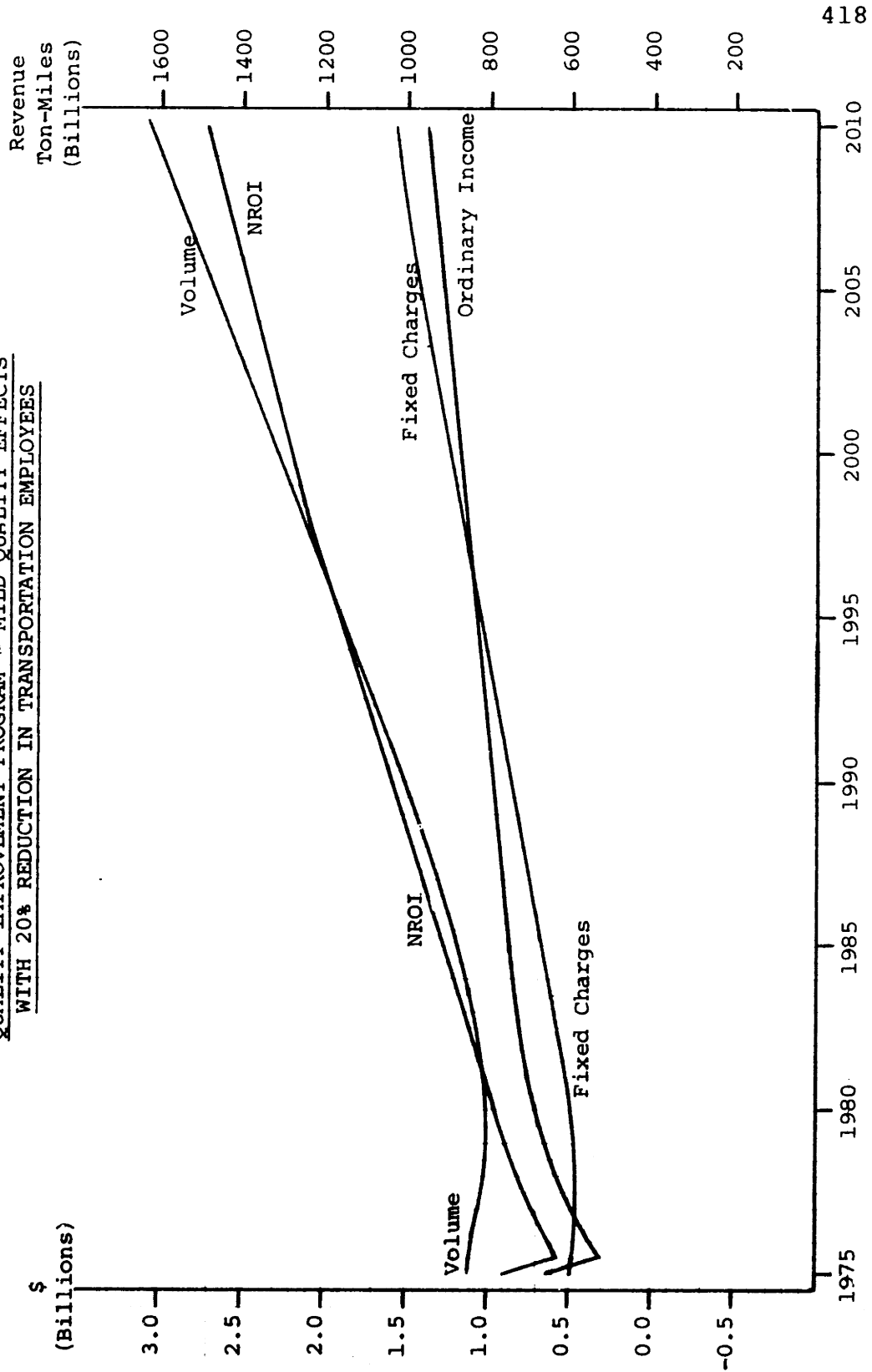
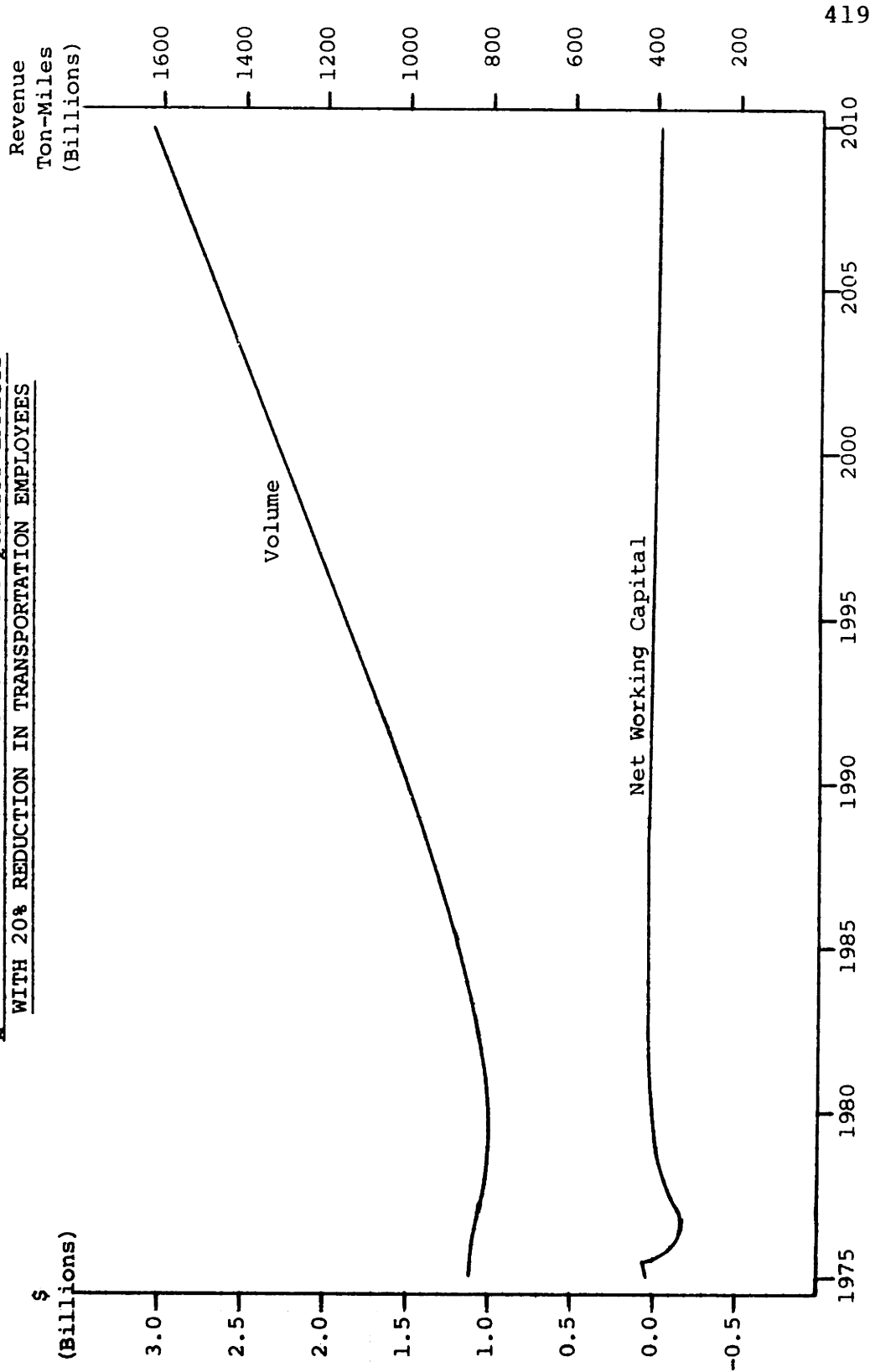


FIGURE 5-24
QUALITY IMPROVEMENT PROGRAM - MILD QUALITY EFFECTS
WITH 20% REDUCTION IN TRANSPORTATION EMPLOYEES



debt is available. Thus volume and fixed charges only drop slightly initially. As maintenance expense is reduced and unit costs fall with improving quality, NROI quickly grows, and by 1980 sufficient interest coverage exists to allow capacity expansion. Thus, volume, NROI and fixed charges all proceed to grow through 2010, with increasing quality continuing to decrease unit costs over time.

The labor savings have another important effect besides their sustaining NROI initially to allow better interest coverage and hence less capacity decline. Net working capital, which fell to \$-800 million in Case VI, only declines to \$-150 million here and rebounds more quickly, in spite of the additional debt obligations in this case. Thus, only minimal external aid would be required and only for a short period of time, while the industry serves more volume in this case than in Case VI.

The long-run results of this case, while markedly better than Case VI due to the labor savings, are still not that impressive. Volume only grows to 1630 billion revenue ton-miles by 2010, while demand is at 1730 billion in that year. Also, net working capital remains near zero. Thus, given the numerical assumptions of the case, the quality improvement program with the labor savings is not sufficient to allow adequate growth and profitability (as

measured through the industry's ability to improve their liquidity situation).

In a comparative sense, however, this case has important implications. A substantial increase in labor productivity allows the industry to almost entirely internally finance a massive quality improvement program while at the same time maintaining almost constant volume and a fair level of reported earnings even before the payoff to the quality improvement is felt strongly. Once the effects of the better quality system begin to become pronounced, they are complemented by the labor savings and lead to a fair degree of growth and profitability.

5.2.11 Case XI: Quality Improvement Program - Mild Quality Effects With 25% Increase In Car Productivity.

In this case, as well as several subsequent cases, the issue of freight car productivity is investigated. Productivity, as defined here, is measured in revenue ton-miles per car-year and is heavily dependent upon a more common measure of car utilization known as the car cycle. The car cycle is a measure of average time between carloadings, and thus is inversely proportional to productivity if load size and length of haul remain constant. In this study, the effects of load size and length of haul are as-

sumed to increase productivity by a maximum of 10% over its 1973 level by the year 2010. Thus, as a first order approximation, productivity is inversely proportional to car cycle, and a 25% increase in productivity could be effected by a 20% reduction in car cycle, which is a substantial, but not unreasonable, change to consider, as will now be explained.

In the recent past, the car cycle has been on the order of 25 days,¹ indicating that an average freight car carries only about 16 loads per year. Of these 25 days, the cars are only moving in trains for 4 days, spend 6 days at shipper sidings, and spend the remaining 15 days in yards being classified and shuttled about, or sitting idle. The key to car cycle reduction is therefore the large yardtimes, which are largely under control of the railroads themselves.²

One of the major reasons for the large amount of time spent in yards is the complicated routing that a freight car typically takes, requiring it to be dropped of, reclassified, and picked up several times during its trip from origin to final destination. Each time a car is

¹ The numerical data quoted in this discussion is drawn from pp.289-292 of [3].

² Part of the 15-day yard time is due to seasonal lulls in demand, which are not under railroad control.

routed through a yard, time is spent separating it from the cars it arrives with, deciding which train to send it out on, "blocking" it with other cars to be sent out on the same train, and finally waiting for the train to arrive. If the car misses its connection, it must wait for the next train going in the appropriate direction. Since this process is repeated at each yard, the time consumed rapidly adds up and thus constitutes the major portion of the car cycle.

The 25% improvement in car productivity of interest here is possible through a 20% reduction in car cycle, which would result if 5 of these 15 days spent in yard were eliminated. Since the model does not explicitly deal with operating policies and the possible tradeoffs between car cycle, locomotive requirements, and labor requirements, the car productivity improvement is implemented assuming everything else stays the same. Thus, the model outputs are indicative of a situation where car productivity increases, ceteris paribus, and should be interpreted as such.

Real-world alternatives that are indicative of the types of options that might lead to reductions in yard times without changing locomotive or labor requirements are:

- i) Better car routing with the same train frequencies and lengths. By routing cars through fewer yards, yard times could be reduced. Also, if train routings were improved to allow yard bypasses, there might be reductions in labor and locomotive requirements not dealt with by the model.
- ii) Improved yard efficiency through better blocking and dispatching rules.
- iii) Shorter, more frequent trains with reduced crew sizes. For example, if one train per day runs between two yards, and is made up of 100 cars, 4 power units, and 4 crew members, it might be replaced by 2 trains per day, each with 50 cars, 2 power units, and 2 crew members. Locomotive and labor requirements remain the same, while frequency is doubled, reducing wait times at yards. This type of option is currently not possible due to work rule restrictions on crew size. However, it is entirely plausible, as the unions have nothing to lose by it.

The above list of examples is not exhaustive, but is meant to be indicative of the types of changes that might be made to cause a 25% increase in car productivity through

yard-time reductions without changing other significant cost factors.

In terms of dollar savings, the annual reductions in costs associated with a 25% car productivity increase are less than those of the 20% reduction in transportation employees discussed in the previous example. If car productivity were increased by 25%, 20% fewer cars would be required at any level of volume, thus leading to a 20% reduction in the fixed charges and depreciation associated with freight cars. In 1971, the last year for which detailed data was available on the industry's capital accounts [6], freight car depreciation was \$375 million (current dollars), and freight car gross book value accounted for 70% of total equipment gross book values. If it is assumed that 75% of total fixed charges are attributable to equipment, and that 70% of this is attributable to freight cars, based on their proportion of gross book value, then the 1971 fixed charges associated with freight cars would be on the order of \$300 million (current dollars). Thus, depreciation plus fixed charges for freight cars would have totalled about \$700 million (current dollars) in 1971, and a 20% reduction would imply an annual saving of only \$140 million, or 115 million constant 1967 dollars. In spite of the simplifications made in arriving at this figure, and in spite of the volume difference be-

tween 1971 and 1975 (the year for which labor savings were computed in the previous case), it is quite evident that the savings here would be considerably less than the \$450 million (1967 dollars) per year associated with labor.

The 20% reduction in car requirements can therefore be seen to be a less effective means of improving annual financial performance than the 20% reduction in transportation employees considered in the previous case. This will be evident when the outputs of this case are presented. However, before they are presented, some discussion is in order about the implementation of the car productivity increase in the model.

In this case, car productivity is increased by 25% beginning in 1976. The immediate effect is a 25% surplus in the number of cars on line, as locomotive productivities have not changed, and thus capacity is initially constrained only by the number of locomotives. The model does not allow the sale of cars until the end of their normal lives, so the industry is not able to immediately dispose of the excess cars¹ and their associated costs as was possible in the case of labor. Thus, the jump in car productivities in

¹ In any event, there would be no one to sell them to, as all U.S. railroads would have excess cars on their hands, and it is doubtful if foreign markets would be readily available for 300,000 used cars. It might be possible to scrap the excess cars, but this is not considered here.

1976 does nothing to alleviate car-related fixed costs (interest and depreciation) in the short run. A major short-run benefit that would be possible is the complete curtailment of car purchases until retirements had brought the number of cars down to that required by the growing demand for rail service. However, it is questionable if this is really a feasible option, since if car purchases were completely stopped for several years, car suppliers would go out of business, and this could have detrimental consequences for the railroad industry.

Thus, modelling the course of events that would ensue from a sudden increase in the productivity of the car fleet can be seen to be a complex problem. On the one hand, model and actual constraints make it difficult to dispose of the excess cars, and on the other hand, the concerns of the car suppliers make it impossible to completely curtail purchases, so that in spite of the car surplus, the industry would probably have to continue buying some cars.

This concern for the car suppliers was taken into consideration in deciding upon how to "make" the model react to the sudden surplus of cars it finds itself with in 1976. Rather than implementing special policy equations that would reduce annual car purchases to zero while the surplus cars were being retired, no change to the policy equations that govern the model's car acquisition process was made.

The nature of these equations is such that they will respond to the current state of affairs (a current car surplus and a 20% reduction in the cars necessary to serve the five-year traffic forecast) in a moderate manner, reducing the desired annual car installations so that the proper fleet size would be achieved in about ten years. Thus, it takes the model about ten years before the increase in car productivity is reflected fully in depreciation expense and fixed charges. This period of adjustment is more realistic than the assumed instantaneous reduction in car cycle which "causes" it in the model. Hence, the outputs of this case and all others in which car productivity is increased may be interpreted as being caused by a gradual reduction in car cycle.

Important interim benefits are realized as the freight car fleet is gradually adjusted to its proper size. This is because the cost of additional capacity is effectively reduced to the cost of additional locomotives plus the cost of the decreased annual car installations. This has some interesting effects on the model's outputs, as will now be explained.

The results of this case are depicted in Figures 5-25 and 5-26. The initial dips in earnings and net working capital are identical to those in Case VI, as there are no immediate changes in income statement expenses caused by

FIGURE 5-25
QUALITY IMPROVEMENT PROGRAM - MILD QUALITY EFFECTS
WITH 25% INCREASE IN CAR PRODUCTIVITY

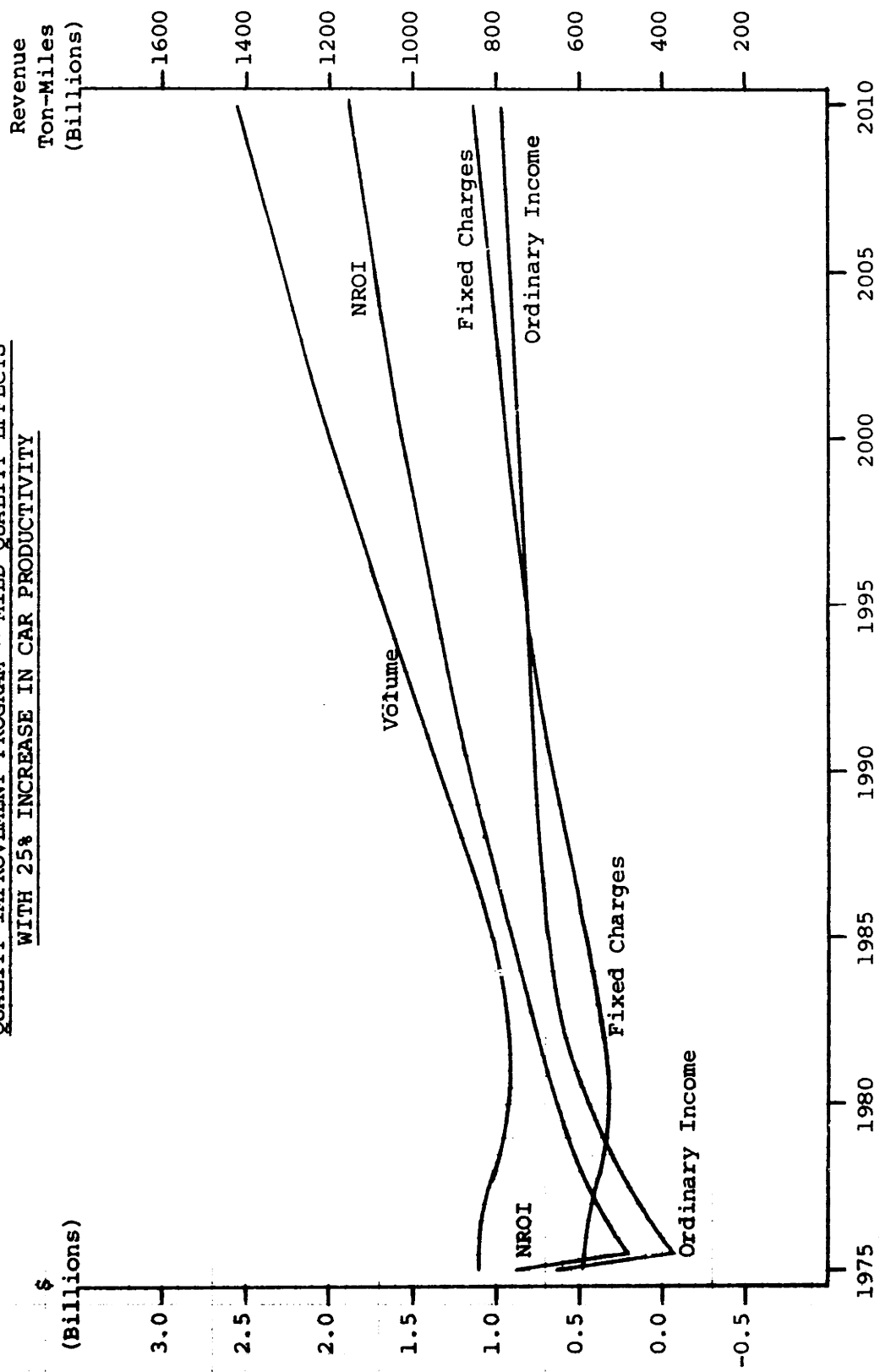
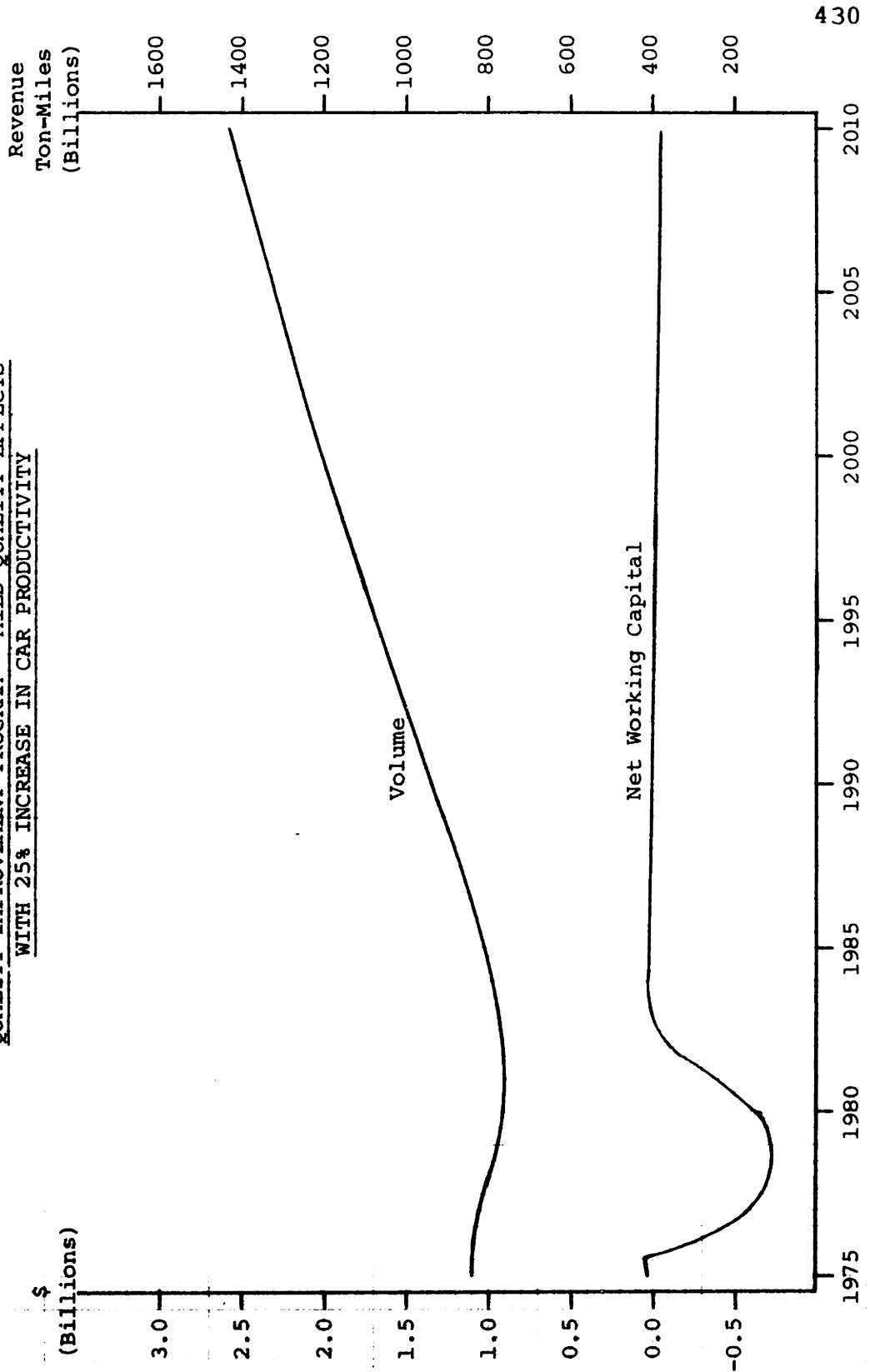


FIGURE 5-26
QUALITY IMPROVEMENT PROGRAM - MILD QUALITY EFFECTS
WITH 25% INCREASE IN CAR PRODUCTIVITY



the increased car productivities. However, the lower cost of additional capacity soon becomes evident. Fixed charges are similar to those of Figure 5-15 through 1985 because of the identical severely constrained equipment debt in both cases. Due to the surplus of freight cars, however, in this case the constrained investment funds are allocated more to locomotive purchases. Inasmuch as locomotive capacity is constraining volume initially, similar dollar outlays in this case purchase more capacity, as they are spent mostly on locomotives. Thus capacity is prevented from falling as much as it did in Case VI.

As earnings quickly rise with quality improvement, more equipment debt becomes available and much of it is allocated to locomotive purchases, so that by 1982 capacity has begun to grow, while this turnaround did not occur until 1985 in Case VI. By 1985, NROI is about \$100 million higher in this case due to the additional volume, and at this time the full impact of the car productivity increase begins to be felt in the income statement.

With more volume (and hence NROI) around 1985, and due to the improved earnings allowed by the reduced car costs, the industry is able to expand capacity faster to take advantage of the reduced operating costs achieved by the quality improvement program. Thus, the long-run result is more growth and profits in this case. However, net work-

ing capital behaves exactly the same in the long run as in Case VI, due to the use of the extra earnings generated by the additional volume for the further promotion of growth.

Thus, the overall result of increased car productivity is a moderate improvement in the growth allowed by the quality improvement program. By reducing the need for cars in the short run, improved car productivity allowed the initially severely constrained equipment debt to be allocated more to locomotives. This kept capacity and volume from falling as much initially as they would have otherwise. In turn, higher NROI was realized sooner allowing more equipment debt to become available. This increased availability, coupled with the lower cost of capacity caused by improved car productivity, led to more long-term growth than would have otherwise been the case.

As expected, the overall results of this case were not as impressive as those of the previous case, in which labor costs were slashed. The long-run effect of improved car productivity is more evident as a reduction in the cost of additional capacity than as a reduction in costs at any one level of volume. The model uses this reduced cost of capacity to fulfill its growth objective more fully, thus achieving higher earnings primarily due to the additional capacity it can purchase.

In this and the previous case, the results were not

that impressive, as all the demand for rail service was not met and net working capital remained at a dismal level through 2010. The next case analyzes the joint effects of improved labor and equipment productivities.

5.2.12 Case XII: Quality Improvement Program - Mild Quality Effects With 20% Reduction In Transportation Employees And 25% Increase In Car Productivity.

The labor and car productivity increases of the previous two cases are implemented simultaneously here, and the results are presented in Figures 5-27 and 5-28. The outcome of this case is best understood if compared to Case X, as the results here are heavily influenced by the labor savings dealt with in that case.

By comparing the results of this case to those of Case X, it is apparent that the major difference caused by the car productivity improvement has to do with volume. Specifically, the relatively "cheap" capacity allowed by the car surplus in the early years enables identical constrained capital expenditures (as evident in the similarity of fixed charges initially) to result in more volume in this case, as these expenditures are funnelled into locomotive purchases. The resultant additional volume at no additional cost (in terms of fixed charges) raises NROI by about \$200

FIGURE 5-27
QUALITY IMPROVEMENT PROGRAM - MILD QUALITY EFFECTS
WITH 20% REDUCTION IN TRANSPORTATION EMPLOYEES
AND 25% INCREASE IN CAR PRODUCTIVITY

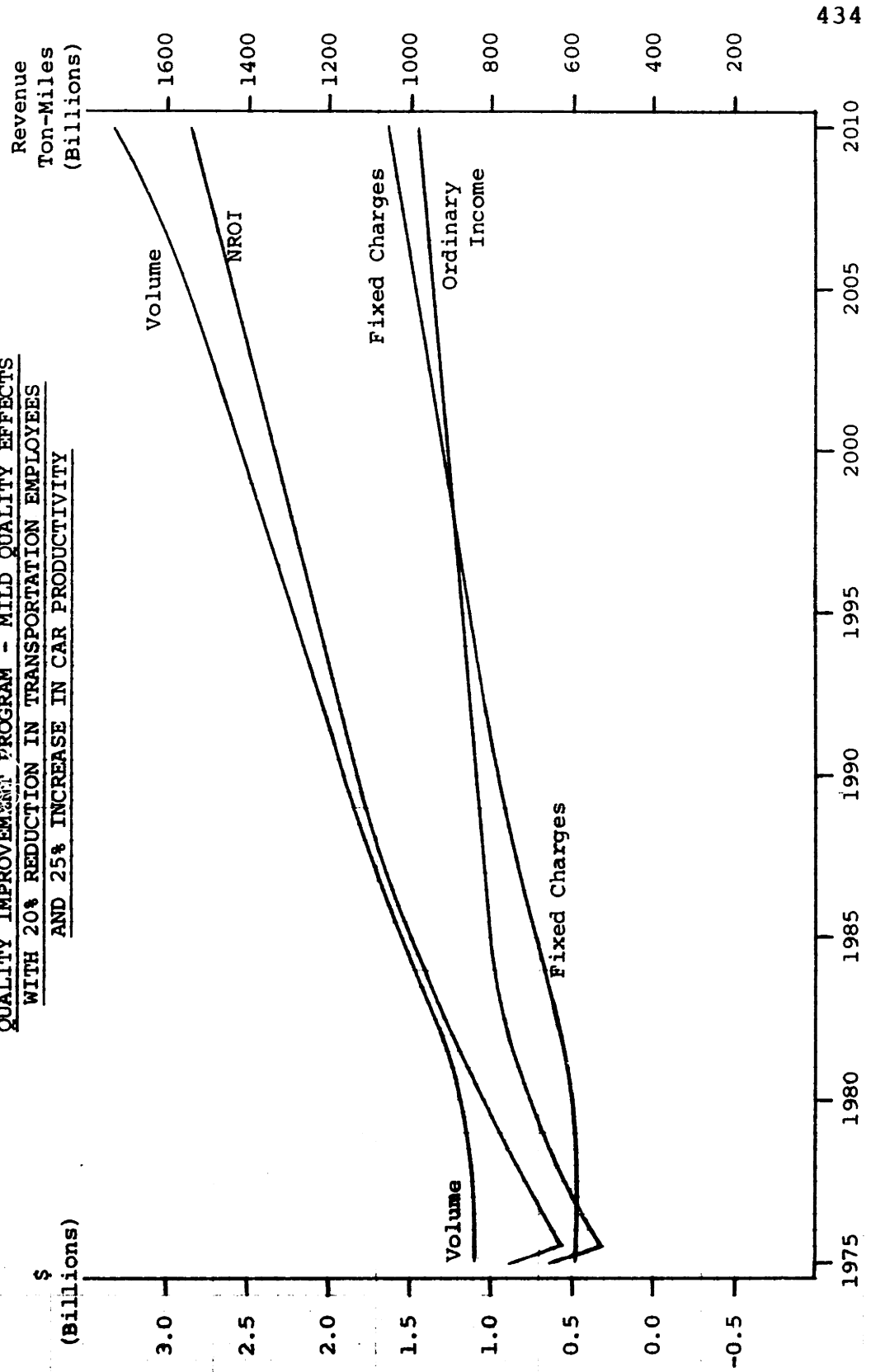
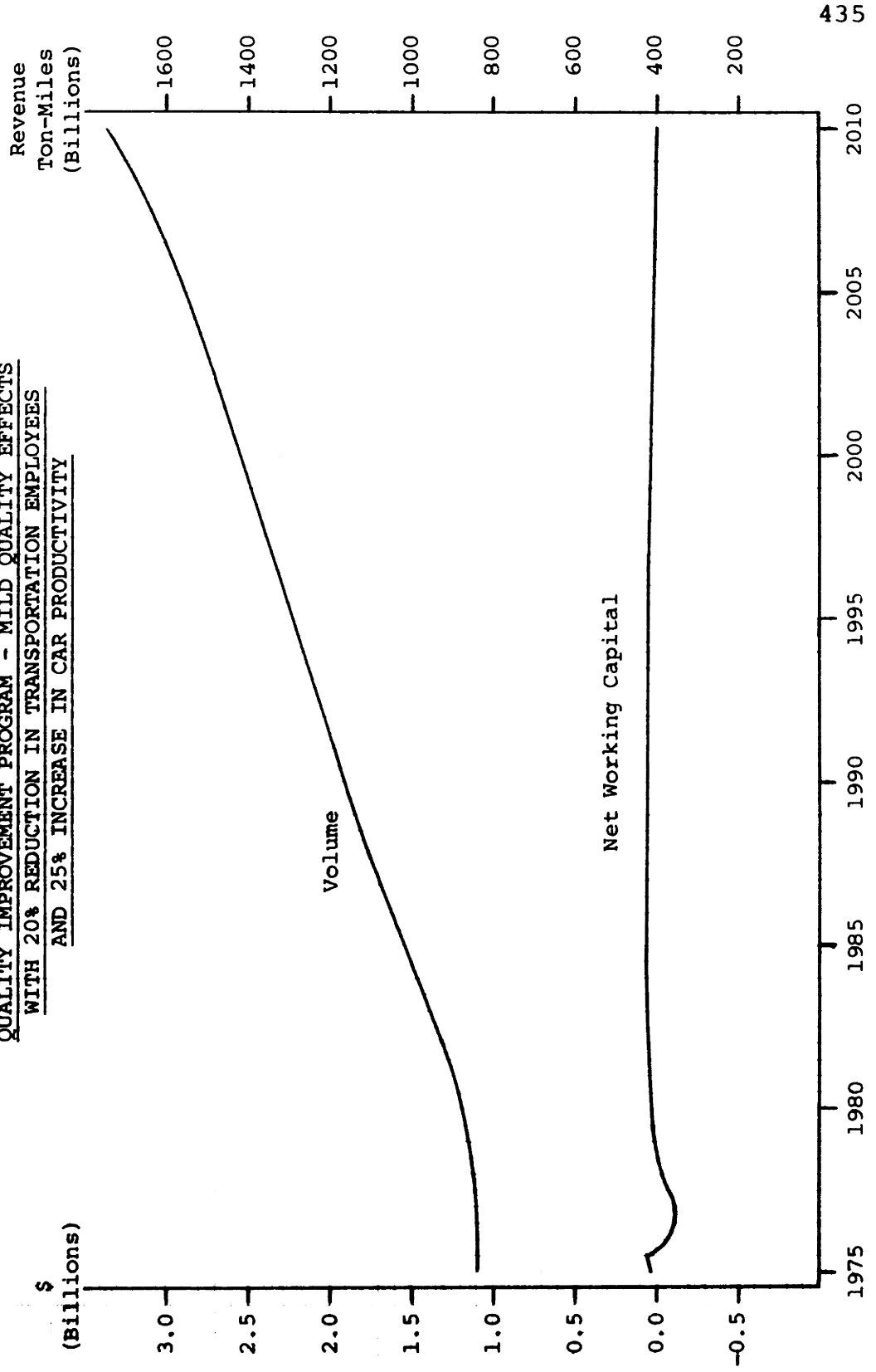


FIGURE 5-28
QUALITY IMPROVEMENT PROGRAM - MILD QUALITY EFFECTS
WITH 20% REDUCTION IN TRANSPORTATION EMPLOYEES
AND 25% INCREASE IN CAR PRODUCTIVITY



million in 1982, so that interest coverage improves, allowing further volume expansion. By 1987, capacity catches up with demand, and the car surplus has been eliminated, so that the "price" of capacity, while lowered by the improved car productivity, is higher than it was during the car surplus. After this time, the savings from the labor reductions combine with those of the quality improvement program and the car productivity increase to promote profitable growth, serving all the demand through 2010. However, the savings are not sufficient to bolster net working capital, as it remains near zero.

