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A METHODOLOGY FOR EVALUATING THE ECONOMIC IMPACTS OF APPLYING RAILROAD SAFETY STANDARDS

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FINAL REPORT

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16. Abstract

This report presents a methodology for evaluating the economic impacts of applying railroad safety standards. The scope is considered broad enough to permit evaluation of all the safety standards thus far proposed by the Federal Railroad Administration and to allow for detailed analysis of individual equipment, track, and human factors standards. At the same time, the details and examples are fairly specific in order to present insight into the techniques and problems which might be encountered.

In addition to treatment of the elements involved in impact analysis, discussions are given of other aspects of the methodology such as the proper analysis time span, the effects of inflation and interest rates, quantification problems and the role of sensitivity analysis. Special attention is given to accidents and accident prediction and also to data availability and data acquisition. An example is given of the use of the methodology using the safety standards addressed to plain bearings on freight cars.

Volume 2 of this report is the manual whose step-by-step procedures are intended for the implementation of economic impact analysis.

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Union railroads and the information provided by them on accident costs and the economic impacts of safety standards. In addition, Southern and N&W provided extensive data and analyses on bearing overheatings and failures. The Chessie System, the Canadian National and Canadian Pacific also contributed relevant bearing data.

Additional input was obtained from numerous interviews with rail suppliers, the National Safety Council, the National Transportation Safety Board, the National Highway Traffic Safety Administration, the Brotherhood of Locomotive Engineers, and the United Transportation Union, and the results of these interviews have been taken into account in formulating our recommendations.

Special appreciation is due Mr. Richard Crisafulli of the FRA Office of Policy and Plans for his guidance and helpful suggestions throughout the contract. We are also grateful for the helpful comments and constructive criticism of Messrs. Rolf Mowatt-Larssen and John McNally of the Office of Safety.

The research documented in this report is largely the outgrowth of the dramatic rise in railroad accidents in the late 1960's which focused public attention strongly on railroad safety and generated pressure for corrective legislation. Congress responded to this situation by passing the Railroad Safety Act of 1970, which provided the Federal Railroad Administration with a clear mandate to improve railroad safety. The FRA has a continuing concern that safety standards applied to the railroad industry be cost effective and fully justified. Although cost-effectiveness should be a basic characteristic of any safety standard, it is especially important in railroad applications because of the weakened financial condition of much of the industry.

The methodology presented in this report will facilitate FRA's assessment of the cost-effectiveness of the safety standards being developed by the administration.

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EXECUTIVE SUMMARY

This report presents a methodology for evaluating the economic impacts of railroad safety standards. The scope is considered broad enough to permit evaluation of all the safety standards thus far proposed by the Federal Railroad Administration and to allow for detailed analysis of individual equipment, track and other standards. At the same time, the details and examples are fairly specific in order to present insight into the techniques and problems which might be encountered. Although pertinent conceptual issues are discussed, this report is not intended as an exhaustive treatise on economic analysis. Neither is it a substitute for the cost-effectiveness manual* which is specifically designed as a step-by-step aid in performing impact analyses.

An overview of the methodology is presented in Section 1.2 with a summary in flow chart form in Figure 1. From a priority list of safety-related problems, a standard, or set of standards, is selected. From available data sources, information is extracted to provide cost and benefit values for railroads and for society at large.

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*Economic Impact Manual for Railroad Safety Standards, prepared for the Federal Railroad Administration under Contract No. DOT-FR-20057, December 1974.

Major railroad costs are due to inspections, maintenance and replacements. Two important considerations, somewhat interrelated, are industry condition relative to the proposed standard and the manner and extent of railroad compliance with the standard. Other costs, such as record keeping and decreased utilization, must be included in the total compliance costs. Societal costs are the direct and indirect costs of safety standards not borne by the railroad industry. A sample list of such costs includes the safety standard development and implementation costs and increased shipper costs from lack of cars.