Thus, in spite of all the improvements made to the system, the improvements in performance were not that striking. This observation is heavily influenced by the assumption of mild quality effects, for as the next three cases show, the financial performance is rather remarkable if there is a stronger payoff to fixed plant improvement.

5.2.13 Case XIII: Quality Improvement Program - Strong Quality Effects With 20% Reduction In Transportation Employees.

This and the following two cases are repeats of the previous three cases, only with strong quality effects assumed. Thus, the appropriate "base" case against which to compare their results is Case VII (Figures 5-17 and 5-18).

The financial performance resulting from a quality improvement program in conjunction with labor cost savings is extremely impressive now, as shown in Figures 5-29 and 5-30. As in Case X, the initial dip in earnings at the start of the improvement program is only \$350 million, due to the labor savings. These savings are complemented by falling maintenance outlays (as the deferral backlog is exponentially reduced) and improved operating costs so that NROI quickly grows in spite of fairly constant volume through 1980. Since the labor savings cause NROI to be higher, interest coverage is better and volume only dips slightly in this case, as compared to Case VII. The better interest coverage promotes faster capacity expansion, and capacity catches up to demand by 1990, as evidenced by the deceleration in volume (and NROI) growth at that time. After 1990, all the demand continues to be served with profits growing healthily as a result of the labor savings and the reduced operating costs allowed by the better system quality (the entire backlog of deferred expenditures is effectively eliminated by the year 2000, as in all the quality improvement cases). The combination of these two factors allows ordinary income to remain substantially above fixed charges, a result that has not occurred in any other case. Aiding in this effect is the healthy level of net working capital after 2000, as will

FIGURE 5-29
QUALITY IMPROVEMENT PROGRAM - STRONG QUALITY EFFECTS
WITH 20% REDUCTION IN TRANSPORTATION EMPLOYEES

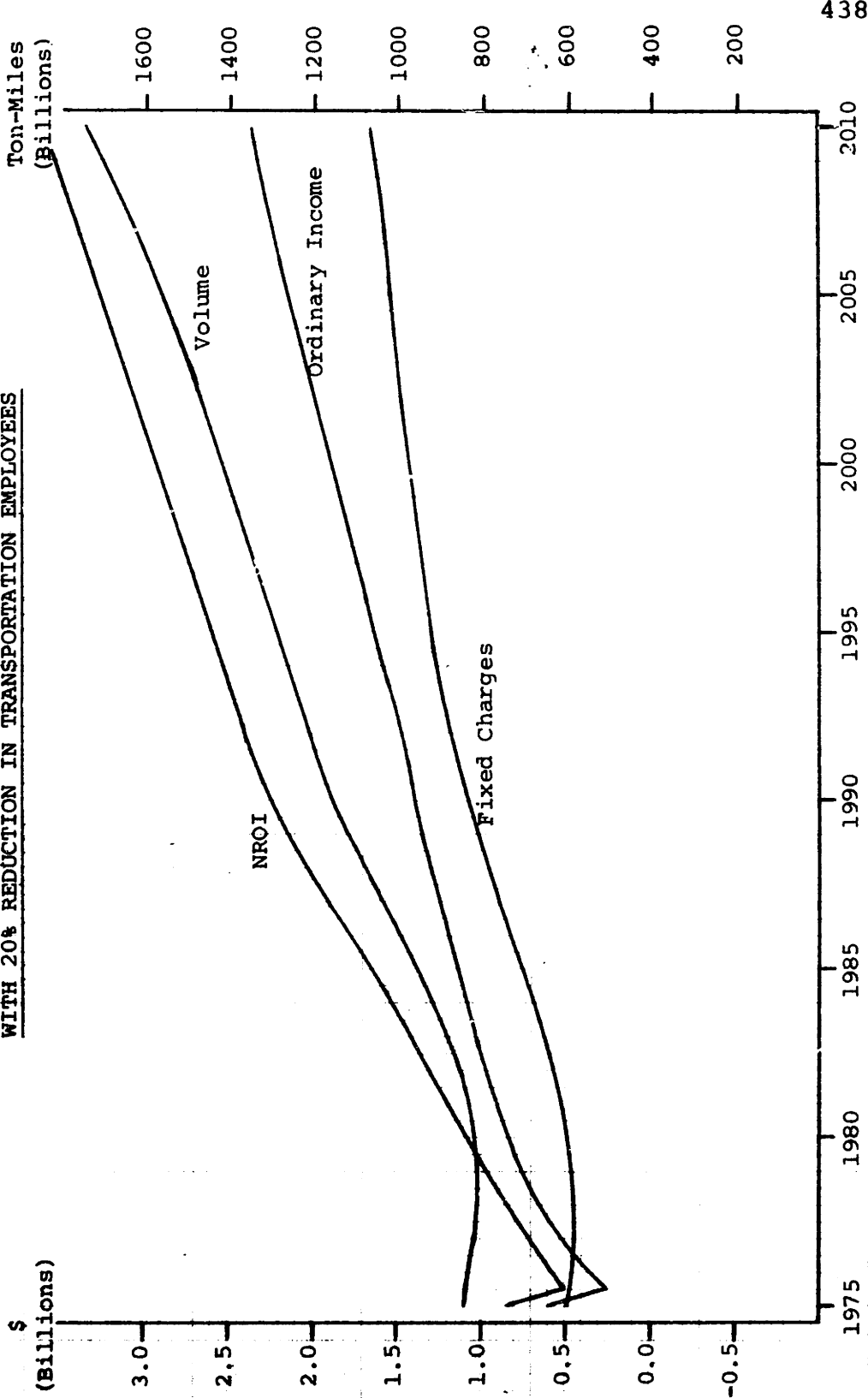
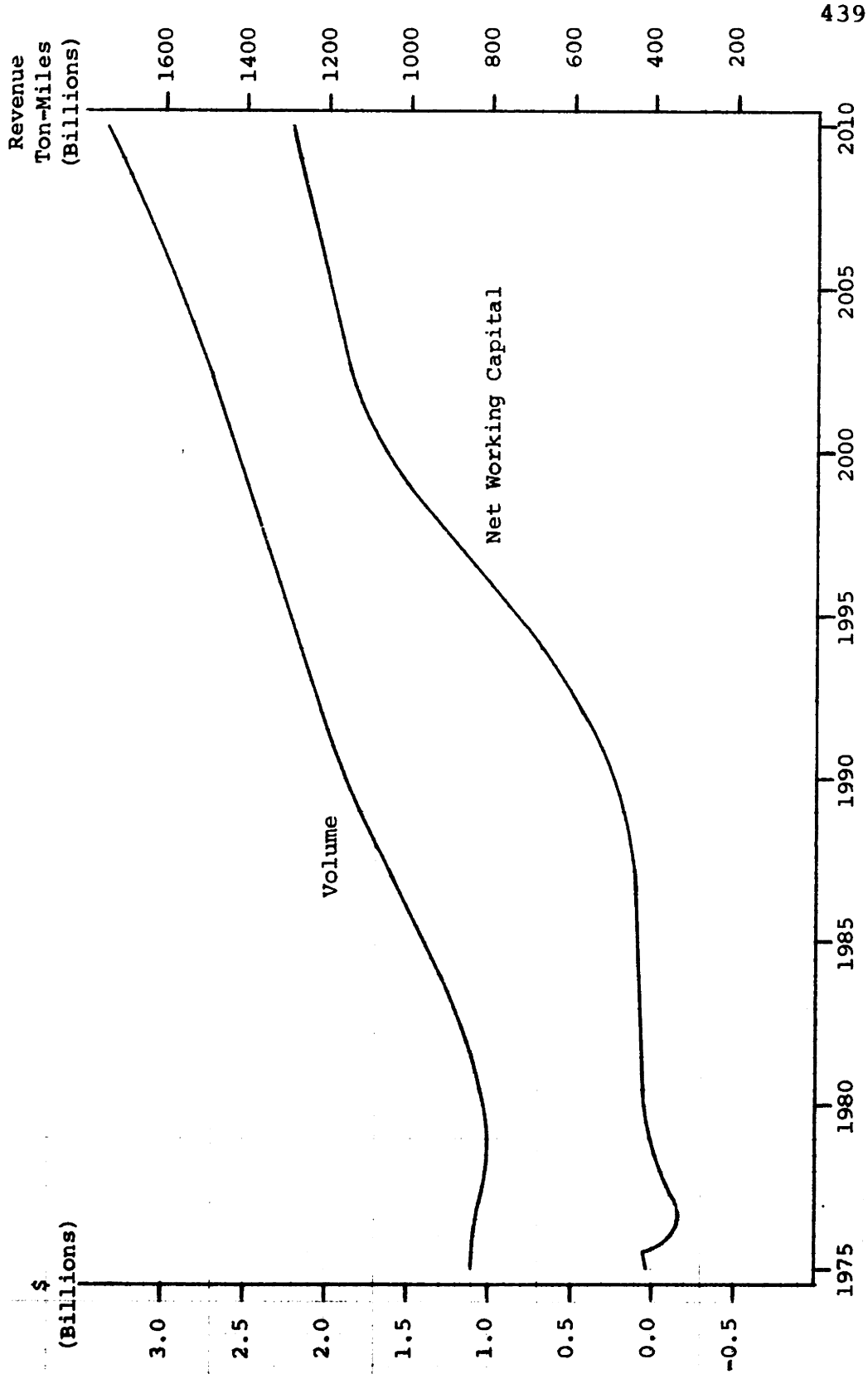


FIGURE 5-30
QUALITY IMPROVEMENT PROGRAM - STRONG QUALITY EFFECTS
WITH 20% REDUCTION IN TRANSPORTATION EMPLOYEES



now be discussed.

As in Case X, where labor cost savings accompanied a quality improvement program, net working capital hardly dips at all initially due to the increased cash flow allowed by the labor savings. However, for the first time in all these cases, net working capital manages to grow to a respectable level. The savings accruing from the stronger quality effects and the labor force reduction are substantial enough to cause a "breakthrough" in the "sticky" zero net working capital range, even though cash uses for dividends and rolling stock purchases increase as net working capital approaches \$+100 million. Not only do the earnings aid net working capital, but net working capital aids the earnings. This is because 10% per year is earned on the growing net working capital, and by 2010 this shows up as an additional \$200 million in ordinary income, thus helping to keep it above fixed charges. Furthermore, as net working capital approaches its desired level in 2000 (hence the deceleration in its growth), more internal funds are available for equipment purchases, so less equipment debt than would otherwise be the case is issued. This also helps keep fixed charges below ordinary income.

On an absolute basis, if all the assumptions about the future are close to the actual conditions that will occur,

this case indicates that the performance of the railroad industry can be impressive with high profits and net working capital. On a comparative basis, the impact of labor cost savings dramatically improves the performance resulting from quality improvement, allowing the almost complete internal financing of the massive improvement program, while at the same time promoting faster growth. The additional growth in turn magnifies the payoff to the improved system quality and to the improved labor productivity, as the savings accruing from each are variable in volume. Thus, the potential that labor cost reductions have for stimulating the financial condition of the industry is again evident.

5.2.14 Case XIV: Quality Improvement Program - Strong Quality Effects With 25% Increase In Car Productivity.

The results of this case, which operates under the same assumptions about car productivities and industry response to a car surplus as did Case XI, are presented in Figures 5-31 and 5-32.

As with the mild quality effect cases, the initial impact of increased car productivity on the quality improvement program is slightly more volume and NROI at about the same level of fixed charges, as constrained investment

FIGURE 5-31
 QUALITY IMPROVEMENT PROGRAM - STRONG QUALITY EFFECTS
 WITH 25% INCREASE IN CAR PRODUCTIVITY

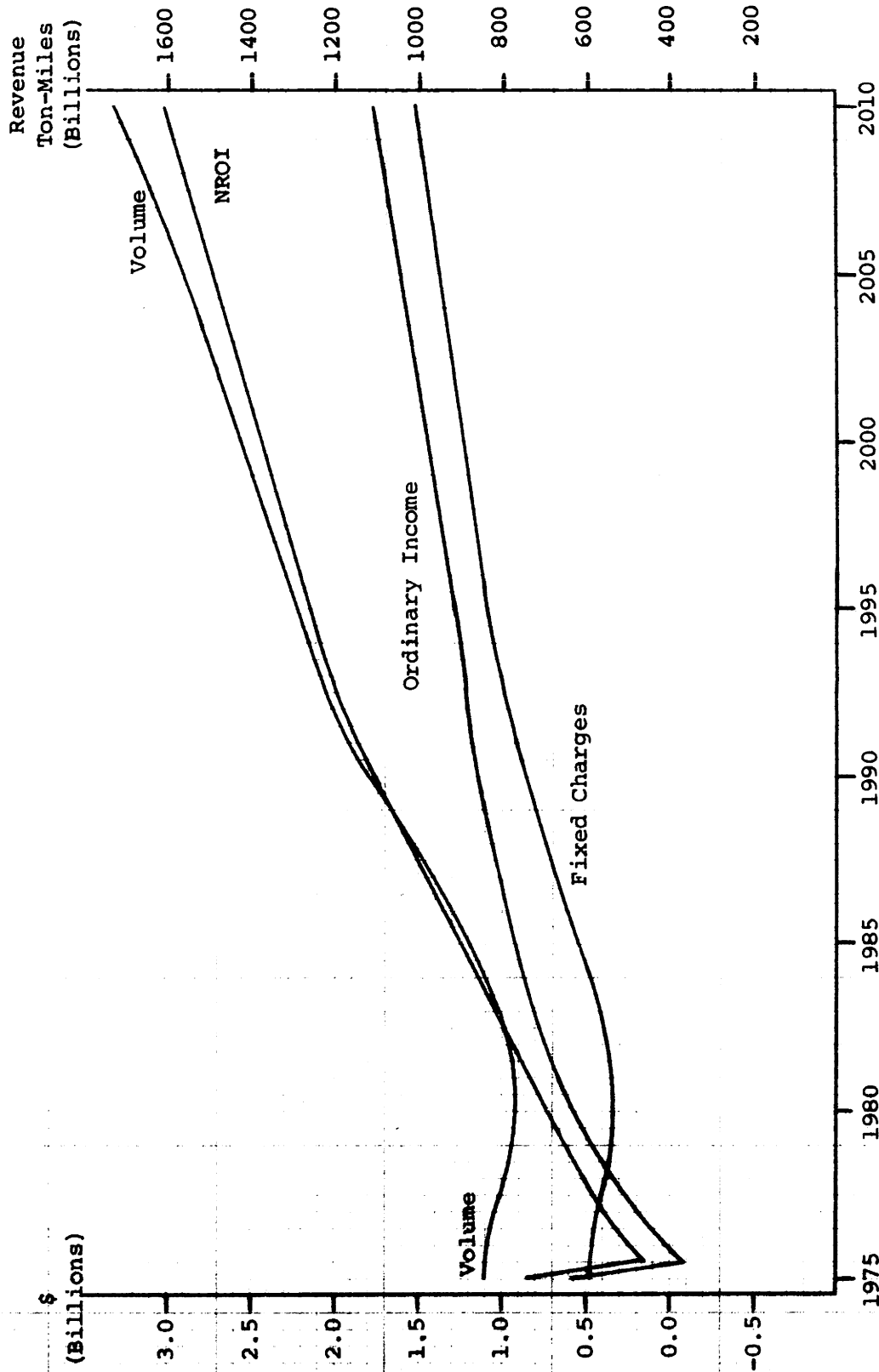
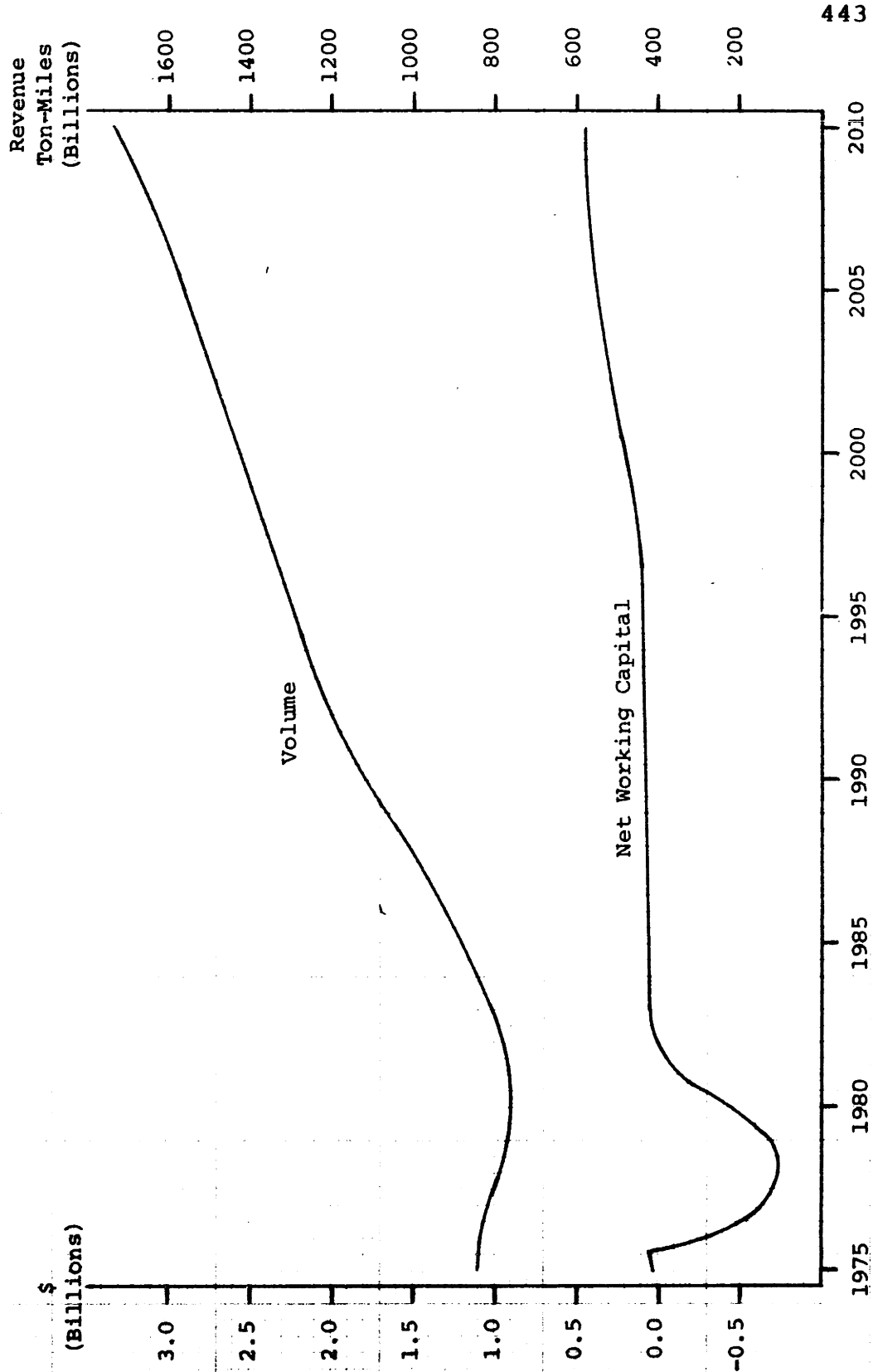


FIGURE 5-32
 QUALITY IMPROVEMENT PROGRAM - STRONG QUALITY EFFECTS
 WITH 25% INCREASE IN CAR PRODUCTIVITY



funds are allocated to locomotives. This can be seen by comparing Figures 5-31 and 5-17. Again, the long-run effects are also centered around the faster volume and NROI expansion allowed by the effective decrease in the cost of additional capacity, however with strong quality effects, the results are more pronounced. In this case, capacity catches up to demand by 1992, as can be discerned by the deceleration in volume growth at this time. Furthermore, ordinary income remains above fixed charges, as it did in the previous case, and net working capital is again able to begin growing, although not as dramatically as in the labor reduction case.

While not quite as effective as the labor force reduction considered in the previous case, the increased car productivity causes a considerable improvement to the results of the quality improvement program. It thus seems that with a strong payoff to quality improvement, moderate internal changes to the industry's cost structure, such as those considered in this and the previous case, can form the basis for impressive long-term growth and profitability. In the next case, the joint effects of these two changes are considered.

5.2.15 Case XV: Quality Improvement Program - Strong Quality Effects With 20% Reduction In Transportation Employees And 25% Increase In Car Productivity.

By combining the improvements of the two previous cases, dramatic results are achieved, as illustrated in Figures 5-33 and 5-34. Not only is the industry almost capable of internally financing the massive quality improvement program, but they are also able to rapidly expand capacity such that demand is caught up with by 1984. Also, profitability is so high in the early years that net working capital begins to grow rapidly by 1980, five years sooner than in Case XIII. The most interesting result, however, is the behavior of fixed charges. So much cash flow is being generated by 1988 (even though the quality improvement program has only eliminated 75% of the expenditure backlog by this time), that internal funds begin to be extensively used for financing equipment purchases. By 1995, 50% of all equipment investments are cash financed, and by 2010, this has increased to 70%. The result of all this cash financing is a downturn in fixed charges, in spite of the growing volume and equipment fleets.

It must be remembered that all this amazing profitability and growth is achieved through substantial, but not drastic, increases in labor and equipment productivities even though an \$8 billion quality improvement program is

FIGURE 5-33
QUALITY IMPROVEMENT PROGRAM - STRONG QUALITY EFFECTS
WITH 20% REDUCTION IN TRANSPORTATION EMPLOYEES
AND 25% INCREASE IN CAR PRODUCTIVITY

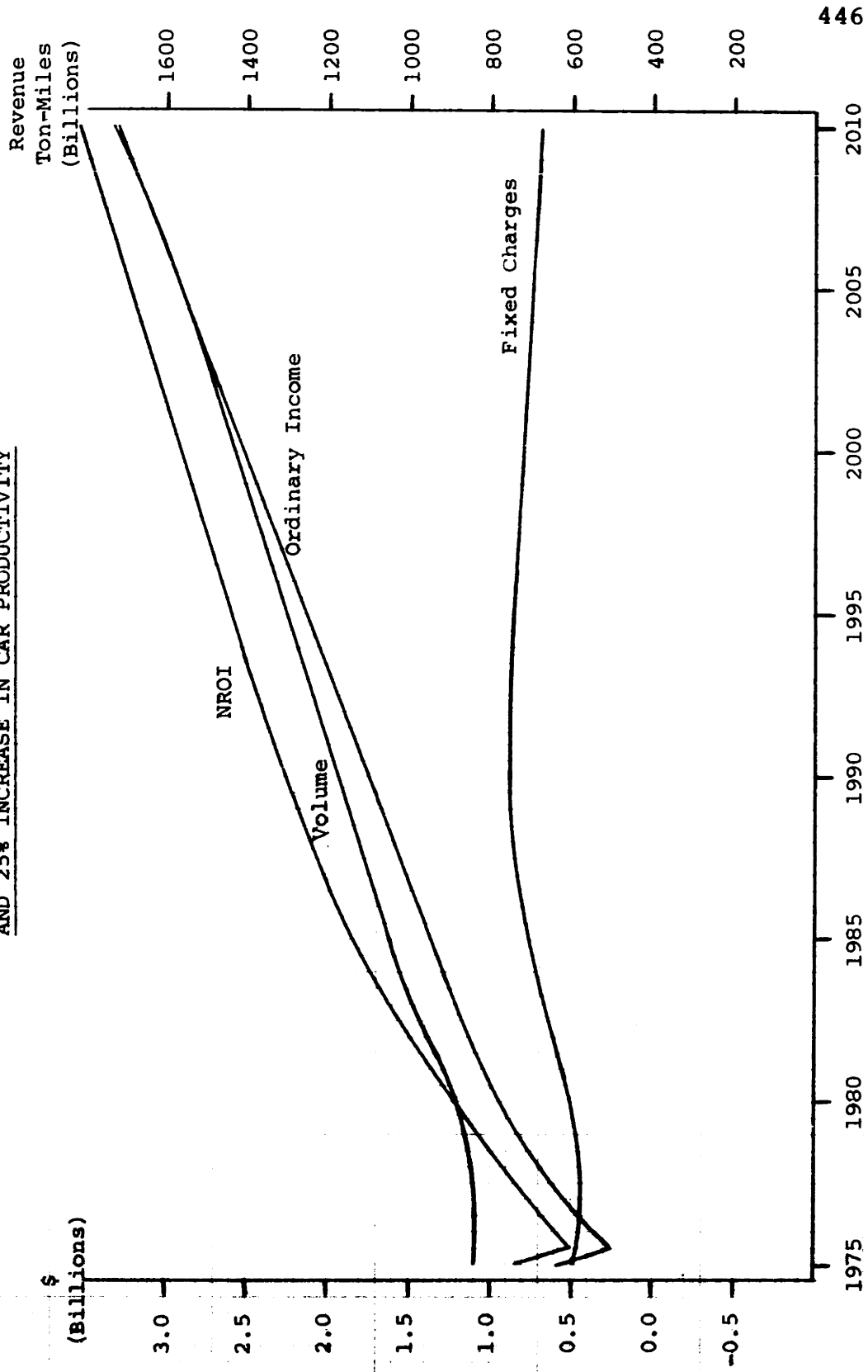
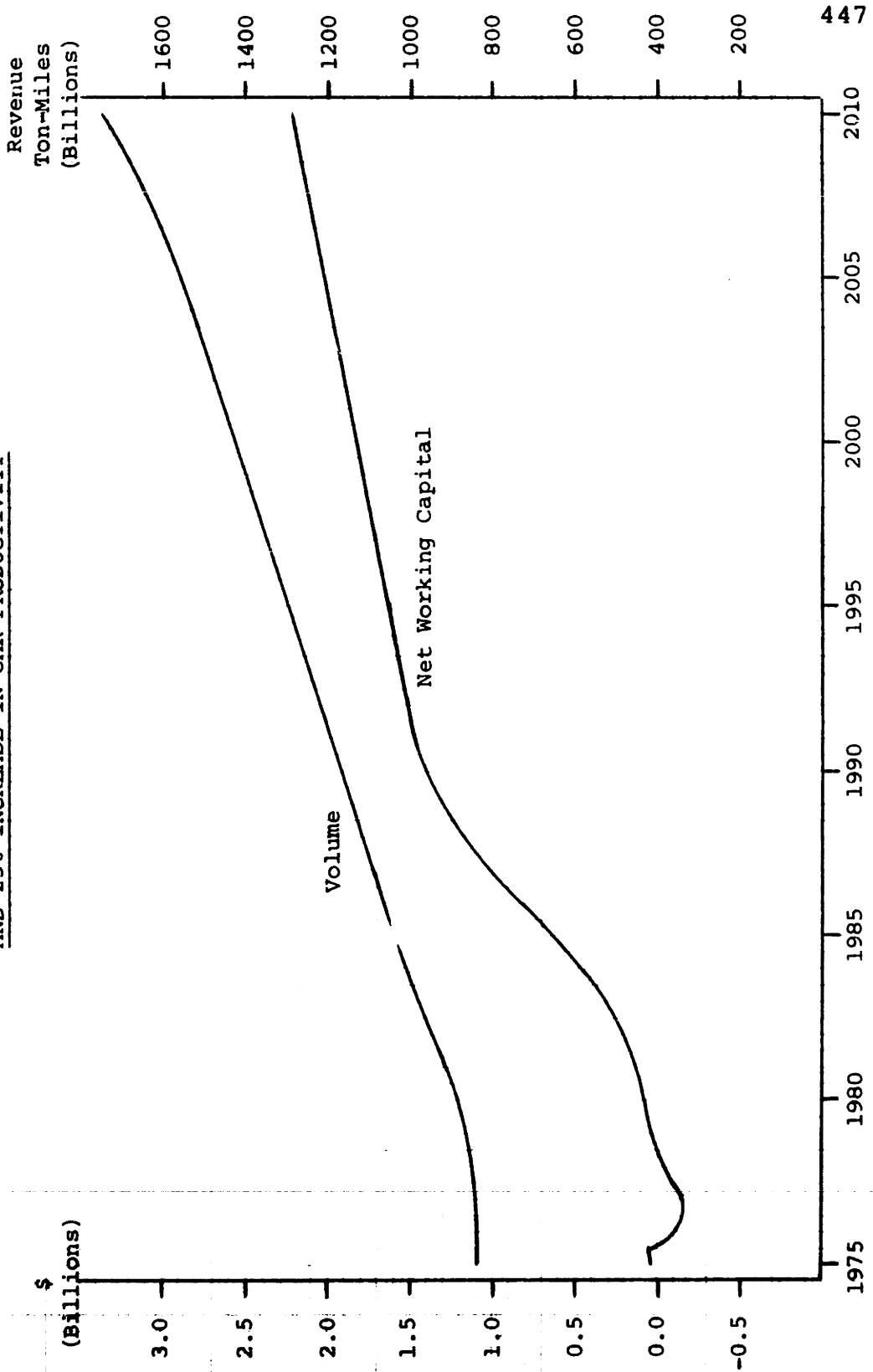


FIGURE 5-34
QUALITY IMPROVEMENT PROGRAM - STRONG QUALITY EFFECTS
WITH 20% REDUCTION IN TRANSPORTATION EMPLOYEES
AND 25% INCREASE IN CAR PRODUCTIVITY



initially draining funds. However, the assumed payoff to this program is critical in determining the results achieved here, as Case XII, which was identical to this case except for the extent of the quality effects on costs and productivities, led to only fair performance. Thus, the importance of the quality effect assumptions in determining the specific results is highlighted by the comparison of this case and Case XII. The sensitivity of the results to these assumptions is one of the most important observations that can be made in these analyses.