Since reduction of accidents is the principal benefit resulting from the promulgation of safety standards, a large part of the labor in this type of impact analysis is in obtaining and processing accident data. It is essential to determine the type and frequency of accidents which will be reduced by the establishment of a particular standard, and to develop accident probabilities for use in forecasting future accident numbers. Pertinent information includes a 15-year projection of "prevented" accidents and also data on accident costs. Prevented accidents represent benefits both to the railroad industry and to society at large.

In addition to general and detailed treatment of the above elements of analysis, discussions are given of other aspects of the methodology such as the proper analysis time span, the effects of inflation and interest rates, quantification problems and the role of sensitivity analysis.

Any economic impact analysis is oriented around data availability which is a key consideration. All the costs and cost trends as well as the present industry condition come from the data base. Probabilities, which play a major role in this type of analysis, are also derived from the data base. Section 4.0 of this report discusses data deficiencies and problems and makes specific recommendations to remedy problems in this general area. Table 10 summarizes the more serious data deficiencies, in terms of availability to Federal Railroad Administration personnel, along with recommendations for correcting or bypassing these deficiencies.

Some deficiencies, on freight car component failure, for example, exist because that information has not been collected on the FRA reporting form. The remedy is fairly simple. Similarly, the inclusion of car and locomotive days lost on the reporting form would provide lost utilization cost data in a simple manner. However, carriers are very reluctant to provide other types of information such as court case awards for personal injuries. For this information, court record perusals and estimation procedures must be used.

Other problems are discussed, such as the reporting threshold, which confuses year to year comparisons and credibility, when the railroads are asked to report their own violations.

If all of the data requirements for conducting a cost-effectiveness analysis of safety standards were met, the actual calculations could be performed in a simple, straight-forward manner with a minimum expenditure of time and manpower. Thus, the cost of conducting cost-effectiveness analysis is directly related to the data available for making the basic calculations. Little of the necessary data is immediately available and substantial additional data development is necessary in order to perform a complete analysis. The Federal Railroad Administration (FRA) does have the authority to correct most of the data gaps through revisions in the accident reporting system. We recommend that this authority be exercised, not just to provide information for cost-effectiveness analysis, but to provide the basic data necessary to quantify what railroad safety really means to the railroad industry and to the country as a whole.

A test of the cost-effectiveness methodology is performed in Section 5.0, using those standards addressed to plain bearings on freight cars. The result was that strict enforcement of the standards would not be cost effective. The implications of this result are discussed in Section 5.11.

Although part of the cost-effectiveness is due to increased inspection and replacement costs, another more subtle factor is also contributory. This is the infant mortality phenomenon, that is, the relatively high failure rate of new installations. Strict adherence to the above safety standard requires more frequent repacking and replacement of hardware, which increases infant mortalities.

Courses of action are discussed in Section 5.11, ranging from procedures to alleviate infant failures to accelerated conversion of plain friction bearings to roller bearings. Also recommended is more research into the basic causes of bearing failures and earlier detection of bearings in distressed condition.

In developing this report, a high priority was placed on presenting workable procedures that can be used immediately for economic impact evaluation. However, any attempt to reduce decision making, in the area of railroad safety standards, to a cookbook procedure based on economic efficiency is ill advised. Conversely, any decision making in the absence of adequate economic information, is irresponsible. The net cost of a project expressed as a single dollar value (or, more realistically, as a probable range of values) is only one of the decision making tools. Although it is a major tool, it omits two important ingredients, unquantifable costs and benefits such as human values, and exogenous considerations such as political and social feasibility, organizational constraints and timing. Furthermore, a single measure, such as net cost, masks inequities in the sometimes large redistributions of wealth which occur under a program. These incidence effects such as civil penalties, for example, are chronically neglected in economic analyses on the tacit assumption that any maldistribution can be rectified ex post facto. Often a redistribution cannot be done in a practical way.

In light of the above considerations, economic analysis is seen to have limitations. It is entirely proper that certain ingredients can be omitted. Cost-effectiveness is a powerful and indispensable tool for decision making on public projects. It is neither more nor less than that.