5.3 SUMMARY OF CHAPTER 5.

In this chapter, fifteen cases were presented as a means of analyzing the dynamic effects of quality degradation, quality improvement, labor and equipment cost savings on the long-run financial performance of the railroad industry. While the specific numerical results of each case are dependent upon the assumptions made, the sensitivity of these results to the various factors considered is indicative of the relative effects they have on the performance of the industry, or on the performance of any railroad whose financial condition is similar to that generally prevailing throughout the industry.

The first case dealt with the hypothetical future of the industry under the assumption that further quality degradation had no effects whatsoever on the industry's cost structure. It thus represented the performance that would result from the model's cost functions and policies in conjunction with the assumed future conditions if constant system quality was maintained (in spite of the annual underspending on the fixed facilities). As was evident in the outputs of that case, the overall effect of the assumptions was the proportionality of operating expenses (including passenger expense) to revenues (including passenger revenues), and hence the long-run proportionality of NROI to freight volume. This behavior was primarily due to the assumed linear variability of all operating costs in the long run, and therefore might be somewhat pessimistic if indeed there are significant long-run fixed costs omitted from the model.

In any event, the implications of this case were continued marginal financial performance and a cost/revenue relationship not entirely conducive to growth, given the current traffic mix and rate structure of the industry (which are assumed not to change in any of the cases analyzed).

In the next three cases, the dynamic effects of quality degradation were introduced as a means of perturbing

the behavior observed in Case I. Even with the assumption of mild quality effects, which only lead to a 15% increase in total costs at 1975 volume levels as the result of tripling the present backlog of deferred expenditures on way and structures, the decay of earnings and the ability to profitably provide capacity became quite evident. Declining long-run profitability as the result of inadequate maintenance is a commonly accepted notion, and the running of these three cases with the model allowed the dynamic quantification of this notion under varying assumptions as to the true state of affairs it implies. Furthermore, the effects of volume growth in conjunction with quality decay were investigated, revealing a growing dependence on external (possibly federal) funds to maintain solvency unless some changes were made to the cost/rate structure in effect. The importance of the equipment debt constraint as a means of maintaining solvency from within was thus introduced, indicating that government-forced growth in the face of deteriorating earnings of private enterprise entails government-supplied funds, other externally-supplied funds, or other forms of intervention to maintain solvency unless the private enterprise is allowed to determine its own course of events.

Case V, which dealt with a drastic reduction in labor costs through a rather unrealistic trimming of the labor

force, highlighted the dynamic effects of inadequate maintenance. By using the cost savings achieved by the labor force reduction to raise reported earnings and improve liquidity in the short-run rather than investing these savings towards the future by upgrading the fixed facilities, the industry again was faced with long-term earnings deterioration. Thus, the need for a long-term perspective on the importance of system quality was indicated. While this perspective might exist in the industry, the financial ability to realize it might not. The remaining cases therefore dealt with the implications of a quality upgrading program and various means by which it might be financed and complemented, particularly from within the industry.

Cases VI and VII were concerned with the elimination of the backlog of deferred expenditures on way which exists in the industry today. With no other changes made to the assumed relationships between costs and revenues, the industry was able to undertake this massive program with only minimal external aid because it was allowed to forego capital expenditures on equipment in the short-run while funds were allocated to way and structures. By reversing the earnings deterioration cycle associated with quality degradation, growth and fair long-term profitability were achieved. However, fixed plant rehabilitation, even with strong quality effects on costs, was not enough to cause

a dramatic improvement in earnings. Also, the industry was unable to serve all the demand for its service since the funds allocated to way and structures were diverted from equipment purchases,

The next two cases therefore addressed the implications of forced volume growth in conjunction with the rehabilitation program. Because the industry's revenues are limited, it cannot expand capacity and improve the physical plant without additional sources of funds. As was evident in Cases VIII and IX, massive infusions of external funds would be necessary to keep the railroads solvent, and unless the payoff to quality improvement was significant, additional measures would be required for the industry to free itself from its dependence on these funds. It should be recalled that the external funds supplied were assumed to be loans at 8%, which were supposed to be repaid. A government-supplied subsidy, which would have been much better from the industry's standpoint, was not considered, as this study is primarily concerned with the internal options that may be used to improve the industry's financial condition and to finance the rehabilitation program. The only external option explicitly considered was reduced interest rates. Thus, the stage was set for the remaining six cases which analyzed the joint effects of labor and equipment productivity improvements in conjunc-

tion with the quality improvement program. The equipment debt constraint was assumed to be in effect for all six of these cases to minimize the reliance on external funding and thus to avoid the many issues involved about the nature of that funding. Rather, the focus was on the industry's ability to improve its own situation given that it was allowed to determine what this situation would be.

Cases X through XII therefore dealt with the quality improvement program in conjunction with improved labor productivity, improved car utilization, and with both of these changes in effect simultaneously. The magnitudes of the annual savings possible from either option were discussed and compared on the basis of one level of volume, and the complications arising from industry concerns about car suppliers in the face of a sudden surplus of cars were pointed out. Because of the relative magnitude of the labor savings possible and the assumed inability of the industry to completely curtail car purchases, the labor option was more effective in improving upon the performance caused by the quality improvement program. The model was useful in computing the dynamic volume-dependent impacts of both options taking all the other interacting factors into account in determining these impacts, thus expanding upon the initial conclusion that the labor alternative would be better. One of the most significant impacts aris-

ing from the many processes occurring was the initial behavior of net working capital when the labor alternative was in effect. Due to the savings accruing immediately from the work force reduction which were due to the assumption that the industry did not have to compensate employees initially laid off, the industry was able to service more debt while simultaneously almost eliminating its need for external funds in the early years of the rehabilitation program.

While the labor and equipment alternatives both improved upon the performance caused by the quality improvement program, the total improvement in system behavior caused by rehabilitation in conjunction with both of these changes was somewhat disappointing, as the industry's liquidity situation did not change from its current poor state. This result was of course dependent upon the specific numerical assumptions made, particularly those concerning the mild quality effects. Thus, the next three cases were repeats of Cases X through XII, except that strong quality effects were assumed.

By changing the assumed payoff to quality improvement, the results changed dramatically. Cases XIII through XV all achieved improved liquidity positions with respect to all the previous cases. In Case XV, where the quality improvement program was undertaken in conjunction with both the

labor and equipment productivity increases, the industry was able to internally finance almost all of the rehabilitation program while simultaneously quickly expanding its capacity to catch up with demand and improving its liquidity situation. Thus, Case XV showed the potential of lower labor costs and improved car utilization in allowing the industry to internally correct its problems if in fact major cost reductions could be achieved by quality improvement.

The question arises as to the applicability of all these observations to the real system of interest, particularly due to the dependence of the results upon the uncertain payoffs to fixed plant improvement. Even though the use of the model as a comparative tool has been stressed because of the uncertainty involved in predicting the future scenario, the relative effects which are sought in the comparison of cases are dependent upon the quality effects assumed, as was evident in the outputs. However, this dependence is one of the key observations possible. If the payoff to fixed plant improvement is less than that of the mild quality effect assumption, the worth of improving the fixed plant is questionable. If the payoff is somewhere near or in between either of the assumptions made, fixed plant improvement is seen as a desirable, but not completely effective means of achieving high profitabil-

ity. On the other hand, if the strong effects assumed underestimate the return possible through quality improvement, then rehabilitating the fixed plant might be all the industry needs in order to achieve a very substantially improved financial condition

The model has been useful in quantifying the dynamic impacts of the alternatives tested. While it is possible to state without the model that the labor alternative considered would cause better results than the car productivity improvement, or that further quality degradation can have serious implications for the industry's profitability, the model allows us to see the magnitudes of the improvements or implications, their dependence on time, and their dynamic effects on other system components. Thus, while many of the conclusions reached in this study will represent nothing new with regard to the industry's finances since the issues dealt with here are among the most commonly addressed, the model has been useful in quantifying the dynamic nature of the issues of concern. Furthermore the model could be used to study a much wider range of problems than was the case in this study, so its usefulness is not limited to commonly addressed issues. Such issues were chosen for analysis here because of the widespread interest in them, and the model has been useful in promoting a better understanding of their dynamic nature.

5.4 NOTES ON CHAPTER 5

- [1] Economics And Finance Department, Association Of American Railroads; "Yearbook Of Railroad Facts, 1975 Edition".
- [2] Economics And Finance Department, Association Of American Railroads; "Statistics Of Railroads Of Class I In The United States"; Statistical Summary 59; July 1975.
- [3] Task Force On Railroad Productivity; "Improving Railroad Productivity, A Report To The National Commission On Productivity And The Council Of Economic Advisors"; Washington, D.C.; November 1973.
- [4] A.A.R. Staff Studies Group; "Returns On Investments In Fixed Plant Rehabilitation"; Staff Memorandum 75-18; September 1975.
- [5] United States General Accounting Office; "Information Available On Estimated Costs To Rehabilitate The Nation's Railroad Track And A Summary Of Federal Assistance To The Industry; Report To The Subcommittee On Federal Spending Practices, Efficiency, And Open Government Senate Committee On Government Operations By The

Comptroller General Of The United States"; November 1975.

- [6] Bureau Of Accounts, Interstate Commerce Commission; "Transport Statistics In The United States, Part I"; for the year ended December 31, 1971; published 1972.

Chapter 6

SUMMARY AND CONCLUSIONS

This thesis has been concerned with the development and application of a systems dynamics model of the United States railroad industry. The model was calibrated and validated based upon the period of 1963-1973, and it was applied in the analysis of the financial behavior of the industry. It was shown that further deterioration of the fixed facilities can have significant impacts of decay on the profitability of the industry. It was also shown that reversing the earnings deterioration cycle which currently plagues the industry by means of eliminating the present huge backlog of deferred expenditures on way can form the basis for long-term growth and profitability. Furthermore, the effectiveness of labor and equipment productivity improvements in complementing the massive rehabilitation program were discussed and demonstrated with the model. Lastly, the model was used to give an indication of the extent of external aid required to keep the industry solvent under various future conditions. In Section 6.1, a general summary of the research effort is given, followed by a discussion of the study conclusions and their implications in Section 6.2. Finally, further

applications of the existing model, as well as refinements and extensions of its scope are suggested in Section 6.3.

6.1 SUMMARY OF THE RESEARCH EFFORT.

The railroad industry, while a vital component in America's freight transportation system, is plagued by poor earnings. Chapter 1 gave a brief review of the financial condition of the industry and discussed some of the important factors which are interacting to cause its poor financial performance. Specifically, regulation, changing traffic mix to lower-value, lower-revenue bulk commodities due to the loss of high-value traffic to the more efficient trucking industry, cost inflation, poor labor productivity and equipment utilization, and the declining quality of the physical plant were identified as some of the key factors involved in promoting the current undesirable state of affairs.

It was also pointed out in Chapter 1 that the many factors which interact to determine the industry's financial condition could be conceptualized as forming a complex feedback system.

Of particular interest in this study has been the feedback loop which relates poor earnings to the inability of the railroads to maintain and invest in their fixed facilities, which in turn causes system quality deterioration, leading to escalations in operating costs and thus further reductions in earnings. This research has focused on the dynamic consequences of the continuation of this vicious earnings deterioration cycle and on the potential that the reversal of this feedback loop has in promoting growth and profitability. Furthermore, the ability of the industry to finance and complement this reversal from within, through improved labor productivity and car utilization, was investigated.

Because of the complex feedback nature of the industry's financial system, systems dynamics, a modelling approach developed to enable the effective study of such systems, was chosen as the technique to be used in addressing the issues of concern in this research. Chapter 2 gave a brief introduction to the nature of the methodology and the philosophy employed in constructing and using systems dynamics models, and Chapter 3 explained the structure of the model developed for the railroad industry.

Due to the complexity of the system which determines

the railroad industry's financial performance, many simplifications were made in constructing the model. Also, in order to use the model, many assumptions had to be made as to the future course of numerous system parameters. These simplifications and assumptions were discussed in Chapters 3 and 5. In addition, Appendix D indexes all the assumptions and simplifications made so they may be easily located in the body of the text. Appendix D also contains the author's a priori expectations as to the importance of the various assumptions and simplifications in affecting the model's numerical outputs, as it was impossible to test them in this study due to their large number. The expected impact of these simplifications on the study conclusions is addressed in Section 6.2.

As was evident in the model's description in Chapter 3, its structure is rather complex in spite of the simplifications made in developing it. Many of the simplifications had to do with particular system components, such as policies, cost functions, constraints on debt availability, etc. The model's complexity, and usefulness, arises from the fact that it includes the major interactions between these components. Specifically, its structure includes, and can be used to study, the

dynamic interactions of such factors as maintenance of way poliicies, quality of the fixed facilities, operating costs, capital costs, labor and equipment productivities, profitability, solvency, and the ability to provide capacity in the face of an assumed inelastically growing demand and fixed traffic mix. Chapter 3 gave a detailed description of the model's structure, indicating the many interrelationships between these, and other factors. It also showed that feedback exists in the industry's financial system in various and complicated manners.

The issue of model validity was then dealt with in Chapter 4. The validity of a model depends upon how well it represents the real system being modelled, and is thus a function of its structural and numerical similarity with the actual system. In order to test the validity of a simulation model of the type developed here, it is typically run through a past interval of time so that its behavior may be compared with that of the system it represents, and revisions made to the structure or parameterization of the model if it fails to compare favorably with the observed facts. In this study, the model was run approximately twenty times through the interval 1963-1973, with minor revisions to structure and parameters being made after each run in order to achieve improved compatibility with actual data on dozens of variables

over that time period. The end results of this validation process for the more important system variables were presented in Chapter 4, indicating that the model was capable of approximating the true system behavior to a fair degree.

The model was then applied to numerous future situations, the results of which were presented and discussed in Chapter 5. The focus of the model applications was on the dynamic financial impacts of quality degradation or improvement, and the ability of the industry to internally finance and complement the effects of a quality improvement program through improved labor and equipment productivities. The conclusions that may be reached on the basis of the observations made in the previous chapter, along with their implications, are the subject of Section 6.2.

This research has been useful in several respects. First, a framework has been established for the application of systems dynamics to the overall financial system that affects the railroad industry. This framework may also be used as a guide to the modelling of individual railroads or groups of railroads. Indeed, it is perhaps better suited to that purpose since the management of a particular railroad could provide specific statements of

the policies followed by their organization and good estimates of the cost functions and system parameters that affect their profitability. Subsequently, they would be able to use a model developed for their company in order to obtain estimates of the overall corporate impacts resulting from changes in their policies. Since the model would be based upon their understanding of the details of their own operations (i.e., specific cost functions, policies, etc.), it would most likely be a more accurate predictor than the model developed here.

Second, a model of the American railroad industry was developed that has a wide range of applicability. This model may be used in the future to analyze a much broader spectrum of issues than was the case in the study. Third, therefore, this research has been useful in the analysis of the issues to which it was addressed. By providing approximate quantitative statements of the dynamic effects of the alternatives tested, the model allowed a better understanding of the many implications of these alternatives both in the short and the long run.

Lastly, and perhaps most importantly, this research provided insight into the overall structure of the system which determines railroad profitability and financial performance. Constructing the model forced the explicit

identification of all the factors (policies and parameters) and interactions which comprise this system. It also required the specification of the individual factors, so that the behavior caused by their interactions could be addressed through model use. However, even if the system components had not been specified for implementation on a computer, the insight gained into the roles and interactions of these various system components was useful in and of itself.

6.2 CONCLUSIONS.

In forming conclusions from the analyses performed in this study, several important facts must be kept in mind. First of all, the model deals with the industry in the aggregate, so the observations presented in the previous chapter and the conclusions made here also apply to the industry in the aggregate. The degree to which the observations and conclusions are relevant for any one railroad therefore depends upon how similar it is to the industry in general in terms of system quality, earnings, policies, etc., as represented in the model.

Second, because the model is a macroscopic represen-

tation of the industry in the aggregate, many simplifications were made in constructing it. Thus, conclusions about the specific numerical results of any one alternative tested with the model should not and will not be made here. Rather, the model was used in this study as a comparative tool. That is, it was applied to obtain approximate numerical statements of the relative effectiveness of various alternatives aimed at improving the long-run financial performance of the industry. Because of the complex, interactive nature of the system dealt with, the alternatives tested can have many inter-related impacts throughout. Thus, this seemingly "imprecise" method of applying the model is useful in that it allows the relative effectiveness of alternatives to be judged on the basis of the overall dynamic impacts they have. In developing a model of such a broad perspective, therefore, accuracy had to be sacrificed somewhat. However, this loss in accuracy does not detract from the model's usefulness as a comprehensive comparative tool.

Third, the interest in comparing alternatives in this study is in their relative effectiveness in allowing the industry to meet an assumed growing demand for its service profitably and without excessive reliance on external funds to maintain solvency. Because the

railroads have a role to fulfill in the economy and are regulated, this type of comparison was felt to be more meaningful than one which centered around a purely economic measure of the worth of the alternatives. Thus, such measures as net present value are not used here in the comparison of alternatives.

Fourth, while a wide range of issues is addressable with the model, this study focused on the issues of labor productivity, car utilization, and the quality of the fixed facilities. These problem areas have been the subjects of discussion and/or study for years, and the conclusions reached here represent commonly accepted viewpoints. However, this study has provided some additional quantitative evidence upon which these conclusions may be based. Specifically, the outputs of the model indicate the approximate extent and timing of overall system responses which can occur under various assumed future conditions.

Fifth, the model has been calibrated and structured based upon observed data over a ten-year span, in which traffic volumes varied between 622 billion revenue ton-miles and 852 billion revenue ton-miles, while in this study the model is projected 35 years into the future and deals with volumes ranging from 300 billion to 1700 billion revenue ton-miles. Thus, these projected futures

are not predictions of the future, as they represent how the industry, with the technology and financial environment of the recent past, would fare under a wide range of circumstances. That is, the system itself is assumed not to change, regardless of the situation. In reality, if the situation changed dramatically (i.e., widespread bankruptcy or excessive profitability), the system itself would change in response to the situation. These situation-induced system changes are completely unknown at the present time, and thus are not modelled. This further emphasizes that the model should be used as a comparative tool (given the current system) rather than an absolute predictor. Any conclusions drawn here are therefore based on the model's use as a comparative tool, as it was assumed in all cases that the parameters, policies, and external factors affecting the industry were similar to those observed (or assumed) for the period 1963-1973.

Lastly, the sensitivity of the conclusions reached here to the simplifications and assumptions of the model has not been tested. Due to the large number of assumptions and simplifications, it was impossible to test their effects on the model's outputs, and hence on the conclusions reached, in this study. However, it is the author's belief that the conclusions reached here are

insensitive to the assumptions made.

With these qualifications having been made, the study conclusions and their implications may be presented.

1) Continued maintenance (and investment) of way deferral on the part of the industry can have serious impacts on its long-run profitability and growth potential. By raising unit costs relative to unit revenues, continued quality degradation can cause a continual decline in earnings. Furthermore, by reducing the NROI possible from a given volume of traffic, poorer system quality results in lower return being generated from a given level of investment in rolling stock. Inasmuch as the industry is already heavily dependent on debt for financing equipment acquisitions, declining NROI leads to increasing difficulty in meeting fixed charges and debt repayments, so that the ultimate effect of continued quality degradation is either: (a) the undesirability or inability to acquire further expansion funds, or (b) widespread insolvency. These results were evident in the first four cases presented. In those cases, quality was declining, and the industry was able to remain solvent by reducing their capital expenditures on rolling stock and thus their fixed charges and debt obligations. Expanding in the face of escalating operating costs led

to insolvency, as the return generated from the additional investment in rolling stock was inadequate to cover the additional costs of the equipment. While the observations made in the first four cases are numerically dependent upon the parameters and policies of the model (which the author believes are realistic), it is logical to conclude that continuing investment with dynamically declining returns, regardless of the specific rate of decline (i.e., as caused by the model parameters and policies), would lead to such a result eventually.

2) Improvement of the quality of the fixed facilities is very important, if not necessary, to the long-run health of the industry. Even with a mild payoff to quality improvement, the characteristics of growth and increased profitability were evident in the cases run. This was because the reversal of the quality deterioration cycle stopped the dynamic decay of earnings and led to a cost/revenue structure that was more conducive to profitable growth. Quality improvement (or at least no further decline in system quality) can be important in forming the basis for growth and profitability in the long run. This was evidenced by the growth and long-run profitability achieved by combining labor and equipment productivity increases with a quality improvement

program. On the other hand, in Case V, where a drastic reduction in labor costs was used to boost earnings and liquidity in the short run while quality was allowed to decline, overall system decay eventually occurred. (Of course, the extent of the decay is a function of the assumed mild numerical impacts of quality degradation. However, the values used do not seem too unreasonable.) Because quality improvement seemed so important to the long-run health of the industry, various methods of financing and complementing a quality improvement program were tested. The results of these investigations form the bases for the following conclusions.

3) Without changes to its cost/rate structure other than those eventually accruing from improved system quality, the industry can internally finance a major portion of a quality improvement program aimed at eliminating its backlog of deferred maintenance of way if it is willing/allowed to forego growth in the near future. By reducing capital expenditures on equipment, funds can be diverted to way and structures. Several issues arise with respect to this conclusion. First of all, since the railroads are common carriers, they might not be legally allowed to forego growth. This "forcing" by the government entails heavier reliance upon external

(i.e., federal) funds to finance the quality improvement program, as the limited revenues of the industry cannot be used to finance such a massive rehabilitation program if they must also be used to expand capacity. Thus, if society is to receive continuously growing and higher quality rail service (which would result from a higher quality system), a substantial amount of public funds would be necessary to allow the industry to provide this service to the public. However, if the return to fixed plant rehabilitation were high enough, these funds could be (but not necessarily should be) supplied in the form of loans, which would be repaid. Second, while concern was expressed over the effects of zero car purchases on car suppliers in the improved car productivity cases, the effects of severely reduced purchases were not explicitly considered. Since these reductions are crucial to the industry's internal ability to finance a quality improvement program (with or without a car productivity increase), their feasibility should also be taken into consideration in judging the extent to which the industry could finance the program. It is possible that pressure from the equipment manufacturers could result in less severe reductions in equipment purchases during the early years of the improvement program, and hence a bigger

drop in net working capital than computed by the model. Therefore, it is seen that the extent of the industry's ability to internally finance a quality improvement program can be constrained by more than revenues. Legality or shipper concerns as well as the concerns of the equipment suppliers could place important restrictions upon the industry's ability to reduce capacity. The "if" in the statement of this conclusion is therefore an important word, as the finances of the railroad industry are highly interdependent with the finances of other segments of the economy. However, an individual railroad might be able to take advantage of capacity reduction as a means of financing the rehabilitation of its fixed plant if there was an alternative (profitable and high quality) railroad capable of handling some of its traffic for a short period of time.

4) Significantly increased transportation labor productivity is an extremely effective method of improving the financial condition of the industry. Through a major work force reduction, the industry is able to internally finance a larger portion of its improvement program and to complement the payoffs to this program. However, labor savings alone might not be enough for the industry to achieve long-term growth and profitability,

as was evident in Case V where drastic labor savings were coupled with quality degradation. Thus, increased labor productivity provides a valuable complement to quality improvement. The important issue that has not been explicitly addressed is the magnitude, timing, and implementation of the productivity improvements. In the cases analyzed with the model, labor productivity was assumed to increase instantaneously in 1976 allowing an immediate work force reduction at no cost to the industry. However, union pressures would likely prevent such a reduction, and labor agreements would probably cause the industry to compensate the displaced employees. Furthermore, because the model cases run assumed there was no cost to the industry in compensating the displaced employees, there is a further implication. Specifically, while the initial work force reduction allows less reliance on federal funds for quality improvement, it would entail government funds in the form of unemployment benefits for the displaced workers until such time as they found other, more productive jobs in the economy. So again, while the effectiveness of the alternative was considered from the railroad's standpoint, its overall feasibility and implications involve more than the industry itself.

5) Major improvements in car utilization can have significant impacts on the industry's long-run profitability if achieved in conjunction with increased labor productivity and the performance of a quality improvement program. The increase in freight car productivity considered was of identical magnitude (25%) as that considered for transportation labor productivity in the quality improvement cases. When viewed alone, increased car productivity was therefore less effective than the labor alternative as a means of lowering costs, due to the relative magnitudes of labor and equipment costs. However, the magnitude of the increase in car productivity considered is more feasible than a similar increase in transportation labor productivity, due to union concerns constraining the latter, and due to the potential which exists for the former through reduced yard-times. In spite of the possible infeasibility of the labor option, the model was useful in showing the potential that this option could have alone and in conjunction with the car productivity improvement. The model indicated that if the payoff to quality improvement is strong, these two productivity increases together could lead to very substantial long-term profitability and liquidity. Again, the impacts on affected interests

other than the railroad industry itself (i.e., labor, shippers, car suppliers) would have to be considered in determining the feasibility of the options tested, while the model merely demonstrates their impacts on the industry alone.

6) As is apparent in all the above conclusions, there seems to be no one alternative that can cure the industry's problems. This is because the effectiveness of each alternative is constrained, either for technological reasons (i.e., the maximum cost reductions accruing from fixed plant improvement, or the maximum feasible increase in car utilization possible) or for socio-economic reasons (i.e., the legality of the industry to forego the growth demanded by shippers, or the possibility of union opposition to labor force reductions and the compensation required for displaced employees). While little can be done about the technological constraints, the socio-economic constraints can be "relaxed" through government aid. Thus, it seems that a combination of technologically feasible changes within the industry coupled with the "relaxation" of its socio-economic constraints through government involvement, can lead to long-term growth and profitability.

7) As previously mentioned in this chapter, model

construction and use provided valuable insight into the overall structure of the system which determines railroad profitability and financial performance. Even if the model components had not been specified in detail for computer implementation, the insight gained into the roles and interactions of these various system components was enlightening in and of itself.

The above conclusions and discussions, while not necessarily new to the field of railroad economics, are based upon the quantitative outputs provided by the model and their interpretation as the impacts on the industry alone in given hypothetical situations. The model has therefore been useful in providing quantitative bases for these statements, and need not be limited to the study of such common problems as was the case here. Further areas of model application are discussed in the next section.

6.3 DIRECTIONS FOR FURTHER RESEARCH.

The model developed in this research effort has a much wider range of applicability than indicated by the (numerous) cases analyzed in Chapter 5. The types of alternatives which can be tested with it were indicated in Chapter 3, where the model structure, and thus the

changes possible to this structure, was presented. In spite of the many problem areas that could be addressed with the model, there are specific issues that have been raised by the analyses performed in this study that beg further investigation. Particularly, the impacts of various types and sizes of federal aid programs aimed at fixed plant rehabilitation (with or without productivity or other improvements on the part of the industry) immediately come to mind. It would be interesting to see the effects of various types of subsidies (i.e., \$1 billion per year for 5 years, \$2 billion per year for 5 years, \$1 billion per year for 10 years, etc.) on the net working capital of the industry, assuming that all the demand for rail service is met. Various magnitudes of loan programs, with various interest rates and terms of repayment, could also be analyzed as means of financing the rehabilitation program while the industry was forced to serve all the demand for its service. Furthermore, all these options could be tested in conjunction with other changes such as those in labor and equipment productivities, reductions or increases in freight rates (although the assumed inelastic demand would have an important impact on the interpretation of the results achieved), different assumptions about labor pay increases over time, etc. Thus, there are many problems of great interest that could be

addressed with the present model.

It is also desirable to see the model refined. In spite of the enormous effort put into its development, it is still rather crude. Areas where significant improvements might be made are those of the model's cost functions and the functions relating quality of the fixed facilities to costs and productivities. Because the model was developed for the industry in the aggregate, the operating cost functions had to be derived from aggregate, reported statistics and the quality effect curves had to be given various assumed numerical ranges. Thus sensitivity analyses were required. If, on the other hand, a similar type of model was developed for a particular railroad with the extensive cooperation of the management, it is likely that information would be available on the specific nature of their cost functions, maintenance backlog, payoffs to fixed plant rehabilitation, etc. Also, specific policy statements of the corporation would be available from the management, whereas the policies of the industry used in this study were derived from the observed overall results of the actual policies in effect in the individual companies. Thus, refinement of the model is most likely dependent upon its being changed and applied to a particular railroad with the extensive cooperation of that railroad's

management in the specification and parameterization of the model's components.

Finally, there is the issue of the scope of the model. The entire area of service quality, demand elasticities, and operating policy has been ignored here. While the system analyzed in this study (Figure 1-2) is very important in affecting railroad profitability, it only represents part of the total system (Figure 1-i) involved. Thus, it would be desirable to have the model extended to account for those factors (and their interactions with the rest of the system) which have been omitted.

Service quality, demand sensitivity (and the effects of competition in determining this sensitivity), and operating policies were omitted in this study because they are difficult (but not impossible) to represent mathematically at the macroscopic level of detail of the model. Furthermore, there has been a significant lack of research into their overall interactions with the rest of the financial system, particularly at an aggregate level compatible with the model developed in this research. Thus, while these factors could have been included in the model in a simple fashion similar to that used for quality and its effects, and sensitivity

analyses performed on the various assumptions made, this was not done here to keep the degree of uncertainty with respect to major system components to a minimum. That is, only one assumption about each of these uncertain major factors, rather than a range of assumptions, was tested. It is hoped that this research will provide incentives for further research into the overall relationships between these factors and the rest of the total system which determines railroad profitability. Once this is accomplished, the model's scope could be widened without addition to its internal uncertainty, and a more comprehensive range of issues could be addressed. Specifically, the effects of rate increases and changes in operating policies (and hence in service quality) on demand, costs, profitability, and on the entire system could be analyzed. Furthermore, because the total system would be represented in the model, all the impacts of an alternative tested with the model would be accounted for. This would further enhance the model's usefulness in analyzing all types of alternatives, including those addressed in this study, as some of their effects were not accounted for in the model.