1.0 INTRODUCTION

The following report discusses a methodology for evaluating the economic impacts of railroad safety standards and summarizes the results of work completed in Task I of RFP-DOT-FR-20047 and the subsequent updating and validating of this work. This report is presented to assist in understanding the basic methodological steps involved and to summarize the conceptual issues encountered in performing cost-effectiveness analysis. It is not intended to be an exhaustive treatise of the subject nor as a replacement for the cost-effectiveness manual for use and application by the Federal Railroad Administration (FRA), and which is bound separately. The methodology outlined here is considered broad enough to permit evaluation of all the safety standards thus far proposed by FRA, and will allow for detailed analysis of specific equipment, track and human factors standards.

In developing the recommended procedures, CONSAD sought, through its field interviews, to solicit suggestions which would improve the workability and comprehensiveness of the methodology to be employed. In this regard, we are particularly grateful for the assistance provided by the Association of American Railroads (AAR), and for the cooperation and guidance provided by members of the FRA staff and individual railroads. We would like to acknowledge, in particular, the helpful suggestions made by the Frisco, Illinois Central Gulf, Norfolk and Western, Southern, Penn Central, Southern Pacific, Canadian National, Canadian Pacific, Western Pacific and Union railroads, and the information provided by them on accident costs and the economic impacts of safety standards.

Additional input was obtained from numerous interviews with rail suppliers, the National Safety Council, the National Transportation Safety Board, the National Highway Traffic Safety Administration, the Brotherhood of Locomotive Engineers, and the United Transportation Union, and the results of these interviews have been taken into account in formulating our recommendations.

In the development of this methodoloy, considerable importance was placed on constructing workable procedures that could be used immediately by FRA in determining the economic implications of the new safety standards, and which would be generally accepted by the railroad industry. Of the criteria used to evaluate alternate approaches, greater emphasis was placed on data availability and the general workability of the methods being recommended.

An important part of any economic analysis is the data base. Probabilities, which play a major role in this type of analysis, are derived from the data base. Also all the costs and cost trends as well as the present industry condition come from the data base. However, two problems are usually associated with data: acquisition and allocation. In many cases, it is difficult to obtain data at all, let alone up-to-date, consistent and compatible data. And even with the best of data, there is the considerable problem of allocating the appropriate portions to the safety standard being addressed. For example, some plain journal bearing data included Canadian equipment, some did not. Some information, such as the percent of freight cars which are stabilized, is practically non-existent. Allocation is illustrated by the periodic inspection standards. Obviously, not all the inspection costs can be allocated to bearings because all the other parts of the suspension and draft system are inspected at the same time.

A problem peculiar to failures and accidents is that of withheld or altered information. For example, the probability of failure of a bearing versus months after repack depends upon the number of actual failures and the number of cars of that repack age. Since overdate cars are operating illegally, there is an understandable reluctance to report their true age. This understatement of the number of overdate cars exaggerates the derived probability of failure.

The crucial point in judging any method is, of course, its fitness in solving the problem it addresses. In economic analysis, there is no single generally-accepted procedure to follow, since in practically every analysis, procedures must be tailor-made to fit the particular circumstances. Thus, the procedures outlined in the following report have been tailor-made for FRA's application to safety standards and incorporate considerations of data availability, application costs, and potential impacts on the railroad industry and the general public.

Implicit in their design is the recognition that any economic impact analysis performed by FRA, which subsequently leads to the promulgation of a safety standard, would of necessity be subject to review by members of Congress, the railroad industry, railroad labor organizations, and other interested groups.

This report is organized into five sections. Section 2.0 and Section 3.0 treat the economic impact methodology, the former in overview fashion, the latter in detail. Section 4.0 discusses data deficiencies and problems and provides specific recommendations to remedy problems in this general area. The cost-effectiveness methodology is tested in Section 5.0 by examining the impact of the new safety standards which cover plain journal bearings. Background material is included in the appendices.