This thesis has been concerned with the development and application of a systems dynamics model of the U.S.

railroad industry. It is hoped that the presentation made here will provide guidelines and incentives for further development and applications of systems dynamics models in the analysis of the overall financial performance of the industry or its component railroads. Specifically, it is hoped that the model developed in this research will be applied to a wider range of issues than was possible here, that it be refined, and that its scope be extended to address the total system of interest.

Appendix A

MODEL LISTING AND VARIABLE DEFINITIONS

In this appendix, a complete listing of the DYNAMO code of the model is given, followed by alphabetically ordered lists of the model's variables and their meaning.

The model was run on the IBM 370 at M.I.T.'s Information Processing Center, and the model listing includes the control cards necessary to run at this particular installation. Also, the model listing contains many comments (which appear on "NOTE" cards) which indicate what is being computed in a particular section of code and which specify the module (as defined in Chapter 3) to which the code applies. Furthermore, the model listing is arranged in the same order as was Chapter 3, with the appropriate section numbers of that chapter being indicated in the listing. Thus, the reader may quite easily associate the equations given here and the description of what is performed by them given in Chapter 3.

The listing shown is the actual code used to generate the necessary data used in explaining Cases XII and XV of Chapter 5. It should be recalled from their discussions (Sections 5.2.12 and 5.2.15) that these two cases dealt with quality improvement programs in conjunction with a. 20% reduction in transportation employees (12.5% reduction in TTGM employees) and a 25 % increase

in freight car productivity (20% reduction in car cycle). Because increased car productivity is being tested, the alternative method of planning locomotive acquisitions, as mentioned in Section 3.5.2.2, is in effect beginning in 1976. The code which performs this function is given in the listing as the equations for ICNLR1 and NEEDL in the section of the listing identified by the heading "Desired Investments In Rolling Stock". As is shown there, these equations plan locomotive installations by annually adjusting the fleet size 20% of the way to the projected locomotive needs five years hence, a process which is identical in concept to the manner in which freight car installations are planned (Section 3.5.2.1).

Because of the size of the model, and because the general functions performed by its equations were discussed in detail in Chapter 3, explanations of the equations themselves will not be given here. Rather, the interested reader is urged to proceed sequentially through the model listing while at the same time referencing Chapter 3 for the explanations. Each variable used in the model is defined in alphabetical order in Tables A-1 and A-2, which follow the listing. Thus each variable may be easily located for an explanation of what its name means.

Table A-1 alphabetically lists and explains the names used for levels in the model (defined by "L" equations in

the listing), followed by an alphabetically ordered list of the names used for rates (defined by "R" equations in the listing). Table A-2 then alphabetically lists all the other variables (and constants) of the model, and explains the meanings of their names. These variables are defined by "A", "C", "T", and "S" equations in the model listing. These letters denote auxiliaries, constants, tables, and supplementaries. The interested reader is referred to references [6] , [8], and [9] of Chapter 3 for an explanation of these various types of DYNAMO equations, as well as for an explanation of what the "N" (initial value) equations may be used for. An "X" in the listing denotes a continuation card. Also, the subscripts 'J', 'K', 'JK', and 'KL' which appear with the variable names in the listing will not be repeated in Tables A-1 and A-2. These subscripts define the variables at given points in time, as is explained in references [6], [8], and [9] of Chapter 3.

It should be noted that time in the model (denoted by the variable "TIME") starts at zero, which represents mid-1963, and proceeds by intervals of .25 (years). Hence a value of TIME such as 10.5 implies the beginning of 1974 (i.e., $1963.5 + 10.5 = 1974$).

With this brief explanation having been given of the contents of this appendix, the model listing and

definitions of variable names may be presented.

```

//JH0963 JOB 1.
// *LUZ771*,CLASS=R,REGION=192K
/*MITID USER=(      .      )
/*MAIN TIME=2,LINFS=15
//DYN EXFC DYNAMO,PARM=REFRIN
//G.SYSIN DD *
NOTE
NOTE
NOTE
NOTE
NOTE ***** SYSTEMS DYNAMICS MODEL OF *****
NOTE ***** U.S. RAILROAD INDUSTRY *****
NOTE
NOTE
NOTE
NOTE
NOTE ***** INCOME MODULE *****
NOTE SECTION 3.1
NOTE
NOTE TTGM COSTS
NOTE SECTION 3.1.2
NOTE
NOTE TTGM LABOR COSTS
NOTE SECTION 3.1.2.1
NOTE
NOTE TTGM LABOR PRODUCTIVITY
NOTE
A TGPRD.K=TGRPRD*TGLPI.K
C TGRPRD=2.408E6
A TGLPI.K=CLIP(TGLPI1.K,TGLPI2.K,TIME.K,11.5)
A TGLPI1.K=PPN.K*1.4*(1-.81R*EXP(-.185*TIME.K))
A TGLPI2.K=.8+STEP(.066,0.5)+STEP(.087,1.5)+STEP(.014,2.5)
X +STEP(.033,3.5)+STEP(.044,4.5)+STEP(.036,5.5)+STEP(.016,6.5)
X -STEP(.024,7.5)+STEP(.053,8.5)+STEP(.103,9.5)+STEP(.03,10.5)
NOTE
NOTE TTGM LABOR WAGE RATES AND BENEFITS
NOTE
A TGCPM.K=TGRCPM*TGLCI.K
C TGRCPM=99A0
A TGLCI.K=CLIP(TGLCI1.K,TGLCI2.K,TIME.K,11.5)
A ITGLCI.K=C175.K*TGLCI74*TGLPI1.K/TGLPI74
A INFLCI.K=SMOOTH(TGLCI.K,DT)*INFLATQ
N TGLCI=.82A
A TGLCI1.K=MAX(ITGLCI.K,INFLCI.K)
C TGLCI74=1.855
C TGLPI74=1.25
A TGLCI2.K=.828+STEP(.039,0.5)+STEP(.057,1.5)+STEP(.042,2.5)
X +STEP(.034,3.5)+STEP(.076,4.5)+STEP(.079,5.5)+STEP(.056,6.5)
X +STEP(.147,7.5)+STEP(.164,8.5)+STEP(.197,9.5)+STEP(.137,10.5)
NOTE
NOTE TTGM # OF EMPLOYEES AND TOTAL LABOR COST
NOTE
A ITGEMP.K=VOL.K/TGPRD.K

```

A TGEMP.K=ITGEMP.K*WRKRF.K
 A WRKRF.K=1.0-STEP(WFRF,STRTWFR)
 C WFRF=.125
 C STRTWFR=12.5
 A TGTLC.K=TGEMP.K*TGCPM.K

NOTE

NOTE TTGM FUEL COSTS
 NOTE SECTION 3.1.2.2

NOTE

A GFII.K=.00479*VOL.K*QFMC.K
 A FCPG.K=BFCPG*FCI.K
 C BFCPG=.0961
 A TFC.K=GFU.K*FCPG.K
 A FCI.K=CLIP(FCI1.K,FCI2.K,TIME.K,11.5)
 A FCI1.K=FCI74*CI75.K
 C FCI74=2.798
 A FCI2.K=.948-STEP(.028,0.5)+STEP(.027,1.5)+STEP(.009,2.5)
 X +STEP(.044,3.5)+STEP(.034,4.5)+STEP(.024,5.5)+STEP(.059,6.5)
 X +STEP(.015,7.5)+STEP(.01,8.5)+STEP(.252,9.5)+STEP(1.394,10.5)

NOTE

NOTE ALL OTHER TTGM COSTS
 NOTE SECTION 3.1.2.3

NOTE

A TGTOT.K=.00165*VOL.K*MATCI.K*QFMC.K
 A MATCI.K=CLIP(MATCI1.K,MATCI2.K,TIME.K,11.5)
 A MATCI1.K=MATCI74*CI75.K
 C MATCI74=1.421
 A MATCI2.K=.934+STEP(.008,0.5)+STEP(.007,1.5)+STEP(.016,2.5)
 X +STEP(.035,3.5)+STEP(.026,4.5)+STEP(.029,5.5)+STEP(.039,6.5)
 X +STEP(.041,7.5)+STEP(.052,8.5)+STEP(.042,9.5)+STEP(.192,10.5)
 A TTGM.K=TGTLC.K+TFC.K+TGTOT.K

NOTE

NOTE

NOTE MAINTENANCE OF EQUIPMENT
 NOTE SECTION 3.1.3

NOTE

NOTE

NOTE M OF E MATERIAL COSTS : AMOUNT OF MAINT TO DO
 NOTE SECTION 3.1.3.1

NOTE

A MECDCM.K=.00048*QFMC.K*VOL.K
 A METMC.K=MECDCM.K*MATCI.K

NOTE

NOTE

NOTE M OF E LABOR COSTS
 NOTE SECTION 3.1.3.2

NOTE

NOTE

NOTE M OF E LABOR PRODUCTIVITY

NOTE

A MEPRD.K=MEBPRD*MELPI.K
 C MEPRD=353A
 A MELPI.K=CLIP(MELPI1.K,MELPI2.K,TIME.K,11.5)
 A MELPI1.K=1.4*(1-1.14*EXP(-.2121*TIME.K))
 A MELPI2.K=.771+STEP(.056,0.5)+STEP(.086,1.5)+STEP(.058,2.5)
 X +STEP(.029,3.5)
 X +STEP(.041,4.5)+STEP(.034,5.5)+STEP(.024,6.5)+STEP(.002,7.5)
 X +STEP(.045,8.5)+STEP(.124,9.5)+STEP(.038,10.5)

NOTE

NOTE

M OF E LABOR WAGE RATES AND BENEFITS

NOTE

A $MFCPM.K = MFCPCM * MELCI.K$ C $MFCPCM = 8198$ A $MELCI.K = CLIP(MELCI1.K, MELCI2.K, TIME.K, 11.5)$ A $MELCI1.K = MELCI74 * TGLCI1.K / TGLCI74$ C $MELCI74 = 1.881$ A $MELCI2.K = .815 + STEP(.032, 0.5) + STEP(.051, 1.5) + STEP(.047, 2.5)$ X $+ STEP(.055, 3.5) + STEP(.093, 4.5) + STEP(.060, 5.5) + STEP(.173, 6.5)$ X $+ STEP(.122, 7.5) + STEP(.122, 8.5) + STEP(.182, 9.5) + STEP(.139, 10.5)$

NOTE

NOTE

M OF E # OF EMPLOYEES AND TOTAL LABOR COST

NOTE

A $MFFMP.K = MECDCM.K / MEPRD.K$ A $METLC.K = MEEMP.K * MFCPM.K$ A $MXE.K = METMC.K + METLC.K$

NOTE

NOTE

NOTE MAINTENANCE BUDGETING (WAY AND STRUCTURE ,

NOTE

SECTION 3.1.4

NOTE

NOTE

A $NINV.K = (NBVEQ.K + NRVWS.K) * CMIF$ C $CMIF = 1.124$ S $RNI.K = NROI.K / NINV.K$ A $MDR.K = AVGIR.K$ A $IMDNROI.K = MDR.K * NINV.K$ A $LRNROI.K = INTX.K - OINC.K$ A $MDNROI.K = MAX(LRNROI.K, IMDNROI.K)$ A $MDNIAT.K = MDNROI.K - INTX.K + OINC.K$ A $MDNIAT.K = MDNIAT.K / (1 - TAXD)$ A $MNROIAT.K = MDNIAT.K + INTX.K - OINC.K$ A $NROIAT.K = REVS.K - MXE.K - TTGM.K - PX.K - RENTX.K - SLTX.K - DEPX.K$ A $IMAXMW.K = NROIAT.K - MNROIAT.K$ A $MAXMWS.K = MAX(0, IMAXMW.K)$ A $IMWS.K = MIN(0, MWS.K, MAXMWS.K)$ A $BMXWS.K = MAX(LRMWS.K, IMWS.K)$

NOTE

NOTE

NOTE ALL OTHER EXPENSES

NOTE

SECTION 3.1.5

NOTE

NOTE

A $PX.K = CLIP(PX1.K, PX2.K, TIME.K, 10.5)$ A $PX1.K = 500E6 * CI74.K$ A $PX2.K = 1316E6 - STEP(79E6, 2.5) - STEP(237E6, 4.5) - STEP(393E6, 7.5)$ X $- STEP(107E6, 8.5)$ A $RFNTX.K = CLIP(RFNTX1.K, RFNTX2.K, TIME.K, 10.5)$ A $RFNTX1.K = 950E6 * CI74.K$ A $RFNTX2.K = 422E6 + STEP(80E6, 1.5) + STEP(111E6, 3.5) + STEP(126E6, 5.5)$ X $+ STEP(111E6, 7.5) + STEP(190E6, 9.5)$ A $SLTX.K = CLIP(SLTX1.K, SLTX2.K, TIME.K, 10.5)$ A $SLTX1.K = 400E6 * CI74.K$ A $SLTX2.K = 355E6 + STEP(45E6, 5.5)$ A $DEPX.K = DEPEQ.K + DEPWS.K$ A $EXP.K = MXE.K + BMXWS.K + TTGM.K + PX.K + RFNTX.K + SLTX.K + DEPX.K$

NOTE

NOTE

NOTE REVENUES AND OTHER INCOME
 NOTE SECTION 3.1.6
 NOTE
 NOTE

A FRREVS.K=VOL.K*RATES.K
 A RATES.K=CLIP(RATES1.K,RATES2.K,TIME.K,11.5)
 A RATES1.K=.01853*PI75.K
 A PI75.K=CI75.K
 A RATES2.K=.0131-STEP(.00026,.5)-STEP(.00018,1.5)-STEP(.00009,2.5)
 X +STEP(.00012,3.5)+STEP(.00041,4.5)+STEP(.00037,5.5)
 X +STEP(.00081,6.5)+STEP(.00165,7.5)+STEP(.00025,8.5)
 X -STEP(.00001,9.5)+STEP(.00236,10.5)
 A PMEOR.K=CLIP(PMEOR1.K,PMEOR2.K,TIME.K,10.5)
 A PMEOR1.K=1E9*CI74.K
 A PMEOR2.K=1390E6-STEP(154E6,3.5)-STEP(143E6,4.5)-STEP(190E6,7.5)
 X -STEP(64E6,8.5)+STEP(161E6,9.5)
 A RFVS.K=FRREVS.K+PMEOR.K
 A OINC.K=CLIP(OINC1.K,OINC2.K,TIME.K,10.5)
 A OINC1.K=335E6*CI74.K+IONWC.K
 A IONWC.K=(NWC.K-NWC73)*IRATE.K
 C NWC73=210E6
 A OINC2.K=214E6+STEP(51E6,.5)+STEP(74E6,3.5)+STEP(39E6,4.5)
 X -STEP(48E6,6.5)-STEP(69E6,7.5)+STEP(74E6,9.5)

NOTE
 NOTE
 NOTE INCOME STATEMENT
 NOTE SECTION 3.1.7
 NOTE
 NOTE

A NIAT.K=REVS.K+OINC.K-FXP.K-INTX.K
 A TXINC.K=MAX(NIAT.K,0)
 A ITX.K=TAXR*TXINC.K
 C TAXR=.20
 A NIAT.K=NIAT.K-ITX.K
 A CASHF.K=NIAT.K+DEPX.K
 A NROI.K=REVS.K-FXP.K-ITX.K

NOTE
 NOTE
 NOTE
 NOTE ***** FUNDS FLOW AND FINANCE MODULE *****
 NOTE SECTION 3.2
 NOTE
 NOTE

NOTE RETAINED EARNINGS AND NET WORKING CAPITAL LEVELS
 NOTE SECTION 3.2.3.1
 NOTE
 NOTE

L RE.K=RE.J+(DT)(NIATR.JK-DIVR.JK)
 N RF=11.425E9
 R NIATR.KL=NIAT.K
 R DIVR.KL=DIV.K
 L NWC.K=NWC.J+(DT)(SRF.JK-IISF.JK)
 N NWC=738E6
 R SRF.KL=DI.K+CASHF.K+MSRF.K
 A MSRF.K=CSES.K+40E6*PCD.K
 R USF.KL=DIV.K+DP.K+IWS.K+DINE.K+IRS.K

NOTE
 NOTE
 NOTE DIVIDEND POLICY

NOTE SECTION 3.2.3.2

492

NOTE

NOTE

NOTE

A $DIV.K = \text{MAX}(0, IDIV.K)$
A $IDIV.K = DPR.K * NIATR.K$
N $NIATR = 652E6$
A $DPR.K = \text{CLIP}(DPR1.K, DPR2.K, TIME.K, 11.5)$
A $DPR1.K = \text{MAXDPR} * CNWCM.K$
C $\text{MAXDPR} = .25$
A $DPR2.K = .58 + \text{STEP}(.07, .75) - \text{STEP}(.09, 1.75) + \text{STEP}(.36, 3.75)$
X $+ \text{STEP}(.93, 6.75) - \text{STEP}(.74, 7.75) - \text{STEP}(.32, 8.75) - \text{STEP}(.25, 10.75)$

NOTE

NOTE

NOTE INVESTMENT, FINANCE, AND LIQUIDITY POLICIES

NOTE

SECTION 3.2.3.3

NOTE

NOTE

A $CDNWC.K = NWC.K / (PCD.K * 1E6)$
A $CNWCM.K = \text{TABHL}(CNWCT, CDNWC.K, -100, 100, 200)$
T $CNWCT = 0 / 1.0$
A $DNWC.K = DNWC8 * (VOL.K / VOLR) * PCD.K$
C $DNWC8 = 936E6$
C $VOLR = 622E9$
A $DANWC.K = (DNWC.K - NWC.K) / TANWC$
C $TANWC = ?$
A $NCEEQ.K = DIOE.K + NCERS.K$
A $NCERS.K = NCPIRS.K * DIRS.K$
A $NCPIRS.K = \text{MAXPIR}.K * CNWCM.K$
A $\text{MAXPIR}.K = .34 - \text{STEP}(.19, 12.5)$

NOTE

NOTE

NOTE FUNDS ALLOCATION PROCESS

NOTE

SECTION 3.2.3.4

NOTE

NOTE

A $PFA.K = \text{CASHF}.K + \text{MSRF}.K$
A $PIIF.K = DIV.K + DP.K + \text{LBIWS}.K + NCEEQ.K + DANWC.K$
A $IDNP.K = PUF.K - PFA.K$
A $DNP.K = \text{MAX}(IDNP.K, 0)$
A $IOD1.K = \text{MIN}(MFIN.K, IDNP.K)$
A $IIFAI.K = -IDNP.K$
A $IFAWS.K = \text{MAX}(IIFAI.K, 0)$
A $FNWS.K = DIWS.K - \text{LBIWS}.K$
A $IFUWS.K = \text{MIN}(IFAWS.K, FNWS.K)$
A $DNWS.K = FNWS.K - IFUWS.K$
A $DAWS.K = MFIN.K - IOD1.K$
A $IOD2.K = \text{MIN}(DNWS.K, DAWS.K)$
A $IWS.K = \text{LBIWS}.K + IFUWS.K + IOD2.K$
A $IOD.K = IOD1.K + IOD2.K$
A $IFAPS.K = IFAWS.K - IFUWS.K$
A $FNRS.K = DIRS.K - NCERS.K$
A $IFURS.K = \text{MIN}(FNRS.K, IFAPS.K)$
A $DNRS.K = FNRS.K - IFURS.K$
A $IED.K = \text{MIN}(MFINE.K, DNRS.K)$
A $DI.K = IOD.K + IED.K$
A $CURS.K = NCERS.K + IFURS.K$
A $IRS.K = CURS.K + IFD.K$
A $IFRS.K = IRS.K - \text{DIPC}.K - \text{DIPL}.K$
A $\text{FFRSID}.K = \text{IFRS}.K / \text{DIFRS}.K$

A CNLR.K=DCNLR.K*FFRSTID.K
 A CNCR.K=DCNCR.K*FFRSTID.K
 A ILOCS.K=CNLR.K*PLOC.K+DTPL.<
 A ICARS.K=CNCH.K*PCAR.K+DIPC.<
 A FWS.K=IWS.K+BMXWS.K

NOTE

NOTE

NOTE

NOTE ***** FIXED ASSETS AND DEBT MODULE *****

NOTE SECTION 3.3

NOTE

NOTE

NOTE ACCOUNTING: FREIGHT AND PASSENGER CARS

NOTE SECTION 3.3.1

NOTE

NOTE

L GBVROC.K=GBVROC.J+(DT)(CXCARR.JK-CWOR.JK)

N GBVROC=8.83E9

R CXCARR.KL=ICARS.K

R CWOR.KL=ICWOR.K

A ICWOR.K=CLIP(ICWOR1.K,ICWOR2.K,GBVROC.K,1E9)

A ICWOR1.K=DLINF3(ICARS.K,CIFEF)

A ICWOR2.K=GBVROC.K/CLIFF

C CIFEF=20

N ICARS=440F6

L ADCARS.K=ADCARS.J+(DT)(DEPXCR.JK-DWOR.JK)

N ADCARS=3.447E9

R DEPXCR.KL=IDCARS.K

A IDCARS.K=DRCARS*GBVROC.K

C DRCARS=.0325

R DWOR.KL=VLFC*ICWOR.K

C VLFC=.65

A CSCS.K=(1-VLFC)*ICWOR.K

A ADC.K=MAX(ADCARS.K,0)

A NBVROC.K=GBVROC.K-ADC.K

NOTE

NOTE

NOTE ACCOUNTING: FREIGHT AND PASSENGER LOCOMOTIVES

NOTE SECTION 3.3.1

NOTE

NOTE

L GBVROL.K=GBVROL.J+(DT)(CXLOC.R.JK-LWOR.JK)

N GBVROL=4222E6

R CXLOC.R.KL=ILOCS.K

R LWOR.KL=ILWOR.K

A ILWOR.K=CLIP(ILWOR1.K,ILWOR2.K,GBVROL.K,500E6)

A ILWOR1.K=DLINF3(ILOCS.K,LLIFE)

A ILWOR2.K=GBVROL.K/LLIFE

C LLIFE=16.25

N ILOCS=230E6

L ADLOCS.K=ADLOCS.J+(DT)(DEPYLR.JK-DWOLR.JK)

N ADLOCS=1935E6

R DEPYLR.KL=IDLACS.K

A IDLOCS.K=DRLOCS*GBVROL.K

C DRLOCS=.048

R DWOLR.KL=VLFL*ILWOR.K

C VLFL=.78

A CSLS.K=(1-VLFL)*ILWOR.K

A CSFS.K=CSLS.K+CSCS.K+CSOFS.<

A $ADL.K = \text{MAX}(ADLOCS.K, 0)$
 A $NBVROL.K = GBVROL.K - ADL.K$
 A $DFPEQ.K = IDCARS.K + IDLOCS.K + IDOE.K$
 A $NBVEQ.K = NBVROC.K + NBVROL.K + NBVOE.K$
 NOTE
 NOTE ACCOUNTING: OTHER EQUIPMENT
 NOTE SECTION 3.3.1
 NOTE
 NOTE
 L $GRVOE.K = GRVOE.J + (DT) (CXORR.JK - OEWOR.JK)$
 N $GRVOE = 457E6$
 R $CXORR.KL = OIOE.K$
 R $OEWOR.KL = IOEWOR.K$
 A $IOEWOR.K = DLINF3(OIOE.K, DELIFE)$
 C $DELIFE = 12.6$
 N $OIOE = 32E6$
 L $ADOE.K = ADOE.J + (DT) (DEPXOR.JK - DWOOR.JK)$
 N $ADOE = 268E6$
 R $DEPXOR.KL = IDOF.K$
 A $IDOE.K = DROE * GRVOE.K$
 C $DROE = .057$
 R $DWOOR.KL = VLFOF * IOEWOR.K$
 C $VLFOE = .72$
 A $CSOFS.K = (1 - VLFOE) * IOEWOR.K$
 A $NBVOE.K = GRVOE.K - ADOE.K$
 NOTE
 NOTE
 NOTE ACCOUNTING: WAY AND STRUCTURES
 NOTE SECTION 3.3.2
 NOTE
 NOTE
 L $GRVWS.K = GRVWS.J + (DT) (CXWSR.JK - WSWOR.JK)$
 N $GRVWS = 17.187E9$
 R $CXWSR.KL = IWS.K$
 R $WSWOR.KL = .018 * GRVWS.K$
 L $ADWS.K = ADWS.J + (DT) (DEPXWR.JK - DOWNSR.JK)$
 N $ADWS = 2212E6$
 R $DEPXWR.KL = DEPWS.K$
 A $DEPWS.K = .0088 * GRVWS.K$
 R $DOWNSR.KL = .023 * ADWS.K$
 A $NBVWS.K = GRVWS.K - ADWS.K$
 NOTE
 NOTE
 NOTE DEBT AND FIXED CHARGES (INTX)
 NOTE SECTION 3.3.3
 NOTE
 NOTE
 L $DEBT.K = DEBT.J + (DT) (DEBTIR.JK - DEBTRR.JK)$
 N $DEBT = 9.655E9$
 R $DEBTIR.KL = DI.K$
 R $DEBTRR.KL = DP.K$
 A $DP.K = DEBT.K / MT$
 C $MT = 14$
 A $IRATE.K = \text{CLIP}(IRATE1.K, IRATE2.K, TIME.K, 11.5)$
 A $IRATE1.K = .10 - \text{STEP}(IRRED, 12, 5)$
 C $IRRED = 0$
 A $IRATE2.K = \text{TABML}(IRTAB, TIME.K, .25, 11.25, .5)$
 T $IRTAB = .0429 / .044 / .044 / .0452 / .0452 / .0532 / .0532 /$

X .05R3/.0583/.0661/.0661/.08/.08/.087/.087/.075/.075/
X .072/.072/.074/.074/.095/.095

495

L INTX.K=INTX.J+(DT)(INTAR.JK-INTRR.JK)

N INTX=368F6

R INTAR.KL=AINTAR.K

R INTRR.KL=AINTRR.K

A AINTAR.K=DI.K*IRATE.K

A AINTRR.K=INTX.K/MT

A AVGIR.K=INTX.K/DEBT.K

NOTE

NOTE

NOTE DEBT FINANCING CONSTRAINTS

NOTE SECTION 3.3.4

NOTE

NOTE

A SNIBTFC.K=SMOOTH(NIBTFC.K,2)

N NIBTFC=1194E6

A NIBTFC.K=NIBT.K+INTX.K

A MAXINT.K=SNIBTFC.K/CC

C CC=2

A MDEBT.K=MAXINT.K/IRATE.K

A AMFIN.K=((MDEBT.K-DEBT.K)/TAD)-IED.K

C TAD=5

A MFIN.K=MAX(AMFIN.K,0)+RANDFT.K

A RANDET.K=130E6+STEP(250E6,4.5)-STEP(390E6,11.5)

A MAXINTE.K=SNIBTFC.K/CCEQ

C CCEQ=1.0

A MDEBTE.K=MAXINTE.K/IRATE.K

A AMFINE.K=(MDEBTE.K-DEBT.K)/TAD

A MFINE.K=MAX(AMFINE.K,UFINE.K)

A UFINE.K=CLIP(DNRS.K,0,EDCF.K,.5)

A EDCF.K=STEP(EDC,12.5)

C EDC=0

NOTE

NOTE

NOTE

NOTE

NOTE

NOTE ***** QUALITY OF FACILITIES MODULE *****

NOTE SECTION 3.4

NOTE

NOTE

NOTE QUALITY OF FACILITIES AND WEAR AND TEAR

NOTE SECTION 3.4.1

NOTE

NOTE

L OF.K=OF.J+(DT)(MIR.JK-WTR.JK)

N OF=35F9

R MIR.KL=COMXWS.K+CDIWS.K

A COMXWS.K=BMXWS.K/PCOD.K

A CDIWS.K=IWS.K/PCOD.K

R WTR.KL=IWTR.K

A IWTR.K=WTN.K*OF*OC.K

A WTN.K=CLIP(WTN1.K,WTN2.K,GTM.K,1250E9)

A WTN1.K=.00203*GTM.K-1.786E9

A WTN2.K=.0006*GTM.K

A GTM.K=2.4*VOL.K

NOTE

NOTE

NOTE PRICE OF CONSTANT QUALITY DOLLARS
NOTE SECTION 3.4.1.2

NOTE
NOTE
NOTE MW COST AND PRODUCTIVITY INDICES

NOTE
NOTE

A MWLCI.K=CLIP(MWLCI1.K,MWLCI2.K,TIME.K,11.5)
A MWLCI1.K=MWLCI74*TGLCI1.K/T3LCI74
C MWLCI74=1.843
A MWLCI2.K=.816+STFP(.041,0.5)+STEP(.046,1.5)+STFP(.041,2.5)
X +STEP(.056,3.5)+STEP(.067,4.5)+STEP(.083,5.5)+STFP(.055,6.5)
X +STEP(.163,7.5)+STEP(.151,8.5)+STEP(.188,9.5)+STEP(.136,10.5)
A MWLPI.K=CLIP(MWLPI1.K,MWLPI2.K,TIME.K,11.5)
A MWLPI1.K=1.70*(1-1.235*EXP(-.2242*TIME.K))
A MWLPI2.K=.684+STFP(.117,0.5)+STEP(.119,1.5)+STEP(.107,2.5)
X -STEP(.027,3.5)+STEP(.072,4.5)+STEP(.080,5.5)+STFP(.002,6.5)
X -STEP(.038,7.5)+STEP(.126,8.5)+STEP(.235,9.5)+STEP(.045,10.5)
A PCQD.K=(MATCI.K/2.355)/(1.5754*MWLCI.K)/MWLPI.K

NOTE

NOTE

NOTE QUALITY EFFECTS ON COSTS AND PRODUCTIVITIES
NOTE SECTION 3.4.2

NOTE

NOTE

A QFR.K=QF.K/QF73.K
A QF73.K=SAMPLE(QF.K,SAMO.K,30E9)
A SAMO.K=10.5*STFP(200,11)
A QFMC.K=CLIP(QFMC1.K,QFMC2,TIME.K,10.5)
C QFMC2=1
A QFMC1.K=TABHL(QFTABC,QFR.K,.5,1.5,.1)
T QFTABC=1.3/1.27/1.21/1.13/1.06/1.0/.95/.91/.88/.86/.85
A PPN.K=CLIP(PPN1.K,QFMC2,TIME.K,10.5)
A PPN1.K=TABHL(PRDTAB,QFR.K,.5,1.5,.1)
T PRDTAB=.95/.952/.958/.974/.988/1.0/1.01/1.018/1.024/1.028/1.03

NOTE

NOTE

NOTE DESIRED AND MINIMUM M & I FOR WAY AND STRUCTURES
NOTE SECTION 3.4.3

NOTE

NOTE

A IDXWS.K=((DOF-QF.K)/TAQF)+TWTR.K
C DOF=40E9
C TAQF=10
A CDDXWS.K=MAX(IDXWS.K,0)
A DXWS.K=CDDXWS.K*PCQD.K
A DMWS.K=FRM.K*DXWS.K
A DIWS.K=FRJ.K*DXWS.K
A FRM.K=.797-STEP(.04,1.5)+STEP(.064,6.5)-STEP(.033,10.5)
A FRJ.K=1.0-FRM.K
A MINXWS.K=IWTR.K*PCQD.K*MINV2.K
A MINXP.K=.87
A ILMWS.K=FRM.K*MINXWS.K
A ILBIWS.K=FRJ.K*MINXWS.K*CMWCH.K
A EXTRM.K=CLIP(INCMW.K,0,MFLAG,K,.5)
A INCMW.K=DMWS.K-ILMWS.K
A MFLAG.K=STEP(CMPOL,CMSTART)
C CMPOL=1
C CMSTART=12.5

A ALMWS.K=ILBMWS.K+EXTRAM.K
 A LBMWS.K=MIN(DMWS.K,ALMWS.K)
 A EXTRAI.K=CLIP(INCIW.K,0,MFLAG.K,.5)
 A INCIW.K=DIWS.K-ILBIWS.K
 A ALBIWS.K=ILBIWS.K+EXTRAI.K
 A LBIWS.K=MIN(DIWS.K,ALBIWS.K)