2.0 ECONOMIC IMPACT METHODOLOGY: OVERVIEW

This section presents an overview of the recommended methodology for assessing the economic impact of railroad safety standards. Flow charts, which are implementation-oriented, are given for each facet of required analysis. All of the material in this section is discussed in detail in Section 3.0.

The overview summary is presented in Figure 1. From a priority list of safety-related problems, a standard, or set of standards, is selected. From available data sources, information is extracted to provide cost and benefit values for railroads and for society at large. A problem with benefits (and to some extent, with costs) is that dollar values cannot, or should not, be assigned to all types of benefits. For example, it is difficult to put a dollar value on, say, a benefit of 35 lives saved per year. Furthermore, there are types of benefits that are difficult even to quantify, let alone evaluate in dollar units. Some examples of these are the alleviation of bereavement, increased feelings of security, and the increased reliability of shipping.

After benefits and costs have been calculated, quantified and evaluated (in dollar units) as far as is feasible, it is necessary to separate out initial costs (benefits) and ongoing costs (benefits). Any dollar amounts which occur in any year other than the analysis year (that is, the year chosen for comparison of all dollar amounts) must be discounted (or brought forward) to the analysis year. Only then can all dollar amounts be summed.

The results are presented as a package which includes the net (discounted) cost, a list of quantifiable benefits and a list of intangibles, along with qualifying and descriptive comments to provide the basis for the ultimate acceptance or rejection of the subject safety standard.

Data sources and procedures for railroad industry costs are given in Figure 2. The major costs are due to inspections and replacements. An important consideration is the manner and extent of industry compliance with both inspection and replacement regulations. Railroads, especially those in deep financial trouble, are highly motivated to ignore or move slowly in compliance with costly standards. If there are penalties for non-compliance, the railroads will tend to minimize the sum of compliance costs and penalties.

Another important consideration is the condition of the industry relative to the proposed safety standard. This information, along with upgrading-cost data will determine the part replacement compliance costs to railroads. Other costs, such as record keeping and decreased utilization, must be included in the total compliance costs.

Societal costs are the direct and indirect costs of safety standards not borne by the railroad industry. A sample list of such costs, shown in Figure 3, includes the safety standard development and implementation costs and increased shipper costs from lack of cars.

A large part of the labor in assessing the impact of safety standards is in obtaining and processing accident data. Since reduction of accidents is the principal benefit resulting from the promulgation of safety standards, it is essential to determine the type and frequency of accidents which will be reduced by the establishment of a particular standard. The flow chart presented in Figure 4 illustrates the steps involved in matching up the standards with the accidents addressed by that standard, together with the procedures involved in forecasting future accident rates. Pertinent information includes a 15-year projection of "prevented" accidents and also data on accident costs. Prevented accidents represent benefits both to the railroad industry and to society at large.

An important by-product of any analysis of accidents is an assessment of data deficiencies. Since there is probably no better way to discover these deficiencies, it is important to document them along with recommendations for improvement. This output is indicated by the box midway through Figure 4.

The methodology for calculating benefits accruing to the railroad industry and to society at large is flow charted in Figures 5 and 6. The principal railroad benefit is reduced costs because of accident reductions. The principal societal benefits are the avoidance of those accident costs (because of a reduction in accidents) which are not paid for directly by the railroads.

Different techniques are needed for initial and ongoing costs and benefits, as illustrated in Figures 7 and 8. However the railroads finance their compliance expenditures, the initial year or years will probably differ from succeeding years with respect to amounts and methods. Societal costs, similarly, will be characterized by initial program implementation expenses and ongoing monitoring and administration expenses.

The distinction between immediate and ongoing benefits is even more difficult to draw than for costs, but it is safe to assume that all benefits will not begin to be received immediately after implementation of the safety standards. Inspection of a large portion of the track and of the freight car fleet will have to occur, and then some portion of the replacement and repair will be necessary, before benefits are felt. If the implementation of equipment standards takes about two years, as has the implementation of the track standards, it is reasonable to assume that much of the benefit will be appearing at the end of the second year, and all of these benefits will have reached a stable level by the end of the fourth year.

FIGURE 1: Cost-Effectiveness Methodology: Overview of Basic Steps

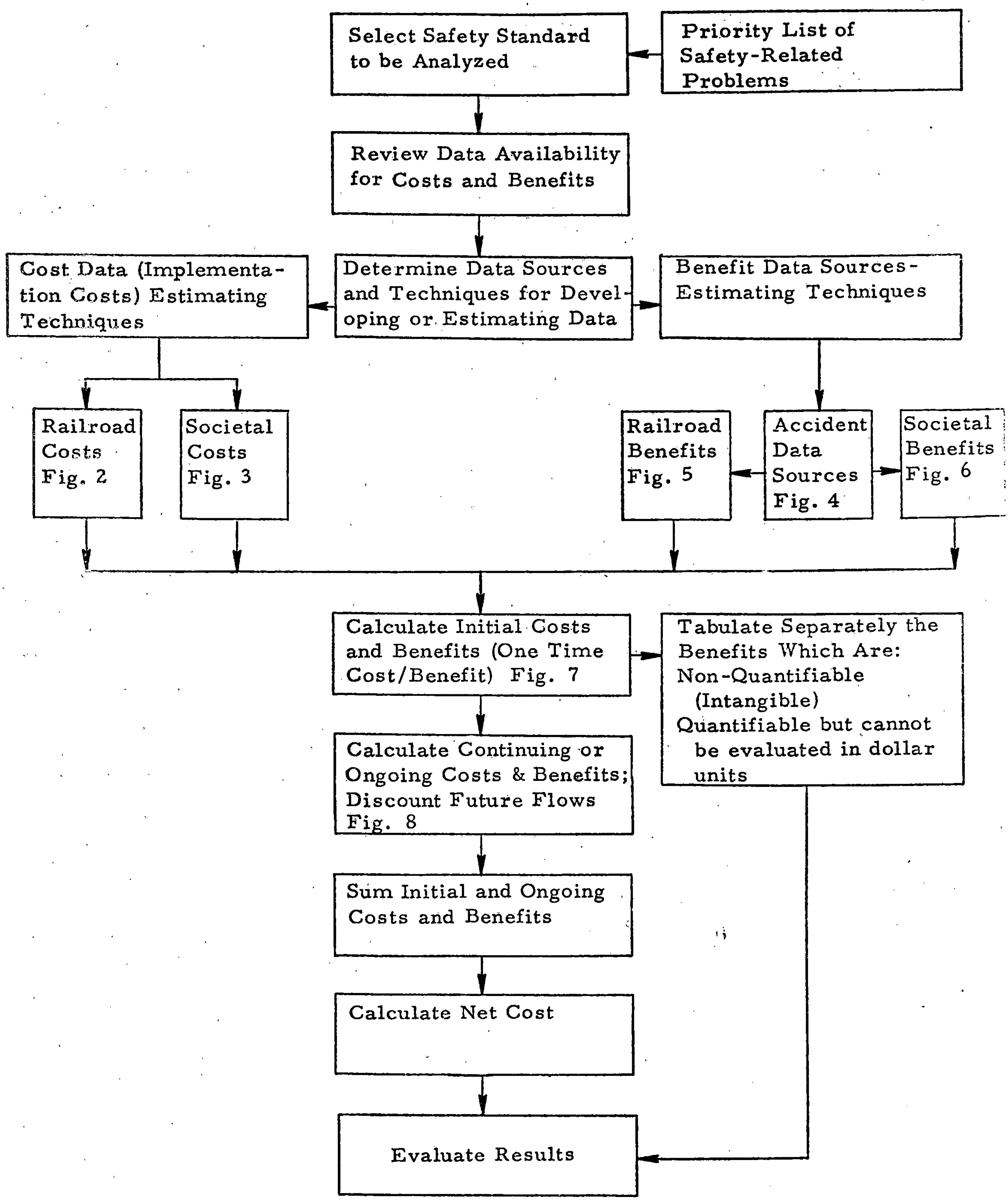


FIGURE 2