NOTE

NOTE

NOTE

NOTE ***** EQUIPMENT NEEDS MODULE *****

NOTE SECTION 3.5

NOTE

NOTE

NOTE SIZE OF FREIGHT CAR & FREIGHT LOCOMOTIVE FLEETS

NOTE SECTION 3.5.1

NOTE

NOTE

L FCO.K=FCO.J*(DT)(CARPRR.K-CARRRR.K)

N FCO=1.401E6

R CARPRR.KL=CNCR.K

R CARRRR.KL=ICRR.K

A ICRR.K=CLIP(ICRR1.K,ICRR2.K*FCO.K,1E5)

A ICRR1.K=DLINF3(CNCR.K,CLIFF)

A ICRR2.K=FCO.K/CLIFF

N CNCR=84E3

A CARS.K=FCO.K*RENTC.K

A RENTC.K=1000*RENTCT.K

A RENTCT.K=TABHL(RCTAB,TIME.K,0,10,1)

T RCTAB=298/335/335/340/355/334/343/370/398/413/458

L FSLO.K=FSLO.J*(DT)(LOCPRR.K-LOCRRR.K)

N FSLO=24048

R LOCPRR.KL=CNLR.K

R LOCRRR.KL=ILRR.K

A ILRR.K=CLIP(ILRR1.K,ILRR2.K*FSLO.K,2000)

A ILRR1.K=DLINF3(CNLR.K,LLIFF)

A ILRR2.K=FSLO.K/LLIFF

N CNLR=1100

A LOCOS.K=FSLO.K*RENTL.K

A RENTL.K=TABHL(RLTAB,TIME.K,0,10,1)

T RLTAB=1400/1751/2086/2149/2243/2618/3050/3620/4145/4464/4807

NOTE

NOTE

NOTE DESIRED INVESTMENTS IN ROLLING STOCK

NOTE SECTION 3.5.2

NOTE

NOTE

A DCCF.K=1+STEP(ICPRD,12.5)

C ICPRD=.25

A CNEED.K=(DEMF.K/(PRDF.K*DCCF.K))*FSF

C FSF=1.10

A ICNCR.K=((CNEED.K-CARS.K)/TAC)+ICRR.K-ICRENT.K

C TAC=5

A ICRENT.K=37E3-STEP(37E3,1,0)+STEP(5E3,2,0)

X +STEP(10E3,3,0)-STEP(36E3,4,0)+STEP(30E3,5,0)+STEP(18E3,6,0)

X +STEP(1E3,7,0)-STEP(17E3,8,0)+STEP(30E3,9,0)-STEP(45E3,10,0)

A DCNCR.K=MAX(ICNCR.K,0)

A DEMF.K=DEMNTF.K+TAC*DTREND.C/DT

A DEMNTF.K=SMOOTHD.K+TREND.C*DTREND.K

N TREND.C=FORDL/DT

```

C  FORDEL=3
A  SMOOTHD.K=SMOOTH(DEM.K,FORDEL)
N  DEM=535E9
A  OLDEM.K=SMOOTH(SMOOTHD.K,NT)
A  DCAT.K=SMOOTHD.K-OLDEM.K
A  DTREND.K=SMOOTH(DCAT.K,FORDEL)
N  DCAT=7.25E9
A  PRDF.K=PRDNTF.K+TAC*PTREND.</DT
A  PRDNTF.K=SMOOTH(P.K+TREND*PTREND.K
A  SMOOTHP.K=SMOOTH(PRDF.K,FORDEL)
N  PRD=261E3
A  OLDPRD.K=SMOOTH(SMOOTHP.K,NT)
A  PCAT.K=SMOOTHP.K-OLDPRD.K
A  PTREND.K=SMOOTH(PCAT.K,FORDEL)
N  PCAT=8.75F3
A  ENC.K=CARS.K-ICRR.K+DCNCR.K+ICRENT.K
A  LNEED.K=DCCF.K*ENC.K/CLR.K
A  CLR.K=CLIP(CLR1.K,CLR2.K,TIME.K,9,0)
A  CLR1.K=55+18.4*EXP(-.159*TIME.K)
A  CLR2.K=TABHL(CLRTAB,TIME.K,0,9,1)
T  CLRTAB=66.5/65.8/65.6/65.5/63.0/62.2/62.2/61.6/60.1/59.4
A  ACLR.K=CARS.K/LOCOS.K
A  ATPCLR.K=DCCF.K*ACLR.K/PCLR.K
A  PCLR.K=CLIP(PCLR1.K,PCLR2.K,TIME.K,10,0)
A  PCLR1.K=55+18.4*EXP(-.159*TM1.K)
A  TM1.K=TIME.K-1
A  PCLR2.K=TABHL(CLRTAB,TM1.K,0,9,1)
A  ICNLR.K=CLIP(ICNLR1.K,ICNLR2.K,TIME.K,12,5)
A  ICNLR1.K=(LNEED.K-LOCOS.K)/TAC+ILRR.K-ILRENT.K
A  LNEED.K=CNEED.K*DCCF.K/CLR.K
A  ICNLR2.K=LNEED.K-LOCOS.K+ILRR.K-ILRENT.K
A  ILRENT.K=351-STEP(16,1,0)-STEP(272,2,0)+STEP(31,3,0)+STEP(281,4,0)
X   +STEP(57,5,0)+STEP(138,6,0)-STEP(45,7,0)-STEP(206,8,0)
X   +STEP(24,9,0)-STEP(343,10,0)
A  DCNLR.K=MAX(ICNLR.K,0)
A  DILOCS.K=DCNLR.K*PLOC.K+DIPL.K
A  DIPL.K=MAX(IDIPL.K,0)
A  IDIPL.K=20E6-2E6*TIME.K
A  DICARS.K=DCNCR.K*PCAR.K+DIPC.K
A  DIPC.K=30F6-STEP(30F6,6,5)
A  DIRS.K=DICARS.K+DILOCS.K
A  DIFRS.K=DIRS.K-DIPC.K-DIPL.K
A  PLOC.K=CLIP(PLOC1.K,PLOC2.K,TIME.K,10,5)
A  PLOC1.K=330E3*CI74.K
A  PLOC2.K=213E3+STEP(28E3,0,5)-STEP(9E3,1,5)+STEP(18E3,2,5)
X   +STEP(19E3,3,5)+STEP(11F3,4,5)+STEP(16E3,5,5)+STEP(16E3,6,5)
X   -STEP(50E3,7,5)+STEP(48E3,8,5)+STEP(20E3,9,5)
A  PCAR.K=CLIP(PCAR1.K,PCAR2.K,TIME.K,10,5)
A  PCAR1.K=19000*CI74.K
A  PCAR2.K=13800-STEP(700,0,5)+STEP(2300,1,5)-STEP(600,2,5)
X   -STEP(1400,3,5)+STEP(1100,4,5)
X   +STEP(2600,5,5)-STEP(1500,6,5)+STEP(500,7,5)
X   +STEP(1900,8,5)+STEP(1000,9,5)
A  DIOE.K=42E6*PCD.K
NOTE
NOTE
NOTE
NOTE ***** VOLUME DETERMINATION MODULE *****
NOTE SECTION 3.6

```


NOTE

NOTE

```

A PRDN.K=580E3*(1-.369*EXP(-.140*TIME.K))
A PRD.K=PRDN.K*DPV.K
A CAPYC.K=PRD.K*CARS.K*DCCF.K
A CAPYL.K=PRD.K*PCLP.K*LOCOS.K
A CAPY.K=MIN(CAPYC.K,CAPYL.K)
A MCAPY.K=1.04*CAPY.K
A VOL.K=MIN(MCAPY.K,DFM.K)
A DEM.K=CLIP(DEM1.K,DEM2.K,TIME.K,11.5)
L DEM1.K=DEM1.J+(DT)*(RDEM.G..IK)
N DEM1=952E9
R RDEM.G.KL=CLIP(DTGR1.K,DTGR2,TIME.K,11.5)
C DTGR2=0
A DTGR1.K=DTGF*DEM.K
C DTGF=.02
A DEM2.K=622E9+STEP(37E9,0.5)+STEP(39E9,1.5)+STEP(40F9,2.5)
X -STEP(19E9,3.5)+STEP(25E9,4.5)+STEP(24E9,5.5)
X -STEP(3E9,6.5)-STEP(25E9,7.5)+STEP(37E9,8.5)+STEP(75E9,9.5)

```

NOTE

NOTE

NOTE

NOTE ***** MISCELLANEOUS MODEL COMPONENTS *****

NOTE

NOTE

NOTE INFLATION

NOTE

NOTE

```

A PCD.K=CLIP(PCD1.K,PCD2.K,TIME.K,11.5)
A PCD1.K=1.478*CI75.K
A PCD2.K=.913+STEP(.016,0.5)+STEP(.016,1.5)+STEP(.027,2.5)
X +STEP(.028,3.5)+STEP(.042,4.5)+STEP(.056,5.5)+STEP(.065,6.5)
X +STEP(.05,7.5)+STEP(.042,8.5)+STEP(.076,9.5)+STEP(.147,10.5)
A CI75.K=EXP((TIME.K-11.0)*LOGN(INFLAT))
A CI74.K=INFLAT*CI75.K
C INFLAT=1.07
C INFLATO=1.017

```

NOTE

NOTE

NOTE DEFLATED OUTPUT VARIABLES

NOTE

NOTE

```

S 7NROI.K=NROI.K/PCD.K
S 7NIAT.K=NIAT.K/PCD.K
S 7NWC.K=NWC.K/PCD.K
S 7DNWC.K=DNWC.K/PCD.K
S 7RFVS.K=REVS.K/PCD.K
S 7EXP.K=EXP.K/PCD.K
S 7DIWS.K=DIWS.K/PCD.K
S 7MFIN.K=MFIN.K/PCD.K
S 7IWS.K=IWS.K/PCD.K
S 7LRIWS.K=LRIWS.K/PCD.K
S 7DMWS.K=DMWS.K/PCD.K
S 7BMXWS.K=BMXWS.K/PCD.K
S 7LBMWS.K=LBMWS.K/PCD.K
S 7DXWS.K=DXWS.K/PCD.K
S 7EWS.K=EWS.K/PCD.K
S 7MFINF.K=MFINF.K/PCD.K
S 7NCERS.K=NCERS.K/PCD.K

```

```

S 7DIRS.K=DIRS.K/PCD.K
S 7IRS.K=IRS.K/PCD.K
S 7IFURS.K=IFURS.K/PCD.K
S 7IFAWS.K=IFAWS.K/PCD.K
S 7IFUWS.K=IFUWS.K/PCD.K
S 7DNWS.K=DNWS.K/PCD.K
S 7DNRS.K=DNRS.K/PCD.K
S 7MAXMWS.K=MAXMWS.K/PCD.K
S 7XTRAM.K=EXTRAM.K/PCD.K
S 7DAWS.K=DAWS.K/PCD.K
S 7INTX.K=INTX.K/PCD.K
S 7OINC.K=OINC.K/PCD.K
S 7CURS.K=CURS.K/PCD.K
NOTE
NOTE
PRINT ZNROI,ZNIAT,ZOINC,ZINTX,VOL,ZNWC,TTGM,MXE,RMXWS,DEPX,EXP,
X TGOIH,TFC,TGTIC
PRINT PCD,PCQD,PPN,QFMC,CARS,LOCOS,CAPYC,CAPYL,PCLR,ACIP,
X ICNLR1,ICNLR2,CNLR,ATPCLR
PI OT ZNROI=R,ZNIAT=I,ZOINC=O,ZINTX=F/VOL=V
PI OT RNI=R/AVGIR=A,IRATF=I
PI OT ZNWC=N,ZDNWC=D
PI OT ZREVS=R,ZEXP=X/VOL=V/QFMC=Q,PPN=P
PI OT ZDIRS=D,ZDNRS=R/7IRS=I,ZMFINE=F/ZCURS=C,ZNCERS=N
PI OT CAPY=C,MCAPY=M,DFM=D
PI OT FCO=F,CARS=C/FSLO=O,LOCOS=L
PI OT MIR=M,WTR=W/QF=Q
PI OT ZDMWS=D,ZBMXWS=B,ZLBMWS=L,ZMAXMWS=M,ZXTRAM=X
PI OT ZDIWS=D,ZIWS=I,ZLBIWS=L,ZDNWS=N/ZDAWS=A,ZMFIN=F
PI OT 7IFAWS=A,ZIFUWS=W,7IFIURS=R
PI OT MFIN=O,MFINE=E/DEBT=O/INTX=F/OI=I,OP=P
SPEC DT=.25/LENGTH=47.5/PLTPER=.5/PRTPER=1.0
RUM O.I.P. - MILD QF, 20% REDUCTION TRANSP EMPS, 20% CC RED
T QFTABC=1.6/1.54/1.42/1.26/1.12/1.0/.90/.82/.76/.72/.70
T PRDTAB=.90/.904/.916/.948/.976/1.0/1.02/1.036/1.048/1.056/1.06
RUM O.I.P. - STRONG QF, 20% REDUCTION TRANSP EMPS, 20% CC RED
QUIT
/*
/*EQ) *****

```

TABLE A-1LEVELS AND RATES - NAMES USED IN MODEL CODELEVELS

<u>LEVEL NAME</u>	<u>MEANING</u>
ADCARS	<u>A</u> ccumulated <u>D</u> epreciation on <u>CARS</u>
ADLOCS	<u>A</u> ccumulated <u>D</u> epreciation on <u>LOComotiveS</u>
ADOE	<u>A</u> ccumulated <u>D</u> epreciation on <u>Other Equipment</u>
ADWS	<u>A</u> ccumulated <u>D</u> epreciation on <u>Way and Structures</u>
DEBT	long-term <u>DEBT</u>
DEMI	<u>DE</u> mand, for years after 1974
FCO	<u>F</u> reight <u>C</u> ars <u>O</u> wned
FSLO	<u>F</u> reight <u>S</u> ervice <u>L</u> ocomotives <u>O</u> wned
GBVOE	<u>G</u> ross <u>B</u> ook <u>V</u> alue of <u>O</u> ther <u>E</u> quipment
GBVROC	<u>G</u> ross <u>B</u> ook <u>V</u> alue of <u>R</u> ailroad- <u>O</u> wned <u>C</u> ars
GBVROL	<u>G</u> ross <u>B</u> ook <u>V</u> alue of <u>R</u> ailroad- <u>O</u> wned <u>L</u> ocomotives
GBVWS	<u>G</u> ross <u>B</u> ook <u>V</u> alue of <u>Way</u> and <u>Structures</u>
INTX	<u>I</u> NTerest eXpense on long-term debt (fixed charges)
NWC	<u>N</u> et <u>W</u> orking <u>C</u> apital
QF	<u>Q</u> uality of the fixed <u>F</u> acilities
RE	<u>R</u> etained <u>E</u> arnings

RATES

<u>RATE NAME</u>	<u>MEANING</u>
CARPRR	owned freight <u>CARs</u> <u>Purchased</u> or <u>Rebuilt</u> <u>Rate</u>
CARRRR	owned freight <u>CARs</u> <u>Retired</u> or <u>Rebuilt</u> <u>Rate</u>
CWOR	<u>Car</u> <u>Write-Off</u> <u>Rate</u>
CXCARR	<u>Capital</u> <u>eXpenditures</u> on <u>CARs</u> <u>Rate</u>
CXLOCR	<u>Capital</u> <u>eXpenditures</u> on <u>LOComotives</u> <u>Rate</u>
CXOER	<u>Capital</u> <u>eXpenditures</u> on <u>Other</u> <u>Equipment</u> <u>Rate</u>
CXWSR	<u>Capital</u> <u>eXpenditures</u> on <u>Way</u> and <u>Structures</u> <u>Rate</u>
DEBTIR	<u>DEBT</u> <u>Issuance</u> <u>Rate</u>
DEBTRR	<u>DEBT</u> <u>Repayment</u> <u>Rate</u>
DEPXCR	<u>DEPre</u> ciation <u>eXpense</u> on <u>Cars</u> <u>Rate</u>
DEPXLR	<u>DEPre</u> ciation <u>eXpense</u> on <u>Locomotives</u> <u>Rate</u>
DEPXOR	<u>DEPre</u> ciation <u>eXpense</u> on <u>Other</u> <u>equipment</u> <u>Rate</u>
DEPXWR	<u>DEPre</u> ciation <u>eXpense</u> on <u>Way</u> and <u>structures</u> <u>Rate</u>
DIVR	<u>DIV</u> idend <u>Rate</u>
DWOCCR	<u>Depreciation</u> <u>Write-Off</u> on <u>Cars</u> <u>Rate</u>
DWOLR	<u>Depreciation</u> <u>Write-Off</u> on <u>Locomotives</u> <u>Rate</u>
DWOOER	<u>Depreciation</u> <u>Write-Off</u> on <u>Other</u> <u>Equipment</u> <u>Rate</u>
DWOWSR	<u>Depreciation</u> <u>Write-Off</u> on <u>Way</u> and <u>Structures</u> <u>Rate</u>

TABLE A-1 (Cont.)RATES

<u>RATE NAME</u>	<u>MEANING</u>
INTAR	<u>INTerest Added</u> due to debt issuance <u>Rate</u>
INTRR	<u>INTerest Removed</u> due to debt repayment <u>Rate</u>
LOCPRR	owned freight service <u>LOComotives</u> <u>Purchased or Rebuilt Rate</u>
LOCRRR	owned freight service <u>LOComotives</u> <u>Retired or Rebuilt Rate</u>
LWOR	<u>Locomotive Write-Off Rate</u>
MIR	<u>Maintenance and Investment</u> in way <u>Rate</u>
NIATR	<u>Net Income After Tax Rate</u> (ordinary income)
OEWOR	<u>Other Equipment Write-Off Rate</u>
RDEMG	<u>Rate of DEM and Growth</u>
SRF	<u>SouRces of Funds rate</u>
USF	<u>USes of Funds rate</u>
WSWOR	<u>Way and Structures Write-Off Rate</u>
WTR	<u>Wear and Tear on the facilities</u> <u>Rate</u>

TABLE A-2
AUXILIARIES, CONSTANTS, TABLES AND
SUPPLEMENTARIES - NAMES USED
IN MODEL CODE

<u>VARIABLE NAME</u>	<u>MEANING</u>
ACLR	<u>Actual Car to Locomotive Ratio</u> (freight service)
ADC	<u>Accumulated Depreciation on Cars</u>
ADL	<u>Accumulated Depreciation on Locomotives</u>
AIN TAR	<u>Auxiliary for Interest Addition Rate</u>
AIN TRR	<u>Auxiliary for Interest Removal Rate</u>
ALBIWS	<u>Auxiliary for Lower Bound on Investment in Way and Structures</u>
ALBMWS	<u>Auxiliary for Lower Bound on Maintenance of Way and Structures</u>
AMFIN	<u>Auxiliary for Maximum unsecured debt FINancing</u>
AMFINE	<u>Auxiliary for Maximum debt FINancing of Equipment</u>
ATPCLR	ratio of <u>Actual To Planned Car to Locomotive Ratio</u> (freight service)
AVGIR	<u>Average Interest Rate</u> on outstanding debt
* * * * *	
BFCPG	<u>Base (1967) Fuel Cost Per Gallon</u>
BMXWS	<u>Budgeted Maintenance eXpense for Way and Structures</u>
* * * * *	
CAPY	<u>CAPacity</u> of rolling stock
CAPYC	<u>CAPacity</u> of freight <u>Car</u> fleet

TABLE A-2 (Cont.)

<u>VARIABLE NAME</u>	<u>MEANING</u>
LCAPYL	<u>CA</u> P <u>ac</u> i <u>ty</u> of <u>L</u> o <u>co</u> m <u>o</u> t <u>i</u> v <u>e</u> f <u>l</u> e <u>e</u> t
CARS	total freight <u>CARS</u> on line (owned plus rented)
CASHF	<u>CASH</u> <u>F</u> low
CC	interest <u>C</u> o <u>v</u> e <u>r</u> a <u>g</u> e <u>C</u> o <u>n</u> s <u>t</u> a <u>n</u> t for unsecured debt constraint
CCEQ	interest <u>C</u> o <u>v</u> e <u>r</u> a <u>g</u> e <u>C</u> o <u>n</u> s <u>t</u> a <u>n</u> t for <u>E</u> q <u>u</u> i <u>p</u> m <u>e</u> n <u>t</u> debt constraint
CDDXWS	<u>C</u> o <u>n</u> s <u>t</u> a <u>n</u> t <u>D</u> o <u>l</u> l <u>a</u> r <u>D</u> e <u>s</u> i <u>r</u> e <u>d</u> <u>e</u> X <u>p</u> e <u>n</u> d <u>i</u> t <u>u</u> r <u>e</u> s on <u>W</u> a <u>y</u> and <u>S</u> t <u>r</u> u <u>c</u> t <u>u</u> r <u>e</u> s
CDIWS	<u>C</u> o <u>n</u> s <u>t</u> a <u>n</u> t <u>D</u> o <u>l</u> l <u>a</u> r <u>D</u> e <u>s</u> i <u>r</u> e <u>d</u> <u>I</u> n <u>v</u> e <u>s</u> t <u>m</u> e <u>n</u> t in <u>W</u> a <u>y</u> and <u>S</u> t <u>r</u> u <u>c</u> t <u>u</u> r <u>e</u> s
CDMXWS	<u>C</u> o <u>n</u> s <u>t</u> a <u>n</u> t quality <u>D</u> o <u>l</u> l <u>a</u> r <u>M</u> a <u>i</u> n <u>t</u> e <u>n</u> a <u>n</u> c <u>e</u> <u>e</u> X <u>p</u> e <u>n</u> s <u>e</u> for <u>W</u> a <u>y</u> and <u>S</u> t <u>r</u> u <u>c</u> t <u>u</u> r <u>e</u> s
CDNWC	<u>C</u> o <u>n</u> s <u>t</u> a <u>n</u> t <u>D</u> o <u>l</u> l <u>a</u> r <u>N</u> o <u>t</u> <u>W</u> o <u>r</u> k <u>i</u> n <u>g</u> <u>C</u> a <u>p</u> i <u>t</u> a <u>l</u> (\$ millions)
CI74	<u>C</u> o <u>s</u> t <u>I</u> n <u>f</u> l <u>a</u> t <u>o</u> r for time \geq 19 <u>7</u> <u>4</u>
CI75	<u>C</u> o <u>s</u> t <u>I</u> n <u>f</u> l <u>a</u> t <u>o</u> r for time \geq 19 <u>7</u> <u>5</u>
CLIFE	average <u>C</u> a <u>r</u> <u>L</u> I <u>F</u> E
CLR	planned <u>C</u> a <u>r</u> to <u>L</u> o <u>co</u> m <u>o</u> t <u>i</u> v <u>e</u> <u>R</u> a <u>t</u> i <u>o</u> one year hence (freight service)
CLR1	<u>CLR</u> for years after 1972
CLR2	<u>CLR</u> for years before 1973
CLRTAB	<u>CLR</u> <u>T</u> A <u>B</u> l <u>e</u> for years before 1973
CMIF	<u>C</u> a <u>s</u> h and <u>M</u> a <u>t</u> e <u>r</u> i <u>a</u> l <u>I</u> n <u>v</u> e <u>n</u> t <u>o</u> r <u>y</u> <u>F</u> a <u>c</u> t <u>o</u> r (to obtain net investment from total net book value)
CMPOL	<u>C</u> h <u>a</u> n <u>g</u> e <u>M</u> a <u>i</u> n <u>t</u> e <u>n</u> a <u>n</u> c <u>e</u> of way <u>P</u> O <u>L</u> i <u>c</u> y (0-1 constant used to force quality improvement programs)

TABLE A-2 (Cont.)

<u>VARIABLE NAME</u>	<u>MEANING</u>
CMSTART	<u>Change Maintenance of way policy START</u> (time at which forced quality improvement program is to start)
CNCR	<u>Change Number of freight Cars Rate</u> (number of freight cars installed)
CNEED	freight <u>Cars NEEDED</u> 5 years hence
CNLR	<u>Change Number of Locomotives Rate</u> (number of freight service locomotives installed)
CNWCM	<u>Conserve Net Working Capital Multiplier</u>
CNWCT	<u>Conserve Net Working Capital Table</u>
CSCS	<u>Cash Supplied by Car Sales</u>
CSES	<u>Cash Supplied by Equipment Sales</u>
CSLS	<u>Cash Supplied by Locomotive Sales</u>
CSOES	<u>Cash Supplied by Other Equipment Sales</u>
CURS	<u>Cash Used for Rolling Stock investments</u>
* * * * *	
DANWC	<u>Desired Addition to Net Working Capital</u>
DAWS	<u>Debt Available for Way and Structures</u>
DCAT	<u>Demand Current Apparent Trend</u>
DCCF	<u>Decrease Car Cycle Factor</u> (to increase car productivity)
DCNCR	<u>Desired Change Number of freight Cars Rate</u> (desired freight car installations)

TABLE A-2 (Cont.)

<u>VARIABLE NAME</u>	<u>MEANING</u>
DCNLR	<u>Desired Change Number of Locomotives Rate (desired freight service locomotive installations)</u>
DEM	<u>DEMAND</u>
DEM2	<u>DEMAND</u> for years before 1975
DEMF	<u>DEMAND Forecast</u> 5 years hence
DEMNTF	<u>DEMAND Near Term Forecast</u>
DEPEQ	total <u>DEPRECIATION</u> expense on <u>EQUIPMENT</u>
DEPWS	<u>DEPRECIATION</u> expense on <u>Way</u> and <u>Structures</u>
DEPX	total <u>DEPRECIATION</u> <u>eXPENSE</u>
DI	<u>Debt Issued</u>
DICARS	<u>Desired Investments in CARS</u>
DIFRS	<u>Desired Investments in Freight service Rolling Stock</u>
DILOCS	<u>Desired Investments in LOCOMOTIVES</u>
DIOE	<u>Desired Investments in Other Equipment</u>
DIPC	<u>Desired Investments in Passenger Cars</u>
DIPL	<u>Desired Investments in Passenger Locomotives</u>
DIRS	<u>Desired Investments in Rolling Stock</u>
DIV	<u>DIVIDENDS</u>
DIWS	<u>Desired Investments in Way and Structures</u>

TABLE A-2 (Cont.)

<u>VARIABLE NAME</u>	<u>MEANING</u>
DMWS	<u>Desired Maintenance of Way and Structures</u>
DNP	<u>Debt Needed for Primary uses of funds</u>
DNRS	<u>Debt Needed for Rolling Stock</u>
DNWC	<u>Desired Net Working Capital</u>
DNWCB	<u>Desired Net Working Capital in Base year (1963)</u>
DNWS	<u>Debt Needed for Way and Structures</u>
DP	<u>Debt rePaid</u>
DPR	<u>Dividend Payout Ratio</u>
DPR1	<u>DPR for years after 1974</u>
DPR2	<u>DPR for years before 1975</u>
DQF	<u>Desired Quality of Facilities</u>
DRCARS	<u>Depreciation Rate for CARS</u>
DRLOCS	<u>Depreciation Rate for Locomotives</u>
DROE	<u>Depreciation Rate for Other Equipment</u>
DTGF	<u>Demand Time Growth Factor</u>
DTGR1	<u>Demand Time Growth Rate for years after 1974</u>
DTGR2	<u>Demand Time Growth Rate for years before 1975</u>
DTREND	<u>Demand TREND</u>
DXWS	<u>Desired eXpenditures on Way and Structures</u>

TABLE A-2 (Cont.)

<u>VARIABLE NAME</u>	<u>MEANING</u>
EDC	<u>E</u> quipment <u>D</u> ebt <u>C</u> onstrained (0-1 constant used to constrain equipment debt availability)
EDCF	<u>E</u> quipment <u>D</u> ebt <u>C</u> onstrained <u>F</u> lag (variable whose value is EDC)
ENC	<u>E</u> xpected <u>N</u> umber of freight <u>C</u> ars one year hence
EWS	total <u>E</u> xpenditures on <u>W</u> ay and <u>S</u> tructures
EXP	total <u>E</u> xpenses that affect NROI
EXTRAI	<u>E</u> xtra <u>I</u> nterest in way and structures (during forced quality improvement program)
EXTRAM	<u>E</u> xtra <u>M</u> aintenance of Way and structures (during forced quality improvement program)
* * * * *	
FCI	<u>F</u> uel <u>C</u> ost <u>I</u> ndex
FCI1	<u>F</u> uel <u>C</u> ost <u>I</u> ndex for years after 1974
FCI2	<u>F</u> uel <u>C</u> ost <u>I</u> ndex for years before 1975
FCI74	<u>F</u> uel <u>C</u> ost <u>I</u> ndex in 1974
FCPG	<u>F</u> uel <u>C</u> ost <u>P</u> er <u>G</u> allon
FFRSID	<u>F</u> raction of <u>F</u> reight service <u>R</u> olling <u>S</u> tack <u>I</u> nterests <u>D</u> one
FNRS	<u>F</u> unds <u>N</u> eeded for <u>R</u> olling <u>S</u> tack
FNWS	<u>F</u> unds <u>N</u> eeded for <u>W</u> ay and <u>S</u> tructures
FORDEL	<u>F</u> orecast <u>D</u> elay (exponential smoothing constant)

TABLE A-2 (Cont.)

<u>VARIABLE NAME</u>	<u>MEANING</u>
FRI	<u>F</u> raction of expenditures on way and structures classified as <u>I</u> nterments
FRM	<u>F</u> raction of expenditures on way and structures classified as <u>M</u> aintenance
FRREVS	<u>F</u> reight <u>R</u> EVenue <u>S</u>
FSF	<u>F</u> orecast <u>S</u> afety <u>F</u> actor
* * * * *	
GFU	<u>G</u> allons of <u>F</u> uel <u>U</u> sed
GTM	<u>G</u> ross <u>T</u> on- <u>M</u> iles associated with volume
* * * * *	
ICARS	<u>I</u> nterments in <u>C</u> ARS
ICNCR	<u>I</u> ndicated <u>C</u> hange <u>N</u> umber of freight <u>C</u> ars <u>R</u> ate (desired freight car installations before test for non-negativity)
ICNLR	<u>I</u> ndicated <u>C</u> hange <u>N</u> umber of <u>L</u> ocomotives <u>R</u> ate (desired freight service locomotive installations before test for non-negativity)
ICNLR1	<u>ICNLR</u> for years after 1975 (in cases where freight car productivity is being altered exogenously)
ICNLR2	<u>ICNLR</u> for years before 1976 (this variable is used in all years if freight car productivity is not being altered exogenously)
ICPRD	<u>I</u> nterment in freight <u>C</u> ar <u>P</u> ROductivity (exogenously supplied option)
ICRENT	<u>I</u> nterment in number of freight <u>C</u> ar <u>R</u> ENTals

TABLE A-2 (Cont.)

<u>VARIABLE NAME</u>	<u>MEANING</u>
ICRR	<u>I</u> ndicated <u>f</u> reight <u>C</u> ar <u>R</u> etirements (and <u>R</u> ebuilds)
ICRR1	<u>ICRR</u> if owned fleet \geq 100,000 cars
ICRR2	<u>ICRR</u> if owned fleet $<$ 100,000 cars (to prevent retiring more cars than are owned)
ICWOR	<u>I</u> ndicated <u>C</u> ar <u>W</u> rite- <u>O</u> ff <u>R</u> ate
ICWOR1	<u>ICWOR</u> if gross book value of cars \geq \$1 billion
ICWOR2	<u>ICWOR</u> if gross book value of cars $<$ \$1 billion (to prevent writing- off more than is capitalized)
IDCARS	<u>I</u> ndicated <u>D</u> epreciation expense on <u>C</u> ARS
IDIPL	<u>I</u> ndicated <u>D</u> esired <u>I</u> ntestments in <u>P</u> assenger <u>L</u> ocomotives
IDIV	<u>I</u> ndicated <u>D</u> IVidends
IDLOCS	<u>I</u> ndicated Depreciation expense on <u>L</u> OComotive <u>S</u>
IDNP	<u>I</u> ndicated <u>D</u> ebt <u>N</u> eeded for <u>P</u> rietary uses of funds
IDOE	<u>I</u> ndicated Depreciation expense on <u>O</u> ther <u>E</u> quipment
IDXWS	<u>I</u> ndicated constant quality dollar <u>D</u> esired <u>e</u> Xpenditures on <u>W</u> ay and <u>S</u> tructures
IED	<u>I</u> ssuance of <u>E</u> quipment <u>D</u> ebt
IFARS	<u>I</u> nternal <u>F</u> unds <u>A</u> vailable for <u>R</u> olling <u>S</u> tock
IFAWS	<u>I</u> nternal <u>F</u> unds <u>A</u> vailable for <u>W</u> ay and <u>S</u> tructures

<u>VARIABLE NAME</u>	<u>MEANING</u>
IFRS	<u>I</u> nv <u>est</u> ments in <u>F</u> reight service <u>R</u> olling <u>S</u> tock
IFURS	<u>I</u> nternal <u>F</u> unds <u>U</u> sed for <u>R</u> olling <u>S</u> tock
IFUWS	<u>I</u> nternal <u>F</u> unds <u>U</u> sed for <u>W</u> ay and <u>S</u> tructures
IIFAI	<u>I</u> ndicated <u>I</u> nternal <u>F</u> unds <u>A</u> vailable for <u>I</u> nv <u>e</u> stment
ILBIWS	<u>I</u> ndicated <u>L</u> ower <u>B</u> ound on <u>I</u> nv <u>e</u> stment in <u>W</u> ay and <u>S</u> tructures
ILBMWS	<u>I</u> ndicated <u>L</u> ower <u>B</u> ound on <u>M</u> aintenance of <u>W</u> ay and <u>S</u> tructures
ILOCS	<u>I</u> nv <u>e</u> stments in <u>L</u> o <u>C</u> omoti <u>v</u> e <u>S</u>
ILRENT	<u>I</u> nc <u>re</u> ase in number of freight service <u>L</u> o <u>C</u> omoti <u>v</u> e <u>R</u> EN <u>T</u> als
ILRR	<u>I</u> ndicated freight service <u>L</u> o <u>C</u> omoti <u>v</u> e <u>R</u> etire <u>m</u> ents (and <u>R</u> ebuilds)
ILRR1	<u>ILRR</u> if owned fleet \geq 2000 locomotives
ILRR2	<u>ILRR</u> if owned fleet $<$ 2000 locomotives (to prevent retiring more locomotives than are owned)
ILWOR	<u>I</u> ndicated <u>L</u> o <u>C</u> omoti <u>v</u> e <u>W</u> rite- <u>O</u> ff <u>R</u> ate
ILWOR1	<u>ILWOR</u> if gross book value of locomotives \geq \$500 million
ILWOR2	<u>ILWOR</u> if gross book value of locomotives $<$ \$500 million (to prevent writing-off more than is capitalized)
IMAXMW	<u>I</u> ndicated <u>M</u> AX <u>i</u> mum affordable <u>M</u> aintenance of <u>W</u> ay and s <u>t</u> ru <u>c</u> tu <u>r</u> es
IMDNROI	<u>I</u> ndicated <u>M</u> in <u>i</u> mum <u>D</u> esir <u>a</u> ble <u>N</u> ROI

Table A-2 (Cont.)

<u>VARIABLE NAME</u>	<u>MEANING</u>
IMWS	<u>I</u> ndicated <u>M</u> aintenance of <u>W</u> ay and <u>S</u> tructures
INCIW	<u>I</u> NCrease in <u>I</u> vestment in <u>W</u> ay and <u>S</u> tructures (during forced quality improvement program)
INCMW	<u>I</u> NCrease in <u>M</u> aintenance of <u>W</u> ay and <u>S</u> tructures (during forced quality improvement program)
INFLAT	annual <u>I</u> NFLATion factor
INFLATQ	<u>I</u> NFLATion factor per <u>Q</u> arter
INFLCI	<u>I</u> NFLationary increase in TTGM <u>L</u> abor <u>C</u> ost <u>I</u> ndex
IOD	<u>I</u> ssuance of <u>O</u> ther (i.e., unsecured) <u>D</u> ebt
IOD1	<u>I</u> OD for primary uses of funds
IOD2	<u>I</u> OD for additional investment in way and structures (additional to the minimum amount included in the primary uses of funds)
IOEWOR	<u>I</u> ndicated <u>O</u> ther <u>E</u> quipment <u>W</u> rite- <u>O</u> ff <u>R</u> ate
IONWC	<u>I</u> nterest earned/paid <u>O</u> n <u>N</u> et <u>W</u> orking <u>C</u> apital after 1973
IRATE	<u>I</u> nterest <u>R</u> ATE on new debt issues
IRATE1	<u>I</u> RATE for years after 1974
IRATE2	<u>I</u> RATE for years before 1975
IRRED	<u>I</u> nterest <u>R</u> ate <u>R</u> EDuction from assumed normal value after 1975
IRS	<u>I</u> nterest in <u>R</u> olling <u>S</u> tock
IRTAB	<u>I</u> nterest <u>R</u> ate <u>T</u> ABLE for years before 1975

TABLE A-2 (Cont.)

<u>VARIABLE NAME</u>	<u>MEANING</u>
ITGEMP	<u>I</u> ndicated <u>TTGM</u> <u>EMP</u> loyee requirements (man-years)
ITGLCI	<u>I</u> ndicated <u>TTGM</u> <u>L</u> abor <u>C</u> ost <u>I</u> ndex (due to productivity changes and inflation)
ITX	<u>I</u> ncome <u>TaX</u>
IWS	<u>I</u> nterest in <u>W</u> ay and <u>S</u> tructures
IWTR	<u>I</u> ndicated <u>W</u> ear and <u>T</u> ear <u>R</u> ate
* * * * *	
LBIWS	<u>L</u> ower <u>B</u> ound on <u>I</u> nterest in <u>W</u> ay and <u>S</u> tructures (minimum investment in way and structures)
LBMWS	<u>L</u> ower <u>B</u> ound on <u>M</u> aintenance of <u>W</u> ay and <u>S</u> tructures (minimum MW)
LBNROI	<u>L</u> ower <u>B</u> ound on <u>NROI</u>
LLIFE	average <u>L</u> ocomotive <u>LIFE</u>
LNEED	freight service <u>L</u> ocomotives <u>NEEDED</u> one year hence
LOCOS	total freight service <u>L</u> ocomotive <u>S</u> on line (owned plus rented)
* * * * *	
MATCI	<u>M</u> aterial <u>C</u> ost <u>I</u> ndex
MATCI1	<u>MATCI</u> for years after 1974
MATCI2	<u>MATCI</u> for years before 1975
MATCI74	<u>MATCI</u> in 1974
MAXDPR	<u>M</u> aximum <u>D</u> ividend <u>P</u> ayout <u>R</u> atio for years after 1974
MAXINT	<u>M</u> aximum <u>I</u> nterest for unsecured debt constraint

TABLE A-2 (Cont.)

<u>VARIABLE NAME</u>	<u>MEANING</u>
MAXINTE	<u>MAX</u> imum <u>INT</u> erest for <u>E</u> quipment debt constraint
MAXMWS	<u>MAX</u> imum affordable <u>M</u> aintenance of <u>W</u> ay and <u>S</u> tructures
MAXPIR	<u>MAX</u> imum <u>P</u> ercentage of <u>I</u> nterest in <u>R</u> olling stock that must be cash financed
MCAPY	<u>MAX</u> imum <u>CAP</u> acity of rolling stock
MDEBT	<u>MAX</u> imum <u>DEBT</u> for unsecured debt constraint
MDEBTE	<u>MAX</u> imum <u>DEBT</u> for <u>E</u> quipment debt constraint
MDNIAT	<u>MIN</u> imum <u>D</u> esirable (ordinary) <u>Net</u> <u>I</u> ncome <u>A</u> fter <u>T</u> ax
MDNIBT	<u>MIN</u> imum <u>D</u> esirable (ordinary) <u>Net</u> <u>I</u> ncome <u>B</u> efore <u>T</u> ax
MDNROI	<u>MIN</u> imum <u>D</u> esirable <u>NROI</u>
MDR	<u>MIN</u> imum <u>D</u> esirable <u>R</u> eturn on net investment
MEBCPM	<u>M</u> aintenance of <u>E</u> quipment <u>B</u> ase (1967) <u>C</u> ost <u>P</u> er <u>M</u> an-year
MEBPRD	<u>M</u> aintenance of <u>E</u> quipment <u>B</u> ase (1967) labor <u>P</u> ROductivity (material/labor ratio)
MECDCM	<u>M</u> aintenance of <u>E</u> quipment <u>C</u> onstant <u>D</u> ollar <u>C</u> ost of <u>M</u> aterials
MECPM	<u>M</u> aintenance of <u>E</u> quipment <u>C</u> ost <u>P</u> er <u>M</u> an-year

TABLE A-2 (Cont.)

<u>VARIABLE NAME</u>	<u>MEANING</u>
MEEMP	Maintenance of <u>E</u> quipment <u>E</u> mployee requirements (man-years)
MELCI	Maintenance of <u>E</u> quipment <u>L</u> abor <u>C</u> ost <u>I</u> ndex
MELCI1	<u>MELCI</u> for years after 1974
MELCI2	<u>MELCI</u> for years before 1975
MELCI74	<u>MELCI</u> in <u>1974</u>
MELPI	Maintenance of <u>E</u> quipment <u>L</u> abor <u>P</u> roductivity <u>I</u> ndex
MELPI1	<u>MELPI</u> for years after 1974
MELPI2	<u>MELPI</u> for years before 1975
MEPRD	Maintenance of <u>E</u> quipment labor <u>P</u> roductivity (material/labor ratio)
METLC	Maintenance of <u>E</u> quipment <u>T</u> otal <u>L</u> abor <u>C</u> ost
METMC	Maintenance of <u>E</u> quipment <u>T</u> otal <u>M</u> aterial <u>C</u> ost
MFIN	<u>M</u> aximum unsecured debt <u>F</u> INancing
MFINE	<u>M</u> aximum debt <u>F</u> INancing of <u>E</u> quipment
MFLAG	Maintenance of way and structures <u>F</u> LAG (0-1 variable to indicate forced quality improvement program in effect)
MINXP	<u>M</u> INimum eXpenditures (on way and structures) <u>P</u> ercent of wear and tear
MINXWS	<u>M</u> INimum eXpenditures on <u>W</u> ay and <u>S</u> tructures

TABLE A-2 (Cont.)

<u>VARIABLE NAME</u>	<u>MEANING</u>
MNROI _{BT}	<u>Minimum desirable NROI Before Tax</u>
MSRF	<u>Miscellaneous Sources of Funds (cash from asset disposals)</u>
MT	<u>debt Maturity Time (fraction of debt to repay each year)</u>
MWLCI	<u>Maintenance of Way and structures Labor Cost Index</u>
MWLCI ₁	<u>MWLCI for years after 1974</u>
MWLCI ₂	<u>MWLCI for years before 1975</u>
MWLCI ₇₄	<u>MWLCI in 1974</u>
MWLPI	<u>Maintenance of Way and structures Labor Productivity Index</u>
MWLPI ₁	<u>MWLPI for years after 1974</u>
MWLPI ₂	<u>MWLPI for years before 1975</u>
MXE	<u>total Maintenance expense for Equipment</u>
* * * * *	
NBVEQ	<u>total Net Book Value of Equipment</u>
NBVQE	<u>Net Book Value of Other Equipment</u>
NBVROC	<u>Net Book Value of Railroad Owned Cars</u>
NBVROL	<u>Net Book Value of Railroad Owned Locomotives</u>
NBVWS	<u>Net Book Value of Way and Structures</u>
NCEEQ	<u>Necessary Cash Expenditures on Equipment</u>
NCERS	<u>Necessary Cash Expenditures on Rolling Stock</u>

TABLE A-2 (Cont.)

<u>VARIABLE NAME</u>	<u>MEANING</u>
NCP100	<u>Necessary Cash Percentage of Investment in Rolling Stock</u>
NEEDL	<u>NEEDs for freight service Locomotives 5 years hence (used in cases where freight car productivity is being altered exogenously)</u>
NIAT	<u>ordinary Net Income After Tax (ordinary income)</u>
NIBT	<u>ordinary Net Income Before Tax</u>
NIBTFC	<u>ordinary Net Income Before Tax and Fixed Charges</u>
NINV	<u>Net INVESTment</u>
NROI	<u>Net Railway Operating Income (NROI)</u>
NROIBMT	<u>NROI Before Maintenance of way and structures and Tax</u>
NWC73	<u>Net Working Capital at year end 1973</u>
* * * * *	
OELIFE	<u>average Other Equipment LIFE</u>
OINC	<u>Other INCome</u>
OINC1	<u>OINC for years after 1973</u>
OINC2	<u>OINC for years before 1974</u>
OLDDEM	<u>OLD DEMand forecast</u>
OLDPRD	<u>OLD PRoDuctivity forecast</u>
* * * * *	
PCAR	<u>Price (average cost) of additional freight CARS</u>
PCAR1	<u>PCAR for years after 1973</u>

TABLE A-2 (Cont.)

<u>VARIABLE NAME</u>	<u>MEANING</u>
PCAR2	<u>PCAR</u> for years before 1974
PCAT	Productivity Current <u>Apparent</u> <u>Trend</u> (freight cars)
PCD	Price of Constant (1967) <u>Dollars</u> (deflator)
PCD1	<u>PCD</u> for years after 1974
PCD2	<u>PCD</u> for years before 1975
PCLR	Planned Car to Locomotive <u>Ratio</u> (freight service)
PCLR1	<u>PCLR</u> for years after 1973
PCLR2	<u>PCLR</u> for years before 1974
PCQD	Price of <u>Constant</u> (1967) <u>Quality</u> <u>Dollars</u>
PFA	<u>Primary</u> (internal) <u>Funds</u> <u>Available</u>
PLOC	Price (average cost) of additional freight service <u>LOComotives</u>
PLOC1	<u>PLOC</u> for years after 1973
PLOC2	<u>PLOC</u> for years before 1974
PMEOR	Passenger, <u>Mail</u> , <u>Express</u> and <u>Other</u> <u>Revenues</u>
PMEOR1	<u>PMEOR</u> for years after 1973
PMEOR2	<u>PMEOR</u> for years before 1974
PPN	Productivity <u>Percent</u> of <u>Normal</u> (quality productivity multiplier)
PPN1	<u>PPN</u> for years after 1973
PRD	freight car <u>PRoDuctivity</u>

TABLE A-2 (Cont.)

<u>VARIABLE NAME</u>	<u>MEANING</u>
PRDF	freight car <u>PRoDuctivity</u> <u>F</u> orecast 5 years hence
PRDN	freight car <u>PRoDuctivity</u> <u>N</u> ormal (before taking quality effects into account)
PRDNTF	<u>PRD</u> <u>N</u> ear <u>T</u> erm <u>F</u> orecast
PRDTAB	quality <u>PRoDuctivity</u> multiplier <u>T</u> ABLE
PTREND	freight car <u>Productivity</u> <u>T</u> REND
PUF	<u>P</u> rimary <u>U</u> ses of <u>F</u> unds
PX	<u>P</u> assenger <u>e</u> Xpense
PX1	<u>PX</u> for years after 1973
PX2	<u>PX</u> for years before 1974
* * * * *	
QFMC	<u>Q</u> uality of <u>F</u> acilities <u>M</u> ultiplier for <u>C</u> osts
QFMC1	<u>QFMC</u> for years after 1973
QFMC2	<u>QFMC</u> for years before 1974 (also PPN for years before 1974)
QFR	<u>Q</u> uality of <u>F</u> acilities <u>R</u> atio
QFTABC	<u>Q</u> uality of <u>F</u> acilities <u>T</u> ABLE for <u>C</u> ost multiplier
QF73	<u>Q</u> uality of <u>F</u> acilities at year end <u>1973</u>
* * * * *	
RANDET	" <u>R</u> ANdom" unsecured <u>D</u> Ebt availability (actual unsecured debt issued over 1963-1970 treated as an additional source of this debt)

TABLE A-2 (Cont.)

<u>VARIABLE NAME</u>	<u>MEANING</u>
RATES	freight <u>RATES</u> (average revenue per ton-mile)
RATES1	<u>RATES</u> for years after 1974
RATES2	<u>RATES</u> for years before 1975
RCTAB	<u>Rented freight Car TABLE</u>
RENTC	number of <u>RENTed freight Cars</u> on line
RENTCT	<u>RENTC</u> measured in <u>Thousands</u>
RENTL	number of <u>RENTed freight service Locomotives</u> on line
RENTX	<u>RENTal eXpense</u> for facilities and equipment
RENTX1	<u>RENTX</u> for years after 1973
RENTX2	<u>RENTX</u> for years before 1974
REVS	total operating <u>REVenueS</u>
RI75	freight <u>Rate In</u> flator for time \geq <u>1975</u>
RLTAB	<u>Rented freight service Locomotive TABLE</u>
RNI	<u>Return on Net Investment</u>
* * * * *	
SAMQ	<u>SAM</u> pling interval for <u>Quality of facilities</u> (to obtain 1973 year end value)
SLTX	<u>State and Local TaXes</u>
SLTX1	<u>SLTX</u> for years after 1973
SLTX2	<u>SLTX</u> for years before 1974

TABLE A-2 (Cont.)

<u>VARIABLE NAME</u>	<u>MEANING</u>
SMOOTHD	<u>SMOOTH</u> ed <u>D</u> emand
SMOOTHF	<u>SMOOTH</u> ed freight car <u>P</u> roductivity
SNIBTFC	<u>S</u> moothed <u>N</u> et <u>I</u> ncome <u>B</u> efore <u>T</u> ax and <u>F</u> ixed <u>C</u> harges
STRTWFR	<u>S</u> Ta <u>R</u> T <u>W</u> ork <u>F</u> orce <u>R</u> eduction (time at which decrease in TTGM labor requirements is to start)
* * * * *	
TAC	<u>T</u> ime to <u>A</u> dj <u>u</u> st rolling stock <u>C</u> apacity
TAD	<u>T</u> ime to <u>A</u> dj <u>u</u> st <u>D</u> ebt
TANWC	<u>T</u> ime to <u>A</u> dj <u>u</u> st <u>N</u> et <u>W</u> orking <u>C</u> apital
TAQF	<u>T</u> ime to <u>A</u> dj <u>u</u> st <u>Q</u> uality of <u>F</u> acilities
TAXR	effective income <u>T</u> A <u>X</u> <u>R</u> ate
TFC	<u>T</u> otal <u>F</u> uel <u>C</u> ost
TGBCPM	<u>TTGM</u> <u>B</u> ase (1967) <u>C</u> ost <u>P</u> er <u>M</u> an-year
TGBPRD	<u>TTGM</u> <u>B</u> ase (1967) labor <u>P</u> R <u>O</u> ductivity
TGCPM	<u>TTGM</u> <u>C</u> ost <u>P</u> er <u>M</u> an-year
TGEMP	<u>TTGM</u> <u>E</u> M <u>P</u> loyee requirements (man-years)
TGLCI	<u>TTGM</u> <u>L</u> abor <u>C</u> ost <u>I</u> ndex
TGLCI1	<u>TGLCI</u> for years after 1974
TGLCI2	<u>TGLCI</u> for years before 1975
TGLCI74	<u>TGLCI</u> in 1974
TGLPI	<u>TTGM</u> <u>L</u> abor <u>P</u> roductivity <u>I</u> ndex
TGLPI1	<u>TGLPI</u> for years after 1974

TABLE A-2 (Cont.)

<u>VARIABLE NAME</u>	<u>MEANING</u>
TGLPI2	<u>TGLPI</u> for years before 1975
TGLPI74	<u>TGLPI</u> in 1974
TGOTH	<u>TTGM</u> <u>OTHer</u> costs
TGPRD	<u>TTGM</u> labor <u>PRoDuctivity</u>
TGTLC	<u>TTGM</u> <u>TotAl</u> <u>LaBor</u> <u>CoSt</u>
TM1	<u>Time</u> <u>Minus</u> <u>1</u>
TRENDC	<u>TREND</u> <u>CoRreCtion</u> for near-term forecasts
TTGM	total <u>TTGM</u> expenses
TXINC	<u>TaXable</u> <u>INCoMe</u>
* * * * *	
UFINE	<u>Unconstrained</u> debt <u>FINancing</u> of <u>Equipment</u> (equals debt needed for rolling stock)
* * * * *	
VLFC	<u>Value</u> <u>LoSS</u> <u>FracTion</u> for <u>Cars</u>
VLFL	<u>Value</u> <u>LoSS</u> <u>FracTion</u> for <u>LoCoMotiveS</u>
VLFOE	<u>Value</u> <u>LoSS</u> <u>FracTion</u> for <u>OTHer</u> <u>EquiPment</u>
VOL	<u>VOlume</u>
VOLB	<u>VOlume</u> <u>Base</u> for <u>deSired</u> net working capital
* * * * *	
WFRF	<u>TTGM</u> <u>WoRk</u> <u>Force</u> <u>Reduction</u> <u>FracTion</u>
WRKRF	<u>TTGM</u> <u>WoRk</u> <u>force</u> <u>Reduction</u> <u>FacTior</u>
WTN	<u>Wear</u> and <u>Tear</u> <u>Normal</u> (before taking quality effects into account)
WTN1	<u>WTN</u> for gross ton-mileage \geq 1250 billion

TABLE A-2 (Cont.)

<u>VARIABLE NAME</u>	<u>MEANING</u>
WTN2	WTN for gross ton-mileage < 1250 billion
* * * * *	
ZBMXWS	constant (1967) dollar <u>Budgeted Maintenance eXpense for Way and Structures</u>
ZCURS	constant (1967) dollar <u>Cash Used for Rolling Stock investments</u>
ZDAWS	constant (1967) dollar <u>Debt Available for Way and Structures</u>
ZDIRS	constant (1967) dollar <u>Desired Investments in Rolling Stock</u>
ZDIWS	constant (1967) dollar <u>Desired Investments in Way and Structures</u>
ZDMWS	constant (1967) dollar <u>Desired Maintenance of Way and Structures</u>
ZDNRS	constant (1967) dollar <u>Debt Needed for Rolling Stock</u>
ZDNWC	constant (1967) dollar <u>Desired Net Working Capital</u>
ZDNWS	constant (1967) dollar <u>Debt Needed for Way and Structures</u>
ZDXWS	constant (1967) dollar <u>Desired eXpenditures on Way and Structures</u>
ZEWS	constant (1967) dollar total <u>Expenditures on Way and Structures</u>
ZEXP	constant (1967) dollar total <u>EXPenses that affect NROI</u>
ZIFAWS	constant (1967) dollar <u>Internal Funds Available for Way and Structures</u>

TABLE A-2 (Cont.)

<u>VARIABLE NAME</u>	<u>MEANING</u>
ZIFURS	constant (1967) dollar <u>I</u> nternal <u>F</u> unds <u>U</u> sed for <u>R</u> olling <u>S</u> tock
ZIFUWS	constant (1967) dollar <u>I</u> nternal <u>F</u> unds <u>U</u> sed for <u>W</u> ay and <u>S</u> tructures
ZINTX	constant (1967) dollar <u>I</u> nterest <u>e</u> Xpense on long-term debt (fixed charges)
ZIRS	constant (1967) dollar <u>I</u> nterest <u>R</u> ate on <u>R</u> olling <u>S</u> tock
ZIWS	constant (1967) dollar <u>I</u> nterest <u>W</u> ay and <u>S</u> tructures
ZLBIWS	constant (1967) dollar <u>L</u> ower <u>B</u> ound on <u>I</u> nterest <u>W</u> ay and <u>S</u> tructures
ZLBMWS	constant (1967) dollar <u>L</u> ower <u>B</u> ound on <u>M</u> aintenance of <u>W</u> ay and <u>S</u> tructures
ZMAXMWS	constant (1967) dollar <u>M</u> aximum affordable <u>M</u> aintenance of <u>W</u> ay and <u>S</u> tructures
ZMFIN	constant (1967) dollar <u>M</u> aximum unsecured debt <u>F</u> INancing
ZMFINE	constant (1967) dollar <u>M</u> aximum debt <u>F</u> INancing of <u>E</u> quipment
ZNCERS	constant (1967) dollar <u>N</u> ecessary <u>C</u> ash <u>E</u> xpenditures on <u>R</u> olling <u>S</u> tock
ZNIAT	constant (1967) dollar ordinary <u>N</u> et <u>I</u> ncome <u>A</u> fter <u>T</u> ax (ordinary income)
ZNROI	constant (1967) dollar <u>N</u> et <u>R</u> eturn on <u>I</u> ncome
ZNWC	constant (1967) dollar <u>N</u> et <u>W</u> orking <u>C</u> apital
ZOINC	constant (1967) dollar <u>O</u> ther <u>I</u> ncome

TABLE A-2 (Cont.)

<u>VARIABLE NAME</u>	<u>MEANING</u>
ZREVS	constant (1967) dollar Total operating <u>REVENUE</u> S
ZXTRAM	constant (1967) dollar <u>eXTRA</u> <u>Maintenance of way and structures</u> (during forced quality improvement program)

Appendix B

DERIVATION OF COST-RELATED FUNCTIONS¹

In Chapter 3, many functions were presented which the model uses in the determination of freight service operating expenses (inclusive of payroll taxes, but net of depreciation). Specifically, these functions are:

- i) TTGM labor productivity function (Figure 3-2);
- ii) fuel consumption function (Figure 3-3);
- iii) "other" TTGM cost function (Figure 3-4);
- iv) ME material cost function (Figure 3-5);
- v) ME material/labor ratio function (Figure 3-6);
- vi) MW and investment in way material cost function (Figure 3-15), which was used in the derivation of the wear and tear function (Figure 3-16); and,
- vii) MW and investment in way material/labor ratio (Figure 3-14).

It should be recalled from Chapter 3 that the first five functions relate cost bases to volume, and these cost bases are subsequently priced and/or inflated to determine costs. The material cost function and the material/labor ratio function for way and structures

¹ Data sources used in these derivations were [1], [2], [3], and [4].

were used in the derivation of the wear and tear function, which relates volume to constant quality dollar total expenditures on way necessary to keep quality constant. The wear and tear function is used as an input to the MW and investment in way (IW) budgeting processes.

In this appendix, all these functions will be "derived". Specifically, the observed values indicated in the above-mentioned figures will be derived, as it is these values which the functions of interest approximate. The approximating functions in all cases were not derived by "sophisticated" statistical methods such as regression. Rather, a line which appeared to reasonably fit the data was chosen in each case.

B.1 LABOR COST ALLOCATIONS.

All cost categories are divided into labor and non-labor (i.e., fuel, other, and material) costs. Hence, in deriving these functions, it was necessary to estimate the labor components of each category (i.e., ME, MW + IW, and TTGM). These labor costs represent employee earnings, health and welfare benefits, and associated payroll taxes. Obtaining these costs for each accounting category of freight service proved to be the most difficult

part of the overall derivation process, as the reported data on labor costs was more aggregate in nature than the desired information. Specifically, only health and welfare benefits were broken down into ME, MW and TTGM components for both freight and passenger service. Payroll taxes were only available for all labor in total, and employee earnings and numbers were reported for groupings slightly different than those desired here, and were not split between freight and passenger services. However, it was possible to obtain fair approximations to the allocations of employees, their earnings, and payroll taxes to ME, MW, and TTGM by means of a lengthy set of calculations, beginning with the known splits of health and welfare benefits, and proceeding by taking other important factors into consideration. This process will not be discussed here. Rather, the end results of the process are depicted in Tables B-1 through B-3.

Again, the numbers presented in the tables are only approximations to the true employee and labor cost allocations. However, they are fairly accurate, particularly when viewed in total, as the process used in deriving these values was one of allocating known totals (i.e., payroll taxes) to the various categories of expense (i.e., freight service ME). Furthermore, any errors made in the

TABLE B-1

LABOR COSTS FOR TTGM (TRAFFIC, TRANSPORTATION, GENERAL, AND MISCELLANEOUS) EXPENSES --

FREIGHT SERVICE

	<u>63</u>	<u>64</u>	<u>65</u>	<u>66</u>	<u>67</u>	<u>68</u>	<u>69</u>	<u>70</u>	<u>71</u>	<u>72</u>	<u>73</u>
Employees* (thousands)	323.1	315.7	303.6	316.5	299.1	296.4	295.5	291.7	289.4	289.2	290.4
Earnings* (\$ millions)	2421	2458	2516	2730	2645	2805	3007	3077	3450	3847	4320
Health and Welfare Benefits [3] (\$ millions)	71	90	95	102	106	120	124	150	162	201	212
Payroll Taxes* (\$ millions)	178	183	188	220	234	257	273	297	308	341	447
Total Labor Cost (\$ millions)	2670	2731	2799	3052	2985	3182	3404	3524	3920	4389	4979

*Estimates

TABLE B-2

LABOR COSTS FOR MAINTENANCE OF EQUIPMENT EXPENSE --
FREIGHT SERVICE

	63	64	65	66	67	68	69	70	71	72	73
Employees* (thousands)	109.6	108.0	103.7	103.0	97.8	96.9	103.6	100.6	97.1	97.8	96.2
Earnings* (\$ millions)	654	664	677	693	698	747	840	941	995	1072	1168
Health and Welfare Benefits [3] (\$ millions)	19	24	25	30	28	32	35	45	47	56	59
Payroll Taxes* (\$ millions)	60	62	64	72	77	84	96	103	103	115	148
Total Labor Cost (\$ millions)	733	750	766	795	803	863	971	1089	1145	1243	1375

*Estimates

TABLE B-3

LABOR COSTS FOR MAINTENANCE AND INVESTMENT IN WAY --

FREIGHT SERVICE

	63	64	65	66	67	68	69	70	71	72	73
Employees* (thousands)	114.8	112.1	110.5	111.0	108.2	108.1	107.0	106.0	102.8	101.5	101.0
Earnings* (\$ millions)	660	673	698	726	746	790	845	865	963	1050	1156
Health and Welfare Benefits [3] (\$ millions)	20	25	26	29	29	33	33	41	45	55	59
Payroll Taxes* (\$ millions)	63	65	68	78	84	93	99	108	109	120	154
Total Labor Cost (\$ millions)	743	763	792	833	859	916	977	1014	1117	1225	1369

*Estimates

allocation process are likely minor, and should have almost no effect on the model's outputs as to overall profitability. This is because all costs in the model vary linearly with volume. (The piece-wise linear form of the wear and tear function is an exception to this statement, but in the majority of volume ranges dealt with, only one of the linear segments is used. Thus, for all intents and purposes, wear and tear also varies linearly with volume.) Hence, any labor cost underestimated in one expense category is included in another which also varies linearly with volume, with other linear functions (i.e., for materials) taking up the slack caused in any one category by a misallocated labor cost.

The data in Tables B-1, B-2, and B-3 is used in the derivation of all cost functions, as will become apparent in the ensuing discussions.

B.2 TTGM COST FUNCTIONS.

B.2.1 TTGM Labor Costs.

In obtaining TTGM labor costs, the model uses the TTGM labor productivity function of Figure 3-2 to determine the manpower required and then multiplies this by the unit

labor cost. The interest in this appendix is the values of these two parameters over 1963-1973, and these are derived in Tables B-4 and B-5.

B.2.2 TTGM Fuel Costs.