Flow Chart for Cost-Effectiveness Methodology: Railroad Costs

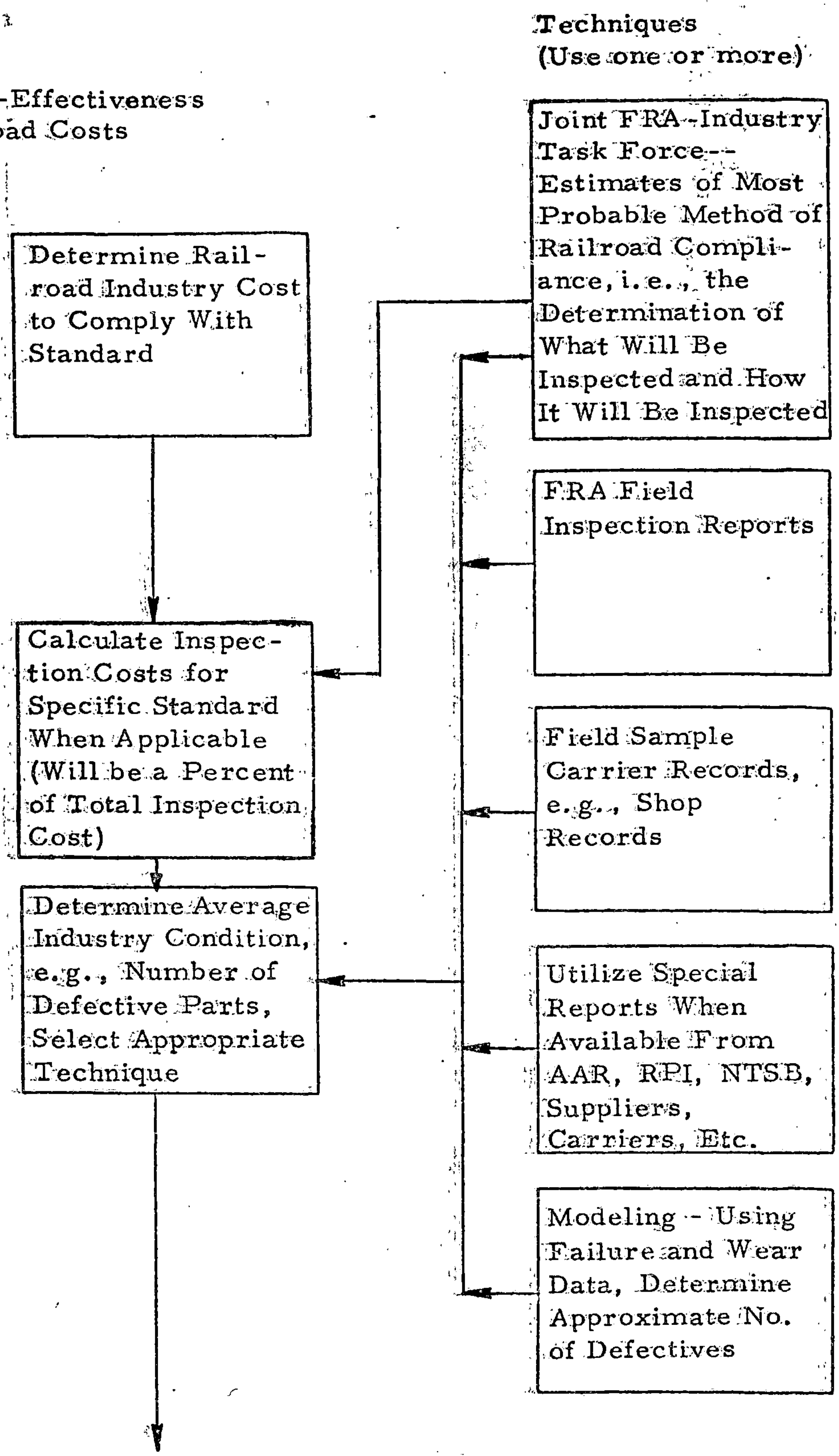


FIGURE 2 (continued)