It should be recalled from Section 3.1.2.2 that the model's fuel consumption function is based upon the number of gallons of diesel oil that would have given rise to the total (diesel and other) fuel costs for freight service over the calibration period, given the cost per gallon of diesel oil. Fuel consumption is then multiplied by unit fuel cost to obtain total fuel cost. The data points used to calibrate the fuel consumption function are derived in Table B-6. These points, and the function fitted to them were depicted previously in Figure 3-3. The actual unit costs of diesel oil given in Table B-6 were used in model validation runs to obtain fuel cost from the fuel consumption function.

B.2.3 Other TTGM Costs.

The data points used to obtain the "other" TTGM cost function of Figure 3-4 are derived in Table B-7. The material cost index shown in Table B-7 was used to deflate data in order to obtain the observed values,

TABLE B-4

TTGM LABOR PRODUCTIVITY -- FREIGHT SERVICE

	63	64	65	66	67	68	69	70	71	72	73
a) Volume [2] (billions of revenue ton- miles)	622	659	698	738	720	744	768	765	740	777	852
b) TTGM Em- ployees [Table B-1] (thousands)	323.1	315.7	303.6	316.5	299.1	296.4	295.5	291.7	289.4	289.2	290.4
c) TTGM Labor Productivity [a/b] (millions of revenue ton- miles per man- year)	1.926	2.085	2.296	2.328	2.408	2.514	2.595	2.620	2.561	2.689	2.938
d) Productivity Index * (1967 = 100)	80.0	86.6	95.3	96.7	100	104.4	107.8	108.8	106.4	111.7	122.0

*This is the variable "TGLPI2" in the model, and is depicted in Figure 3-2.

TABLE B-5

TTGM UNIT LABOR COST -- FREIGHT SERVICE

	63	64	65	66	67	68	69	70	71	72	73
a) TTGM Total Labor Cost [Table B-1] (\$ millions)	2670	2731	2799	3052	2985	3182	3404	3524	3920	4389	4979
b) TTGM Employees [Table B-1] (thousands)	323.1	315.7	303.6	316.5	299.1	296.4	295.5	291.7	289.4	289.2	290.4
c) Unit/Cost Per Man-Year [a/b] (\$)	8259	8652	9220	9642	9980	10738	11516	12079	13546	15176	17143
d) Cost Index* (1967 = 100)	82.8	86.7	92.4	96.6	100	107.6	115.4	121.0	135.7	152.1	171.8

*This is the variable "TGLCI2" in the model.

TABLE B-6

FUEL CONSUMPTION -- FREIGHT SERVICE

	63	64	65	66	67	68	69	70	71	72	73
a) Total Fuel Cost [3] (\$ millions)	NA	NA	295	315	328	357	374	382	NA	434	550
b) Cost of* Diesel Oil [3] (\$/gal)	.0911	.0884	.0910	.0919	.0961	.0994	.1017	.1073	.1088	.1097	.1349
c) Fuel Consumption** [a/b] (millions of gallons of diesel oil)	NA	NA	3242	3428	3413	3592	3677	3560	NA	3956	4077
d) Volume [2] (billions of revenue** ton-miles)	622	659	698	738	720	744	768	765	740	777	852

*This data is the basis for the variable "FCI2" in the model.

**This data is plotted as the "observed" values in Figure 3-3.

TABLE B-7

"OTHER" TTGM COSTS -- FREIGHT SERVICE

	63	64	65	66	67	68	69	70	71	72	73
a) Total TTGM Expenses [3] Plus Allocated Payroll Taxes [Table B-1] (\$ millions)	3829	4049	4154	4340	4477	4813	5165	5565	5814	6293	7127
b) Labor Cost [Table B-1] (\$ millions)	2670	2731	2799	3052	2985	3182	3404	3524	3920	4389	4979
c) Fuel Cost [3] (\$ millions)	271*	279*	295	315	328	357	374	382	386*	434	550

* Estimated by fuel consumption function (Figure 3-3) and actual unit fuel costs [3].

Table continued on next page

TABLE B-7 (Continued)

"OTHER" TTGM COSTS --- FREIGHT SERVICE

	63	64	65	66	67	68	69	70	71	72	73
d) Other TTGM Cost [a-b-c] (\$ millions)	888	1039	1060	973	1164	1274	1387	1659	1508	1470	1598
e) Material Cost Index [2]	.934	.942	.949	.965	1.0	1.026	1.055	1.094	1.135	1.187	1.229
f) Deflated Other TTGM Costs [d/e] ** (millions of 1967 dollars)	951	1103	1117	1008	1164	1242	1315	1516	1329	1238	1300

**These are the observed values plotted against volume in Figure 3-4.

and is also used to inflate functionally-computed values into current costs in model runs.

B.3 ME COST FUNCTIONS.

B.3.1 ME Material Costs.

The observed values of constant 1967 dollar ME material costs plotted against volume with the function which approximates them in Figure 3-5 are derived in Table B-8. The material cost index shown in Table B-8 was used to deflate data in order to obtain the observed values, and is also used to inflate functionally-computed values into current costs in model runs.

B.3.2 ME Labor Costs.

ME labor costs are determined in the model as the product of labor requirements (man-years) and unit labor costs (\$/per man-year). Labor requirements are determined by the constant dollar material cost of maintenance (Figure 3-5) which represents the "amount" of ME required, and the ME material/labor ratio (Figure 3-6) which represents ME labor "productivity". As mentioned in Section 3.1.3.2, the material/labor ratios

TABLE B-8

ME MATERIAL COSTS --- FREIGHT SERVICE

	<u>63</u>	<u>64</u>	<u>65</u>	<u>66</u>	<u>67</u>	<u>68</u>	<u>69</u>	<u>70</u>	<u>71</u>	<u>72</u>	<u>73</u>
a) Total ME Expenses Net of Depreciation [3] Plus Allotted Payroll Taxes [Table B-2] (\$ millions)	1009	1026	1032	1093	1098	1192	1305	1437	1694	1723	1937
b) Labor Cost [Table B-2] (\$ millions)	733	750	766	795	803	863	971	1089	1145	1243	1375
c) Material Cost [a-b] (\$ millions)	276	276	266	298	295	329	334	348	549	480	562
d) Material Cost Index [2]	.934	.942	.949	.965	1.0	1.026	1.055	1.094	1.135	1.187	1.229
e) Deflated Material Cost* [c/d] (millions of 1967 dollars)	295	293	280	309	295	321	317	318	489	404	457

*These are the observed values plotted against volume in Figure 3-5.

used over 1963-1973 represented the ratio of material costs as would be computed by the model to estimated actual man-years of labor. These ratios rather than the actual ones were used to avoid unnecessary validation error caused by combining model-computed material costs with actual material/labor ratios. These ratios (Figure 3-6) are derived in Table B-9, followed by the derivation of ME unit labor costs in Table B-10.

B.4 MW AND IW FUNCTIONS.

The major point of interest in this section is the derivation of the wear and tear function (Figure 3-16). In deriving it, it was first of all necessary to derive the MW and IW material cost function of Figure 3-15, based upon observed values. This material cost function was then used as the basis for an "observed" maintenance and investment in way function, measured in constant quality dollars. Lastly, the "observed" maintenance and investment in way function was used as the basis for the wear and tear function, under the assumption that observed expenditures were a constant percentage of wear and tear. Each of these steps will now be described in turn. Throughout, MW and IW are treated

TABLE B-9

ME MATERIAL/LABOR RATIO -- FREIGHT SERVICE

	63	64	65	66	67	68	69	70	71	72	73
a) ME Material Costs [by applying the function in Figure 3-5 to actual volumes] (millions of constant 1967 dollars)	299	316	335	354	346	357	369	367	355	373	409
b) ME Employees [Table B-2] (thousands)	109.6	108.0	103.7	103.0	97.8	96.9	103.6	100.6	97.1	97.8	96.2
c) Material/Labor Ratio [a/b] (constant 1967 dollars per man-year)	2728	2926	3230	3437	3538	3684	3562	3648	3656	3814	4252
d) Ratio Index* (1967 = 100)	77.1	82.7	91.3	97.1	100	104.1	100.7	103.1	103.3	107.8	120.2

*This is the data presented in Figure 3-6, and is the variable "MELPI2" in the model.

TABLE B-10

ME UNIT LABOR COST -- FREIGHT SERVICE

	63	64	65	66	67	68	69	70	71	72	73
a) ME Total Labor Cost [Table B-2] (\$ millions)	733	750	766	795	803	863	971	1089	1145	1243	1375
b) ME Employees [Table B-2] (thousands)	109.6	108.0	103.7	103.0	97.8	96.9	103.6	100.6	97.1	97.8	96.2
c) Unit Cost Per Man-Year [a/b] (\$)	6686	6948	7388	7716	8198	8904	9370	10826	11796	12708	14288
d) Cost Index* (1967=100)	81.5	84.7	90.1	94.1	100	108.6	114.3	132.1	143.8	155.0	174.3

*This is the variable "MELCI2" used in the model.

in total. Hence, it is assumed that they are identical with respect to material/labor mix and the associated mix of costs.

The reader should note that because the model, and hence all the functions and data discussed in this appendix, is freight-oriented, the investments in way and structures discussed here are only those of freight service (i.e., the Quality of Facilities Level and its rates are only concerned with freight service). The reported data on investments in way was for the sum of freight and passenger services, so the freight allocation "had" to be estimated. This allocation was likely not necessary, as investments in way due to passenger operations were probably minor (i.e., less than \$50 million per year) even in the mid-sixties. However, freight investments were estimated merely for the sake of being consistent with the rest of the model. The allocation of IW to freight service in any year was made based upon the fraction of MW and IW personnel's health and welfare benefits charged to freight service expense¹ that year

¹ All health and welfare benefits are expensed by the industry, even those associated with investment labor. The same is true of payroll taxes. However, due to the small amounts associated with IW, these expenses are capitalized in the model.

(typically more than 90%). Hence the data pertaining to IW in the following tables is slightly less than the commonly reported figures for capital expenditures (which include passenger service).

With the above digression having been made, the data associated with the derivation of the wear and tear function may be presented.

B.4.1 MW And IW Material Costs.

The observed values of MW and IW material costs plotted in Figure 3-15 are derived in Table B-11. Given the function used to approximate these observed values (also depicted in Figure 3-15), it was possible to derive a function which approximated the observed total expenditures on way and structures, measured in constant quality dollars, as follows.

B.4.2 "Observed" MW And IW Function.

As will be explained in Appendix C, the Price of Constant Quality Dollars (PCQD), which measures the current dollars necessary to supply one constant quality dollar, is based upon unit labor costs, unit material costs, and the material/labor ratio. Unit material costs

TABLE B-11

MW AND IW MATERIAL COST -- FREIGHT SERVICE

	<u>63</u>	<u>64</u>	<u>65</u>	<u>66</u>	<u>67</u>	<u>68</u>	<u>69</u>	<u>70</u>	<u>71</u>	<u>72</u>	<u>73</u>
a) Total MW Expense Net of Depreciation [3] w/o Associated Payroll Taxes (\$ millions)	912	956	973	1042	1032	1164	1264	1368	1584	1695	1804
b) Total IW* w/o Associated Payroll Taxes (\$ millions)	231	247	294	363	343	343	395	336	298	349	428
c) Payroll Taxes Allocated to MW and IW Personnel [Table B-3] (\$ millions)	63	65	68	78	84	93	99	108	109	120	154
d) Total Expenses plus Allocated Payroll Taxes [a + b + c] (\$ millions)	1206	1268	1335	1482	1459	1600	1758	1812	1991	2164	2386

*Estimated from data in [2] and [3].

Table continued on next page

TABLE B-11 (Continued)

MW AND IW MATERIAL COST --- FREIGHT SERVICE

	63	64	65	66	67	68	69	70	71	72	73
e) Total Labor Cost [Table B-3] (\$ millions)	743	763	792	833	859	916	977	1014	1117	1225	1369
f) Material Cost [d-e] (\$ millions)	463	505	543	649	600	684	781	798	874	939	1017
g) Material Cost Index [2]	.934	.942	.949	.965	1.0	1.026	1.055	1.094	1.135	1.187	1.229
h) Deflated Material Cost [f/g]* (millions of 1967 dollars)	496	536	572	673	600	667	740	729	770	791	828
i) Gross Ton-Miles Due To Freight Volume* [3] (billions)	1535	1603	1666	1754	1726	1783	1827	1843	1805	1933	2054

*These values define the points plotted in Figure 3-15.

are assumed to inflate according to the material cost index available in [2] used throughout this appendix. The derivations of the material/labor ratio (Figure 3-14) and the unit MW and IW labor costs are given in Tables B-12 and B-13. Again, as was the case with the ME material/labor ratio, the ratio of material costs as would be computed by the model to estimated actual man-years of labor was used to avoid unnecessary validation error.

As will also be apparent in Appendix C, constant quality dollars are a linear function of constant material costs, due to the fact that the Price of Constant Quality Dollars takes into account changes in the material/labor ratio, as well as changes in the unit costs of labor and materials. In fact, the relationship between the two (explained in Appendix C) is:

$$\text{constant quality dollars} = \text{constant 1967 material costs} \times 2.355$$

Hence, the observed total expenditures on way and structures over 1963-1973, measured in terms of constant quality dollars, can be approximated by the function:

TABLE B-12

MW AND IW MATERIAL/LABOR RATIO -- FREIGHT SERVICE

	63	64	65	66	67	68	69	70	71	72	73
a) Material Costs [by applying the function in Figure 3-15 to actual volumes (millions of constant 1967 dollars)	460	526	596	668	634	679	722	717	672	739	874
b) MW and IW Employees [Table B-3] (thousands)	114.8	112.1	110.5	111.0	108.2	108.1	107.0	106.0	102.8	101.5	101.0
c) Material/ Labor Ratio [a/b] (constant 1967 dollars per man-year)	4007	4692	5394	6018	5860	6281	6748	6764	6537	7281	8653
d) Ratio Index* (1967 = 100)	68.4	80.1	92.0	102.7	100	107.2	115.2	115.4	111.6	124.2	147.7

*This is the data presented in Figure 3-14, and is the variable "MWLPI2" in the model.

TABLE B-13

MW AND IW UNIT LABOR COST -- FREIGHT SERVICE

	63	64	65	66	67	68	69	70	71	72	73
a) Total Labor Cost [Table B-3] (\$ millions)	743	763	792	833	859	916	977	1014	1117	1225	1369
b) Employees [Table B-3] (thousands)	114.8	112.1	110.5	111.0	108.2	108.1	107.0	106.0	102.8	101.5	101.0
c) Unit Cost Per Man-Year [a/b] (\$)	6476	6802	7171	7500	7941	8474	9132	9566	10862	12065	13557
d) Cost Index* (1967 = 100)	81.6	85.7	90.3	94.4	100	106.7	115.0	120.5	136.8	151.9	170.7

*This is the variable "MWLCI2" used in the model.

$$\begin{aligned}
 y &= 2.355 x \text{ (function for constant material costs in Figure 3-15)} \\
 &= 2.355 x (.00075x - .660) \\
 &= .00177x - 1.554
 \end{aligned}$$

where: y = billions of constant quality dollars

x = billions of gross ton-miles

B.4.3 Wear And Tear Function.

Given the above function which approximates the observed total expenditures on way and structures in terms of constant quality dollars, the next step was the derivation of the wear and tear function. It was assumed that the observed expenditures (i.e., the function given above used to approximate them) were some constant percentage of the wear and tear rate. Thus, the wear and tear function would be proportional to the above function. The issue to be resolved was the proportionality factor, as follows.

Based upon the above function for "observed" maintenance and investment, the expenditures "made" in 1963 (any year could be used in this derivation) for the actual volume of traffic in that year were \$1088 million (constant quality dollars). Assuming, for the sake of a "round" number not too much in excess of \$1088 million, that wear and tear in 1963 was \$1250 million (constant

quality dollars), the "observed" expenditures would be $1088/1250 = 87\%$ of wear and tear. This leads to:

$$\begin{aligned} \text{wear and tear} &= \frac{1}{.87} \times (\text{"observed" expenditure function}) \\ &= \frac{1}{.87} \times (.00177x - 1.554) \\ &= .00203x - 1.786 \end{aligned}$$

where: wear and tear = billions of constant quality dollars
 x = billions of gross ton-miles

Since the above function leads to negative wear and tear at low volumes, it is only applied for volumes in excess of the arbitrarily chosen value of 1250 billion gross ton-miles (Figure 3-16). For volumes less than 1250 billion gross ton-miles, wear and tear is assumed proportional to volume, as depicted in Figure 3-16. The proportionality factor was chosen so that at 1250 billion gross ton-miles the two methods of computing wear and tear would give identical values, and is:

$$k \times 1250 = .00203 \times 1250 - 1.786$$

$$k = .0006.$$

B.5 NOTES ON APPENDIX B.

- [1] Bureau Of Accounts, Interstate Commerce Commission; "Transport Statistics In The United States, Part I"; for the years ended December 31, 1963 - December 31, 1971; published annually.
- [2] Economics And Finance Department, Association Of American Railroads; "Yearbook Of Railroad Facts, 1973 Edition."
- [3] Economics And Finance Department, Association Of American Railroads; "Statistics Of Railroads Of Class I In The United States"; Statistical Summaries 48-58; published annually 1964-1974.
- [4] Task Force On Railroad Productivity; "Improving Railroad Productivity, A Report To The National Commission On Productivity And The Council Of Economic Advisors"; Washington, D.C.; November 1973.

Appendix C

PRICE OF CONSTANT QUALITY DOLLARS

The Price of Constant Quality Dollars (PCQD) is used in the model to deflate current expenditures on way and structures to a common basis, so that the effects of inflation will be accounted for in measuring the quality added by an expenditure at any point in time. PCQD is also used in the model to relate system quality and wear and tear, both of which are measured in constant quality dollars, to current dollar amounts input to the processes which budget maintenance and investment in way.

The quality supplied by a given expenditure is related to the amount of material handled and/or laid in (i.e., tons of ballast, miles of rail, etc.). However, the expenditures necessary to handle a given amount of material depend on inflation in material costs, inflation in labor costs, and the relative amounts of labor and material used (i.e., the material/labor ratio measured in constant dollar material costs per man-year). Hence, in converting between current expenditures and constant (1967) quality dollars, changes in all three of these factors must be taken into account. Since 1967 is the chosen base year in this study, changes relative to 1967 are

the ones of interest.

With the above explanation having been given for the rationale and general concepts behind PCQD, the function which determines it can be derived. PCQD is a function of time, as the three factors which determine it change with time. The derivation of this function is as follows.

In supplying a given amount of quality to the system (i.e., laying in or handling a given amount of material, measured in terms of the 1967 cost of this material), the following is the relationship between quality dollars supplied and current expenditures:

$$(1) \text{ current expenditures} = \text{PCQD} \times \text{quality dollars}$$

where:

$$(2) \text{ current expenditures} = \text{current material cost} + \text{current labor cost}$$

$$(3) \text{ quality dollars} = 1967 \text{ material cost} + 1967 \text{ labor cost}$$

By expanding equations (2) and (3), and then substituting these expanded forms into equation (1), the function which defines PCQD can be arrived at. Dealing with quality dollars (equation (3)) first, the following is obtained:

$$(3) \text{ quality dollars} = 1967 \text{ material cost} + 1967 \text{ labor cost}$$

where:

$$\begin{aligned} (4) \text{ 1967 labor cost} &= \text{1967 unit labor cost} \times \text{1967 labor requirements} \\ &= \text{1967 unit labor cost} \times \frac{\text{1967 material cost}}{\text{1967 material/labor ratio}} \end{aligned}$$

This is because the 1967 material/labor ratio is measured in terms of 1967 material cost per man-year.

Substituting (4) into (3), the following is obtained:

$$\begin{aligned} (5) \text{ quality dollars} &= \text{1967 material cost} \\ &+ \left[\frac{\text{1967 unit labor cost} \times \text{1967 material cost}}{\text{1967 material/labor ratio}} \right] \end{aligned}$$

which becomes:

$$(6) \text{ quality dollars} = \text{1967 material cost} \times \left[1 + \frac{\text{1967 unit labor cost}}{\text{1967 material/labor ratio}} \right]$$

In Table B-12 and B-13, the following information was available:

$$\text{1967 unit labor cost} = 7941 \text{ \$ per man-year}$$

1967 material/labor ratio = 5860 constant 1967 \$ of material cost
per man-year

Therefore:

$$(7) \text{ quality dollars} = 1967 \text{ material cost} \times \left(1 + \frac{7941}{5860} \right)$$

$$= 2.355 \times 1967 \text{ material cost}$$

Equation (7) was the relationship used in Appendix B (Section B.4.2) to obtain the function which approximated expenditures on way and structures over 1963-1973, in terms of constant quality dollars, from the function which approximated constant dollar material costs over this period (Figure 3-15).

Now, dealing with current expenditures (equation (2)), the following is obtained:

$$(2) \text{ current expenditures} = \text{current material cost} + \text{current labor cost}$$

where:

$$(8) \text{ current material cost} = 1967 \text{ material cost} \times \text{material cost index}$$

The 1967 material cost in equation (8) is the same as the 1967 material cost used in equations (4) through (7) because the same materials are being handled.

In 1967, this amount of material would have required:

$$(9) \text{ 1967 labor requirements} = \frac{\text{1967 material cost}}{\text{1967 material/labor ratio}}$$

However, due to a changing material/labor ratio, the present labor requirements at any point in time are:

$$(10) \text{ present labor requirements} = \frac{\text{1967 material cost}}{\text{present material/labor ratio}}$$

where the present material/labor ratio is measured in terms of constant 1967 dollars of material cost per man-year (i.e., in Table B-12, the 1973 material/labor ratio is 8653 constant 1967 dollars of material cost per man-year, whereas in 1967 this ratio was 5860). The present material/labor ratio can be restated as:

$$(11) \text{ present material/labor ratio} = \text{1967 material/labor ratio} \times \text{ratio index}$$

since the ratio index by definition relates the present ratio to the 1967 ratio (See Table B-12).

So, combining equations (10) and (11), the following

is obtained:

$$(12) \text{ present labor requirements} = \frac{1967 \text{ material cost}}{1967 \text{ material/labor ratio} \times \text{ratio index}}$$

The current cost of these labor requirements is:

$$(13) \text{ current labor cost} = \text{present labor requirements} \times \text{current unit labor cost}$$

$$= \frac{1967 \text{ material cost}}{1967 \text{ material/labor ratio} \times \text{ratio index}} \times 1967 \text{ unit labor cost} \times \text{labor cost index}$$

$$= \frac{1967 \text{ unit labor cost}}{1967 \text{ material/labor ratio}} \times 1967 \text{ material cost} \times \frac{\text{labor cost index}}{\text{ratio index}}$$

However, as previously explained:

$$\frac{1967 \text{ unit labor cost}}{1967 \text{ material/labor ratio}} = \frac{7941}{5860} = 1.355$$

Therefore:

$$(14) \text{ current labor cost} = 1.355 \times 1967 \text{ material cost} \times \frac{\text{labor cost index}}{\text{ratio index}}$$

Substituting equations (8) and (14) into equation (2),
the following is obtained:

$$\begin{aligned}
 (15) \text{ current expenditures} &= \text{current material cost} + \text{current labor cost} \\
 &= 1967 \text{ material cost} \times \text{material cost index} \\
 &\quad + 1.355 \times 1967 \text{ material cost} \\
 &\quad \times \frac{\text{labor cost index}}{\text{ratio index}} \\
 &= 1967 \text{ material cost} \\
 &\quad \times \left(\text{material cost index} + 1.355 \times \frac{\text{labor cost index}}{\text{ratio index}} \right)
 \end{aligned}$$

Finally, by substituting equations (7) and (15) into
equation (1), PCQD can be arrived at, as follows:

$$\begin{aligned}
 (1) \text{ current expenditures} &= \text{PCQD} \times \text{quality dollars} \\
 (7) \text{ quality dollars} &= 2.355 \times 1967 \text{ material cost} \\
 (15) \text{ current expenditures} &= 1967 \text{ material cost} \\
 &\quad \times \left(\text{material cost index} + 1.355 \times \frac{\text{labor cost index}}{\text{ratio index}} \right) \\
 (16) \text{ PCQD} &= \frac{\text{current expenditures}}{\text{quality dollars}}
 \end{aligned}$$

$$\begin{aligned}
 \text{PCQD} &= \frac{1967 \text{ material cost}}{2.355 \times 1967 \text{ material cost}} \\
 &\times \left(\text{material cost index} + 1.355 \times \frac{\text{labor cost index}}{\text{ratio index}} \right) \\
 &= \frac{1}{2.355} \times \left(\text{material cost index} + 1.355 \times \frac{\text{labor cost index}}{\text{ratio index}} \right) \\
 &= \frac{\text{material cost index}}{2.355} + .5754 \times \frac{\text{labor cost index}}{\text{ratio index}}
 \end{aligned}$$

Thus, in the model listing of Appendix A, the equation for PCQD is:

$$\text{PCQD.k} = \frac{\text{MATCI.k}}{2.355} + .5754 \times \frac{\text{MWLCI.k}}{\text{MWLPI.k}}$$

where:

PCQD.k = price of constant quality dollars at time k

MATCI.k = material cost index at time k

MWLCI.k = MW labor cost index at time k

MWLPI.k = MW labor "productivity" (i.e., material/labor ratio) index at time k.

Appendix D

INDEX OF SIMPLIFICATIONS AND ASSUMPTIONS

There were many simplifications and assumptions made in constructing the model and in applying it in the case analyses of Chapter 5. These simplifications and assumptions were identified and discussed in the text. Due to their large number and the length of this thesis, however, the reader may find it beneficial to have them summarized, and indexed for easy location in the text. Thus, this appendix briefly restates and discusses the simplifications and assumptions made, and indicates the pages of the text where they are discussed in more detail.

The simplifications and assumptions made in this study are identified in alphabetical order (alphabetized on a key word which represents the important point addressed) in Table D-1. They are categorized as being of three types: "Basic", "Structural", and "Optional". The simplifications and assumptions of each category will subsequently be dealt with and indexed in Tables D-2 through D-4.

The Basic simplifications and assumptions have to do with the overall issues involved in constructing and using the model. These simplifications cannot be changed

TABLE D-1SIMPLIFICATIONS AND ASSUMPTIONS MADE*

<u>SIMPLIFICATION/ASSUMPTION</u>	<u>TYPE</u>
Aggregation of railroads in modelling industry	Basic
Allocation of funds process & priorities of various uses	Optional
Bankruptcy or insolvency	Basic
Capacity of fixed facilities	Structural
Constant structure of financial system	Basic
Costs (operating costs):	
Basis	Structural
Disaggregation to account for inflation	Structural
Linearity of functions	Optional
ME expense:	
Future course of ME material/labor ratio	Optional
Future course of ME unit labor cost	Optional
Future course of ME unit material cost	Optional

* The phrase "treatment of" applies to most Structural and Basic assumptions and simplifications. The phrases "values assigned" and "values computed" apply to most Optional simplifications and assumptions. These modifying phrases will only appear in this and subsequent tables to distinguish between Optional and Structural simplifications identified by the same "name".

TABLE D-1 (Continued)

<u>SIMPLIFICATION/ASSUMPTION</u>	<u>TYPE</u>
Costs (operating costs) (continued):	
ME expense (continued):	
Total variability of ME labor costs	Optional
Total variability of ME material costs	Optional
MW expense:	
Desired MW	Optional
Fraction of expenditures classified as maintenance	Optional
Future course of MW + IW material/labor ratio	Optional
Future course of MW + IW unit labor cost	Optional
Future course of MW + IW unit material cost	Optional
Maximum affordable MW	Optional
Minimum feasible MW	Optional
MW budgeting process	Optional
Treatment of	Structural
Passenger expense:	
Treatment of	Structural
Values assigned	Optional
Rental expense:	
Treatment of	Structural

TABLE D-1 (Continued)

<u>SIMPLIFICATION/ASSUMPTION</u>	<u>TYPE</u>
Costs (operating costs) (continued):	
Rental expense (continued):	
Values assigned:	Optional
State and local taxes:	
Treatment of Values Assigned	Structural Optional
TTGM expenses:	
Fuel treated as diesel oil	Optional
Future course of TTGM labor productivity	Optional
Future course of TTGM unit fuel cost	Optional
Future course of TTGM unit labor cost	Optional
Future course of TTGM unit "other" costs	Optional
Total variability of TTGM labor costs	Optional
Total variability of TTGM "other" costs	Optional
Debt:	
Availability	Optional
Interest rate	Optional
Repayment rule	Optional

TABLE D-1 (Continued)

<u>SIMPLIFICATION/ASSUMPTION</u>	<u>TYPE</u>
Debt (Continued):	
Treatment of	Structural
Demand:	
Equal to volumes observed over 1963-1973	Optional
Growth rate	Optional
Treatment of	Structural
Dividend Policy	Optional
Equity financing and dividends	Structural
Expenditures on way and structures:	
Desired	Optional
Minimum	Optional
Fixed charges	Structural
Income	Structural
Income tax rate	Optional
Interest rate on short-term investments	Optional
Investments:	
Other equipment:	
Treatment of	Structural
Values assigned	Optional
Policies	Structural
Rolling stock:	
Car to locomotive ratio	Optional

TABLE D-1 (Continued)

<u>SIMPLIFICATION/ASSUMPTION</u>	<u>TYPE</u>
Investments (continued):	
Rolling stock (continued):	
Forecasting parameters	Optional
Future course of equipment prices	Optional
Necessary cash expenditures	Optional
Treatment of	Structural
Volume growth policy	Optional
Way and structures:	
Desired IW	Optional
Minimum IW	Optional
Treatment of	Structural
Liquidity policy:	
Desired addition to net working capital	Optional
Desired net working capital	Optional
Treatment of	Structural
Network size	Structural
Operating policies	Structural
Other income:	
Treatment of	Structural
Values computed	Optional

TABLE D-1 (Continued)

<u>SIMPLIFICATION/ASSUMPTION</u>	<u>TYPE</u>
Productivity and capacities of freight car and locomotive fleets	Optional
Quality of fixed facilities:	
Effects on costs and productivities:	
Not accounted for in calibration	Optional
Numerical values	Optional
Shape of relationships	Optional
Treatment of	
Initial Value	Optional
Treatment of	Structural
Quality of rolling stock	Structural
Quality of service	Structural
Rebuilt equipment	Structural
Rented rolling stock:	
Amount	Optional
Treatment of	Structural
Retirements of assets:	
Equipment:	
Average lives	Optional
Fractions of value lost	Optional
Treatment of	Structural
Road Assets	Structural

TABLE D-1 (Continued)

<u>SIMPLIFICATION/ASSUMPTION</u>	<u>TYPE</u>
Revenues :	
Freight revenues and rates:	
Treatment of	Structural
Values assigned	Optional
Other revenues:	
Treatment of	Structural
Values assigned	Optional
Wear and Tear:	
Functional form	Optional
Numerical values	Optional
Treatment of	Structural

without changing the overall approach taken in this study, as they define this approach. That is, the Basic simplifications and assumptions provide the framework within which the model was constructed and used. They thus represent the highest level in a hierarchy of simplifications and assumptions, as the Basic category provides a framework for the Structural and Optional categories, which deal with the model structure and its specific components.

The second level in the hierarchy of simplifications and assumptions is referred to as Structural. These are inherent in the overall structure of the model, and define it as one particular representation of the real system, given the approach to be taken in modelling and analyzing this system as defined by the Basic simplifications. In order to change any of the Structural simplifications and assumptions, it would be necessary to reconstruct significant portions of the existing model, hence creating a "new" model.

Lastly, there are the Optional simplifications and assumptions. These are associated with particular parameters, policies, functional forms, and model components which "plug into" the overall model structure defined by the Structural simplifications. Because they

individually represent specific portions of the existing model, the Optional simplifications and assumptions can be easily changed to test the effects of these changes on this model's outputs. Hence, these assumptions and simplifications deal with specific aspects of the system that can be studied with the current model.

It should be noted that the categorization of the simplifications and assumptions into three groups involved some discretion on the part of the author, as the boundaries between the groups are not sharp. However, the groupings achieved are indicative of the author's interpretation of the above definitions given for the categories.

Given the definitions and hierarchical relationships of the three categories, it can be seen that the sensitivity of this model's outputs can only be discussed in terms of the Optional assumptions. The Structural assumptions define this model, and discussions of them must concern the validity of the overall model structure. The Basic assumptions can only be discussed in terms of how they too apply to the validity of the overall model, or how the model is to be used. Since these discussions of validity and model use were given in the text, they are only briefly reiterated here, with the reader being

referred to the indicated pages of the text for further discussion and explanation.

The Basic and Structural simplifications will appear in Tables D-2 and D-3. In these tables, the simplifications and assumptions are presented alphabetically, briefly restated, discussed, and indexed in the text. Table D-4 then alphabetically lists (but does not restate) the Optional assumptions testable within the framework provided by the Basic and Structural assumptions. The discussions of the Optional assumptions and simplifications made in this study are given in the body of the thesis, and are indexed (but not repeated) in Table D-4. Table D-4 also gives the author's a priori expectations as to the sensitivity of the model's numerical outputs with respect to "reasonable" changes in the Optional assumptions. "Reasonable" changes are those which comply with the overall purpose and structure of the model. That is, an alteration such as a ten-fold increase in passenger expense (or any other exogenously supplied value) would be considered "unreasonable", as the model is structured around freight operations, under the structural assumption that passenger service can be treated as a (negligible) constant cost.

The sensitivities presented in Table D-4 are the

author's a priori expectations, as it was impossible to test them in this study due to their large number. Furthermore, the sensitivities presented apply to the model's numerical outputs. The sensitivity of the conclusions of this study are not presented, as it is the author's belief that the conclusions reached here are insensitive to the assumptions made. This is because the model was used to address "common" problems in this study, so that the results achieved represented the approximate quantification of commonly accepted qualitative notions. Thus, Table D-4 indicates the sensitivities of the model's absolute numerical outputs. This sensitivity is important, however, as it affects the quantification of the issues addressed here, and also affects any other conclusions that the model may be used to obtain through comparative analyses in the future. Again the model's usefulness as a comparative tool is stressed. Changing the model's Optional assumptions will change its outputs, but will not change the manner in which the model should be used. Because the Structural assumptions detract from the model's ability to accurately predict system state, it should always be used as a comparative tool, regardless of the Optional assumptions made. Structural assumptions other than those made here would

also limit a model's ability to accurately predict system state. Hence, any model of this type (as defined by its structural assumptions) should be used as a comparative tool.

With the above discussion having been given of the nature of this appendix, Tables D-2 through D-4 can now be presented.

TABLE D-2BASIC SIMPLIFICATIONS AND ASSUMPTIONS

1) AGGREGATION OF RAILROADS IN MODELLING INDUSTRY

Statement - It is assumed that aggregate industry conditions are representative of the average conditions of the railroads comprising the industry. Thus, it is assumed that the decisions reached by the industry, treated as one large railroad making decisions based upon its (aggregate) financial state, are representative of the aggregation of the decisions reached by the individual railroads.

Discussion - This is a major simplification, as it ignores the variance in the financial conditions and decisions of the individual railroads. However, most railroads make their decisions in essentially the same manner, and most are in the same (marginal) financial condition. Thus, this simplification, which must be made to study the industry in total, is not unwarranted.

Text - pp. 78, 132

TABLE D-2 (continued)

2) BANKRUPTCY OR INSOLVENCY

Statement - The model does not allow the industry to go out of business, regardless of its financial condition. Thus, negative net working capital must be interpreted accordingly.

Discussion - The model is used to identify the financial conditions which would result by continued operation in assumed scenarios. The model is not used to predict the future. Hence, this assumption is inherent in the model's purpose.

Text - pp. 122-124, 343-345, 398-399

3) CONSTANT STRUCTURE OF FINANCIAL SYSTEM

Statement - The policies, parameters, and external factors which affect the industry's financial performance do not change from those assumed to be in effect in the past, regardless of the state of the system.

Discussion - This "assumption" is extremely important, as it is inherent in the model's structure and purpose. The model is being used to study the financial conditions which would result in assumed scenarios, where the structure of the financial system itself is the major part of the scenario being studied. Situation-induced system changes do not occur in the model. Thus, the model is not to be used as a predictive tool, as in reality the system itself would change in response to a change in its performance. Rather, the model is to be used as a comparative tool, so that the situations caused by various system structures can be compared.

Text - pp. 49-50, 468-469

TABLE D-3STRUCTURAL SIMPLIFICATIONS AND ASSUMPTIONS

1) CAPACITY OF FIXED FACILITIES

- Statement - The capacity of the fixed facilities is assumed to always be great enough for the traffic volumes carried. Investments in way and structures are assumed to contain sufficient additions and betterments to ensure that the capacity of all the fixed facilities, (i.e., line-haul trackage, terminals, etc.) is adequate. Also, these additions and betterments are assumed to not significantly alter network size (discussed below) and hence property taxes.
- Discussion - This is a major simplification. However, there is excessive duplication of fixed facilities in the industry today. Also, the model-determined investments in fixed facilities are heavily influenced by the wear and tear rate which is based upon the past relationship between expenditures (including additions and betterments) and volume. Thus, it does not seem unreasonable to assume that the model's investments in way and structures will generate sufficient capacity without significantly altering the size of the network. However, the volume ranges in which this assumption is valid can be questioned. That is, the current duplication of facilities in the industry coupled with the observed relationship between volume and investment over 1963-1973 might not generate sufficient capacity (particularly terminal capacity) for some of the large volumes (i.e., double those currently existing) considered. This possible shortcoming of the model structure affects its ability to accurately predict system state, but should not detract from the model's usefulness as a comparative tool, given that this simplification is taken into account in forming conclusions. It would be extremely difficult to alter the model to deal with the capacity of the fixed facilities in a realistic fashion.
- Text - pp. 124-126

TABLE D-3 (continued)

2) COSTS (OPERATING COSTS):

2a) BASIS

Statement - All variable costs are assumed to be functions of revenue ton-miles. Traffic patterns, car sizes, and operating policies are assumed not to change significantly in the future, so that all cost bases (i.e., carloadings, gross ton-miles, etc.) are proportional to revenue ton-miles.

Discussion - Since the model is structured around the general relationships of 1963-1973, all other cost bases are in effect related to revenue ton-miles in the same manner as they were over this period. Although most of these relationships are not dealt with in the model, they are implicit in its simple cost functions which were based on data from 1963-1973. Thus, as revenue ton-miles (and other cost bases) increase, so do the model's costs. It would be difficult, and most likely not worth the effort, to include other cost bases in the model.

Text - pp. 85-86

2b) DISAGGREGATION TO ACCOUNT FOR INFLATION

Statement - Each cost category for freight service (i.e., MW, ME, or TTGM) is only disaggregated into several sub-categories (i.e., labor, fuel, material, or "other"), the number of which depend upon the cost category.

Discussion - Due to the aggregate level of the model, and due to data restrictions, further disaggregation was neither desirable nor possible.

Text - pp. 85

TABLE D-3 (continued)

2c) MW EXPENSE, TREATMENT OF

- Statement - MW expense in the model is determined by a budgeting process which takes into account 3 factors: a minimum feasible amount, a desired amount, and a maximum affordable amount.
- Discussion - The budgeting process itself, and the values taken on by each of the 3 factors, may be changed. However, the existence of these three factors, particularly the minimum and desired amounts, is inherent throughout the model, and would be extremely difficult to change. Thus, any alterations made to the model should center around changing the values and/or the "weights" given to these factors in determining MW.
- Text - pp. 101-107, 231-236

2d) PASSENGER EXPENSE, TREATMENT OF

- Statement - Passenger expense is treated as an exogenously supplied value.
- Discussion - The model is oriented towards freight operations, as passenger operations are negligible in the industry today.
- Text - pp. 107-108

TABLE D-3 (continued)

2e) RENTAL EXPENSE, TREATMENT OF

- Statement - Rental expense is treated as an exogenously supplied value.
- Discussion - The model does not deal with the lease/buy issue, and assumes that the numbers of rented cars and locomotives remain constant in the future, with all additional capacity being purchased. This is further discussed below and in the text.
- Text - pp. 107-111

2f) STATE AND LOCAL TAXES, TREATMENT OF

- Statement - State and local taxes are treated as an exogenously supplied value.
- Discussion - This simplification is a part of the overall treatment given to network size (discussed below), and is further discussed in the text.
- Text - pp. 107-109, 125

TABLE D-3 (continued)

3) DEBT, TREATMENT OF

- Statement - Debt is the only available source of external financing in the model, and is broken down into two types: unsecured and equipment debt. Debt repayments are modelled as direct reductions in net working capital, even when it is negative. Thus, these repayments, and the negative net working capital they can cause, must be interpreted properly.
- Discussion - The existence of two types of debt is inherent throughout the model's structure, and is difficult to change. However, the attributes of the two types of debt (i.e., availability, terms, applicability to various uses of funds) can be easily altered. The omission of equity financing from the model is discussed below.
- Text - pp. 116-117, 122-123, 179-191, 340-342

TABLE D-3 (continued)

4) DEMAND, TREATMENT OF

Statement - Demand is modelled as being inelastic to all level of service attributes (i.e., rates, service quality) and growing at a constant rate. Traffic mix is assumed to be fixed, and demand is considered only in terms of aggregate revenue ton-miles.

Discussion - This is a major simplification, but was made due to the high degree of uncertainty (and hence the need for sensitivity analyses) about demand elasticities and reaction times. Thus, the model is to be used to analyze the effectiveness of various alternatives aimed at enabling the industry to profitably serve an assumed growing demand for its service, which is in itself an extensive problem area. This simplification was made due to rail freight demand modelling being a relatively unexplored field. Demand itself can easily be made service- or rate-sensitive in the model. However, sensitivity analyses on the extremely important (and unknown) demand elasticities would be desirable in this case. Also, a macroscopic representation of service quality, which is difficult to model at the aggregate level of this model, would be required. Thus, demand was treated as inelastic in order to reduce the amount of internal uncertainty in the model.

Text - pp. 41-45, 111, 280-282

TABLE D-3 (continued)

5) EQUITY FINANCING AND DIVIDENDS

Statement - Equity financing is not included in the model as a source of external funds. Thus, dividends in the model do nothing for the industry's financial rating credibility and hence for the availability of external funds. Also, stock dividends are not modelled.

Discussion - Equity financing was omitted due to the highly leveraged capital structure of the industry and its inability in the recent past to issue equity. Since many of the factors which constrain unsecured debt availability (i.e., interest coverage) would also constrain the availability of equity, this type of debt financing is used in the model as a proxy for all types of external funding other than equipment debt.

Text - pp. 116-117, 122, 133-134

6) FIXED CHARGES

Statement - Fixed charges in the model represent the interest expense associated with (long-term) debt. The negligible amortizations of discounts on debt issues and the small amounts of interest associated with leased equipment and facilities, which are also accounted for as fixed charges by the industry, are not dealt with separately. Rather, these are assumed to represent interest expense associated with outstanding debt.

Discussion - This "structural" assumption is very unimportant. That is, the small amounts of expense not really associated with outstanding debt (which are treated as if they were) have negligible impacts on the model's outputs. This "structural" assumption is easily changed, but there is no advantage to doing so.

Text - pp. 161, 179-183

TABLE D-3 (continued)

7) INCOME

- Statement - Net income and ordinary income are not differentiated in the model, as extraordinary items and prior period expenses are not modelled.
- Discussion - These usually small, unpredictable items which have been omitted from the model typically represent "pseudo" transactions that do not affect cash flow, which is an important element of the system of interest. Hence their exclusion is unimportant.
- Text - pp. 82

3) INVESTMENTS:

8A) INVESTMENTS IN OTHER EQUIPMENT, TREATMENT OF

- Statement - Investments in equipment other than freight service rolling stock are treated as exogenously supplied values which are always spent, regardless of the financial condition of the industry, and which are not eligible for equipment debt.
- Discussion - These investments in passenger service rolling stock and all other types of equipment are very small in magnitude and thus are unimportant in affecting the model's ability to approximate reality.
- Text - pp. 126, 136, 256

TABLE D-3 (continued)

8b) INVESTMENTS IN ROLLING STOCK (FREIGHT SERVICE), TREATMENT OF

Statement - Investments in rolling stock are determined by the model's funds allocation process acting upon the inputs it receives from the rest of the model. Two major inputs it receives are the desired investments in freight cars and the desired investments in freight service locomotives. These desired amounts are determined by the volume growth policy in effect, forecasts of demand and freight car productivity, and by the car to locomotive ratio which relates locomotive needs to car needs. All additional capacity is assumedly purchased after 1973.

Discussion - While the funds allocation process, the volume growth policy, and the numerical values of the forecasting parameters and the car to locomotive ratio can be easily changed, it is inherent in the model's overall structure that the desired investments in rolling stock be based upon the above-mentioned factors. Changing the general manner in which these desired amounts are arrived at would entail a major structural revision to the model.

Text - pp. 126-128, 136, 262-277

TABLE D-3 (continued)

8c) INVESTMENTS IN WAY AND STRUCTURES, TREATMENT OF

Statement - Desired, minimum, and budgeted investments in way and structures are treated only in terms of their total dollar amount and the impact they have on system quality. No distinction is made between investments in depreciable versus non-depreciable road assets, and no distinction is made between additions, betterments, and replacements. Desired and minimum investments are generated by consideration of the quality of the fixed facilities and the wear and tear caused by traffic passing "over" them. That is, all road assets are treated as if they provide right of way. Investments in way and structures are assumed to always generate sufficient capacity for the volumes carried. All investments made are capitalized in one level and hence even non-depreciable road assets generate depreciation in the model. However, the depreciation rate is based upon past observed depreciation expense and total gross book value of all road assets. Therefore it is implicitly assumed that investments made maintain the relative proportions of depreciable and non-depreciable road assets.

Discussion - This treatment of investment in way and structures is extremely simplified. However, it fulfills the needs of this study. Specifically, system quality is of prime interest here, and this treatment of investment in way and structures is centered around the effects of investment on quality, and the consideration of quality in planning these investments. Since non-depreciable road assets represent most of the historical investment in way and structures, the lack of explicit treatment given to depreciable road assets should be rather unimportant. It should be noted that the gross book values of depreciable and non-depreciable road assets

TABLE D-3 (continued)

8c) INVESTMENTS IN WAY AND STRUCTURES, TREATMENT OF (continued)

Discussion - could be separated quite easily, allowing depreciation to be computed solely on the basis of depreciable road assets alone. To do so, however, would require explicit treatment of investments in depreciable road assets. This might be done in a simple manner similar to that used for other equipment. However, the entire model is centered around investments in the fixed facilities in total. Also, the implicit assumption about aggregate investments in road assets maintaining the relative gross book values of depreciable and non-depreciable road assets is only implicit in the fact that depreciation expense is based upon the gross book value of both types of assets. Since the depreciation expense associated with way and structures is rather minor, this assumption is not that important, and there is no real benefit to be achieved by treating depreciable road assets separately.

Text - pp. 124-126, 174-179, 231-236

8d) INVESTMENT/FINANCING POLICIES

Statement - Most of the model's investment/financing policies were formulated as simple equations representing the notion that the industry performed "as if" certain policies were controlling its actions.

Discussion - Because of the model's level of aggregation, the fact that the industry in total was being treated as a decision-making unit, and due to the fact that policies therefore had to be "derived" from

TABLE D-3 (continued)

8d) INVESTMENT/FINANCING POLICIES (continued)

Discussion - observed data, no other approach to modelling
(continued) investment/financing policies was feasible.

Text - pp. 141-146

9) LIQUIDITY POLICY, TREATMENT OF

Statement - Liquidity is determined in the model by its liquidity policy interacting with the funds allocation process. This policy defines a desired level of net working capital and a desired annual "investment" in liquidity (i.e., a desired addition to net working capital).

Discussion - As with desired investments in rolling stock, the numerical values generated by the liquidity policy may be easily altered. However the concept of a desired addition to net working capital based upon a desired level of net working capital is inherent in the model and is conceptually reasonable. Thus, this treatment of liquidity policy should most likely not be changed.

Text - pp. 137-140

TABLE D-3 (continued)

10) NETWORK SIZE

- Statement - Network size is assumed not to change significantly. Thus, state and local taxes, which contain property taxes, are assumed to remain constant. In cases of increasing volume, the investments in way and structures are assumed to generate sufficient capacity for the volumes carried without altering network size significantly. Furthermore, the assumed additions and betterments which increase the capacity of the fixed facilities are assumed not to alter system gross ton-miles per mile significantly, so that wear and tear can be related to gross ton-mileage as a proxy for gross ton-miles per mile. Lastly, the model does not "allow" network rationalization in the case of decreasing volumes.
- Discussion - These assumptions about network size are heavily influenced by the manner in which investments in way and structures are modelled (discussed above). These assumptions are not realistic, but are simplifying. Again, therefore, the model should not be used as an absolute predictor, but as a comparative tool where these simplifications about network size, investments in way and structures, and the capacity of the fixed facilities are the same for all options tested.
- Text - pp. 125, 208, 371-372

TABLE D-3 (continued)

11) OPERATING POLICIES

Statement - Operating policies are not explicitly modelled. Rather, they are inherent in all the model components which are affected by, or affect, operating policies in actuality. Since the model was calibrated on data from 1963-1973, the operating policies of that period are inherent in the model components. If model components are changed (i.e., externally, due to the testing of an alternative with the model; or for reasons internal to the model, such as quality degradation), operating policies are therefore implicitly assumed to change accordingly. Operating policies are inherent in the model's car to locomotive ratio, the effects of quality on costs and productivities, freight car productivity, and TTGM labor productivity.

Discussion - Operating policies were not explicitly modelled due to the uncertainty involved in the macroscopic effects of changes in these policies on costs, service, and demand. Because of this uncertainty, these policies and their important interactions could have been modelled in a simple fashion and then subjected to sensitivity analyses. However, this was not done in order to reduce the amount of internal uncertainty in the model.

Text - pp. 41-45, 84-85, 270

TABLE D-3 (continued)

12) OTHER INCOME, TREATMENT OF

- Statement - Other income is treated as an exogenously supplied value adjusted for interest earned/paid on deviations in net working capital about its 1973 year end value.
- Discussion - The concern in this study is the profitability of railroad operations themselves. Hence, other income was treated as a constant adjusted for interest earned/paid due to deviations in net working capital which are caused by railroad operations in the model.
- Text - pp. 111-112, 123

13) QUALITY OF FIXED FACILITIES:

13a) QUALITY EFFECTS, TREATMENT OF

- Statement - Wear and tear, fuel consumption, TTGM other costs, ME, TTGM labor costs (i.e., TTGM labor productivity), and equipment ownership costs (i.e., rolling stock productivity) were assumed to be affected by the quality of the fixed facilities. Since operating policies and hence train speeds are not explicitly dealt with by the model, the effects of speed on wear and tear and other speed-related costs are inherent in the effects of quality on these costs.
- Discussion - The factors affected by quality and the nature of their relationship with quality may be easily changed. However, it is most likely that all the above-mentioned factors are affected by quality in some manner.
- Text - pp. 216-231, 325-329

TABLE D-3 (continued)

13) QUALITY OF FIXED FACILITIES (continued)

13b) QUALITY OF FIXED FACILITIES, TREATMENT OF

Statement - Quality is measured as the cumulative difference between budgeted expenditures for both investment and maintenance of way, and wear and tear ("necessary" expenditures). Quality is an aggregate measure of the quality of all road assets, including those which do not provide right of way, which for the sake of the model are assumed to be worn by traffic in the same manner as assets which do provide right of way. Maintenance and investment expenditures are assumed identical in all respects (i.e., impact on quality, labor/(material mix, etc.), and only the total dollar value of these expenditures is dealt with. The specific uses to which these expenditures are put (i.e., repair, replacement, addition, or betterment) are not dealt with by the model. Rather, maintenance and investment are differentiated solely by means of a parameter which dictates the amount of expenditures to charge to expense (and the amount to capitalize).

Discussion - This treatment of quality is highly simplified. However, it lends itself to easy interpretation. Quality is similar in concept to net book value under depreciation accounting adjusted for inflation and over- or under-maintenance. It can therefore be used in measuring the amount of deferred expenditures on way and structures by simply comparing the current quality with a "desired" level of quality representative of what quality would be if there were no deferred expenditures.

Text - pp. 195-207

TABLE D-3 (continued)

14) QUALITY OF ROLLING STOCK

Statement - The model does not deal with the quality of the rolling stock and hence the impacts of this quality on costs. Thus the quality of the rolling stock is assumed not to change from that of the recent past, and this quality is inherent in the cost and asset live parameters estimated.

Discussion - The problem of deferred expenditures on way and structures is much more serious than that of deferred expenditures on equipment. Also, quality of the fixed facilities is easier to model. Thus, quality of the fixed facilities was addressed in this study. Since rolling stock quality is inherent in the model's cost functions and other parameters, it is invariant across cases tested. Thus, its exclusion from the model does not affect the model's usefulness as a comparative tool in studying other aspects of the system of interest.

Text - PP. 96,220

15) QUALITY OF SERVICE

Statement - Quality of service is not modelled.

Discussion - Quality of service less easily lends itself to macroscopic quantification than does quality of the facilities. Also, demand is assumed to be completely insensitive to it. Thus, it was not modelled. This exclusion does not detract from the model's ability to study other problems of interest.

Text - PP. 41-45

TABLE D-3 (continued)

16) REBUILT EQUIPMENT

- Statement - Rebuilds are assumed to play an insignificant role in the model's applications.
- Discussion - Rebuilds were "included" in the model primarily because of their effects on capital expenditures over the validation period. The model is not structured to decide on rebuilding equipment. Rather, rebuilds can be inherently modelled by adjusting model parameters, and this was done for the purpose of model validation.
- Text - pp. 127-128, 258-261

17) RENTED ROLLING STOCK, TREATMENT OF

- Statement - The numbers, and changes in numbers, of rented freight cars and locomotives are treated as exogenously supplied values. In future cases analyzed, the rented fleets are assumed to remain constant (as are the associated rental costs) in absolute size with all additional rolling stock being purchased after 1973.
- Discussion - The lease/buy decision is not one of the issues that the model was developed to study. This simplification should have negligible impact on the model's applicability to the problems of interest.
- Text - pp. 109-111, 257, 262-277

TABLE D-3 (continued)

18) RETIREMENTS OF ASSETS:

18a) RETIREMENTS OF EQUIPMENT, TREATMENT OF

Statement - Equipment is retired (scrapped/sold) and written off as dictated by third order delays controlling these processes for cars, locomotives, and other equipment. These delays cause equipment to be retired in a manner distributed deterministically over time about the average lives of the asset groups concerned. Equipment cannot be disposed of sooner nor later than dictated by the delays. That is, decisions as to "early" or "late" retirements are inherent in the delays' outputs, and these decisions are not explicitly modelled. Retired equipment generates cash from asset disposal.

Discussion - As a long-run approximation to the processes and decisions determining retirements, the use of third order delays is justified. However, these delays cannot respond "properly" to short-term surpluses in equipment fleets as caused by sudden changes in productivities.

Text - pp. 118-119, 166-170, 261-277

18b) RETIREMENTS OF ROAD ASSETS

Statement - Retirements of depreciable road assets are assumed to provide no cash from asset disposal. Retirements of non-depreciable road assets without replacement have been negligible in the past, and the model does not "allow" network rationalization, so the depreciation-like cash flows generated by these retirements are ignored. Salvage from retirements of non-depreciable road assets is implicitly included as a reduction in the model's budgeted MW expense.

Discussion - Because of the relatively minor amount of depreciable road assets, ignoring the cash sup-

TABLE D-3 (continued)

18b) RETIREMENTS OF ROAD ASSETS (continued)

Discussion - plied by their disposals should not be a serious simplification. However, the model's failure to deal with network rationalization in cases of declining volumes tends to make their financial implications somewhat worse than they actually might be. Specifically, a major source of funds (sale of road assets) is ignored, so net working capital most likely is lower in the model than it otherwise would be.

Text - pp. 119-121, 175-179

19) REVENUES

19a) FREIGHT REVENUES AND RATES, TREATMENT OF

Statement - Freight "rates" in the model are represented by average revenue per ton-mile, consistent with the model's aggregate measurement of demand and the assumed fixed traffic mix.

Discussion - Given the manner in which demand (and volume) is measured, this is the easiest and most logical method of representing freight rates, and hence revenues.

Text - pp. 112

TABLE D-3 (continued)

19b) OTHER REVENUES, TREATMENT OF

- Statement - Passenger, mail, express, and other revenues are treated as an exogenously supplied value.
- Discussion - The model is concerned with freight operations, and no attempt is made to deal with the mechanisms generating these relatively small revenues.
- Text - pp. 111

20) WEAR AND TEAR, TREATMENT OF

- Statement - Wear and Tear in the model represents the assumed annual expenditures (maintenance plus investment) required to keep quality constant. Wear and Tear is a function of gross ton-mileage and quality in the model, with train speed effects inherent in the quality effects. Wear and tear plays an important role in the determination of budgeted maintenance and investment in way, and is assumed to be known in advance when budgeting is occurring for any time period (i.e., financial quarter).
- Discussion - The concept of wear and tear is an important one, as many components of the model depend upon it. The actual function used to determine wear and tear is of course optional. Treatment of wear and tear as known in advance is unrealistic, but has only minor impacts on the model's outputs.
- Text - pp. 207-216, 232

TABLE D-4

OPTIONAL SIMPLIFICATIONS AND ASSUMPTIONS

<u>SIMPLIFICATION/ASSUMPTION</u>	<u>LOCATION IN TEXT</u>	<u>EXPECTED SENSITIVITY OF MODEL OUTPUTS</u>
1) Allocation of funds process & priorities of various uses	pp. 141-156	major
2) Costs (operating costs):		
2a) Linearity of functions	pp. 91-101, 210-216, 242-249	minor
2b) ME expense:		
Future course of ME material/labor ratio	pp. 99-100, 333	moderate
Future course of ME unit labor cost	pp. 333	moderate
Future course of ME unit material cost	pp. 333	moderate
Total Variability of ME labor costs	pp. 101, 242-249	minor
Total Variability of ME material costs	pp. 97, 242-249	minor

TABLE D-4 (Continued)

<u>SIMPLIFICATION/ASSUMPTION</u>	<u>LOCATION IN TEXT</u>	<u>EXPECTED SENSITIVITY OF MODEL OUTPUTS</u>
2) Costs (operating costs) (continued):		
2c) MW expense:		
Desired MW	pp. 102-106, 234-236, 390-393	depends upon fraction of expenditures classified as maintenance
Fraction of expenditures classified as maintenance	pp. 232-235	major
Future course of MW + IW material/labor ratio	pp. 204-206, 333	moderate
Future course of MW + IW unit labor cost	pp. 333	moderate
Future course of MW + IW unit material cost	pp. 333	moderate
Maximum affordable MW	pp. 102-106	
Minimum feasible MW	pp. 102-107, 231-234, 335	{ depends upon fraction of expenditures classified as maintenance
MW budgeting process	pp. 101-107	
2d) Passenger expense (values assigned)	pp. 107-108, 334	minor

TABLE D-4 (Continued)

<u>SIMPLIFICATION/ASSUMPTION</u>	<u>LOCATION IN TEXT</u>	<u>EXPECTED SENSITIVITY OF MODEL OUTPUTS</u>
2) Costs (operating costs) (continued):		
2e) Rental expense (values assigned)	pp. 107-111, 334	minor
2f) State and local taxes (values assigned)	pp. 107-109, 334	minor
2g) TTGM expenses:		
Fuel treated as diesel oil	pp. 93-94	minor
Future course of TTGM labor productivity	pp. 90-91, 332	major
Future course of TTGM unit fuel cost	pp. 333	moderate
Future course of TTGM unit labor cost	pp. 332-333	major
Future course of TTGM unit "other" costs	pp. 333	moderate

TABLE D-4 (Continued)

<u>SIMPLIFICATION/ASSUMPTION</u>	<u>LOCATION IN TEXT</u>	<u>EXPECTED SENSITIVITY OF MODEL OUTPUTS</u>
2) Costs (operating costs) (continued):		
2g) TTGM expenses (continued):		
Total variability of TTGM labor costs	pp. 91-92, 242-249	minor
Total variability of TTGM "other" costs	pp. 95, 242-249	minor
3) Debt:		
3a) Availability	pp. 186-190	major
3b) Interest rate	pp. 182, 338	moderate
3c) Repayment rule	pp. 181, 183	moderate
4) Demand:		
4a) Equal to volumes observed over 1963-1973	pp. 280, 282	minor
4b) Growth rate	pp. 281-282, 337	major

TABLE D-4 (Continued)

<u>SIMPLIFICATION/ASSUMPTION</u>	<u>LOCATION IN TEXT</u>	<u>EXPECTED SENSITIVITY OF MODEL OUTPUTS</u>
5) Dividend policy	pp. 133-135, 335	moderate
6) Expenditures on way and structures:		
6a) Desired	pp. 234-236, 390-393	major
6b) Minimum	pp. 231-234	major
7) Income tax rate	pp. 114, 335	minor
8) Interest rate on short-term investments	pp. 123	moderate/minor
9) Investments:		
9a) Other equipment (values assigned)	pp. 136	minor
9b) Rolling stock:		
Car to locomotive ratio	pp. 270-272, 338-339	moderate
Forecasting parameters	pp. 265-269	moderate
Future course of equipment prices	pp. 333	moderate

TABLE D-4 (Continued)

<u>SIMPLIFICATION/ASSUMPTION</u>	<u>LOCATION IN TEXT</u>	<u>EXPECTED SENSITIVITY OF MODEL OUTPUTS</u>
9) Investments (continued):		
9b) Rolling stock (continued):		
Necessary cash expenditures	pp. 142-145, 336-337	major
Volume growth policy	pp. 264, 337-338	major
9c) Way and Structures:*		
Desired IW	pp. 136, 234-236, 390-393	depends upon percentage of expenditures classified as investments
Minimum IW	pp. 136, 145-146, 231-234, 336	
10) Liquidity policy:		
10a) Desired addition to net working capital	pp. 139-140	moderate/minor (depends upon priority given to liquidity)
10b) Desired net working capital	pp. 137-139	
11) Other income (values computed)	pp. 111-112, 123, 334	minor

*Also see 2c) MW expense

TABLE D-4 (continued)

<u>SIMPLIFICATION/ASSUMPTION</u>	<u>LOCATION IN TEXT</u>	<u>EXPECTED SENSITIVITY OF MODEL OUTPUTS</u>
12) Productivities and capacities of freight car and locomotion fleets	pp. 282-289, 338-339	moderate
13) Quality of fixed facilities		
13a) Effects on costs and productivities:		
Not accounted for in calibration	pp. 88, 219-221, 228	minor
Numerical values	pp. 221-230, 325-330	major
Shape of relationships	pp. 221-224, 228-229	minor
13b) Initial value	pp. 201-202	minor
14) Rented rolling stock (amount)	pp. 257, 334	minor
15) Retirements of assets (equipment):		
15a) Average lives	pp. 170-173	minor
15b) Fractions of value lost	pp. 166, 173	minor

TABLE D-4 (Continued)

<u>SIMPLIFICATION/ASSUMPTION</u>	<u>LOCATION IN TEXT</u>	<u>EXPECTED SENSITIVITY OF MODEL OUTPUTS</u>
16) Revenues:		
16a) Freight revenues and rates (values assigned)	pp. 112, 338	major
16b) Other revenues (values assigned)	pp. 111, 334	minor
17) Wear and tear:		
17a) Functional form	pp. 210-216, 242-249	moderate
17b) Numerical values	pp. 212-216	major