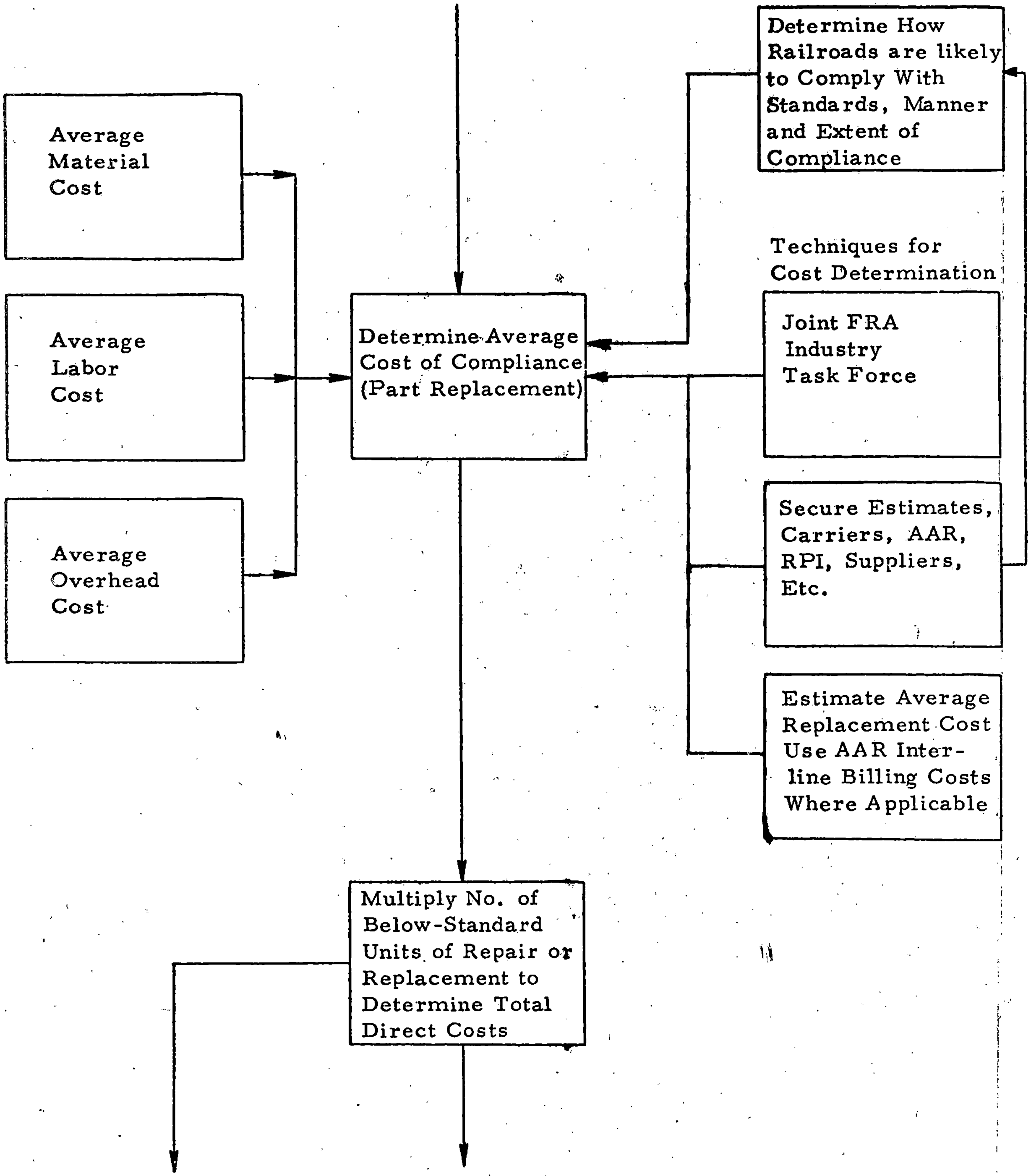
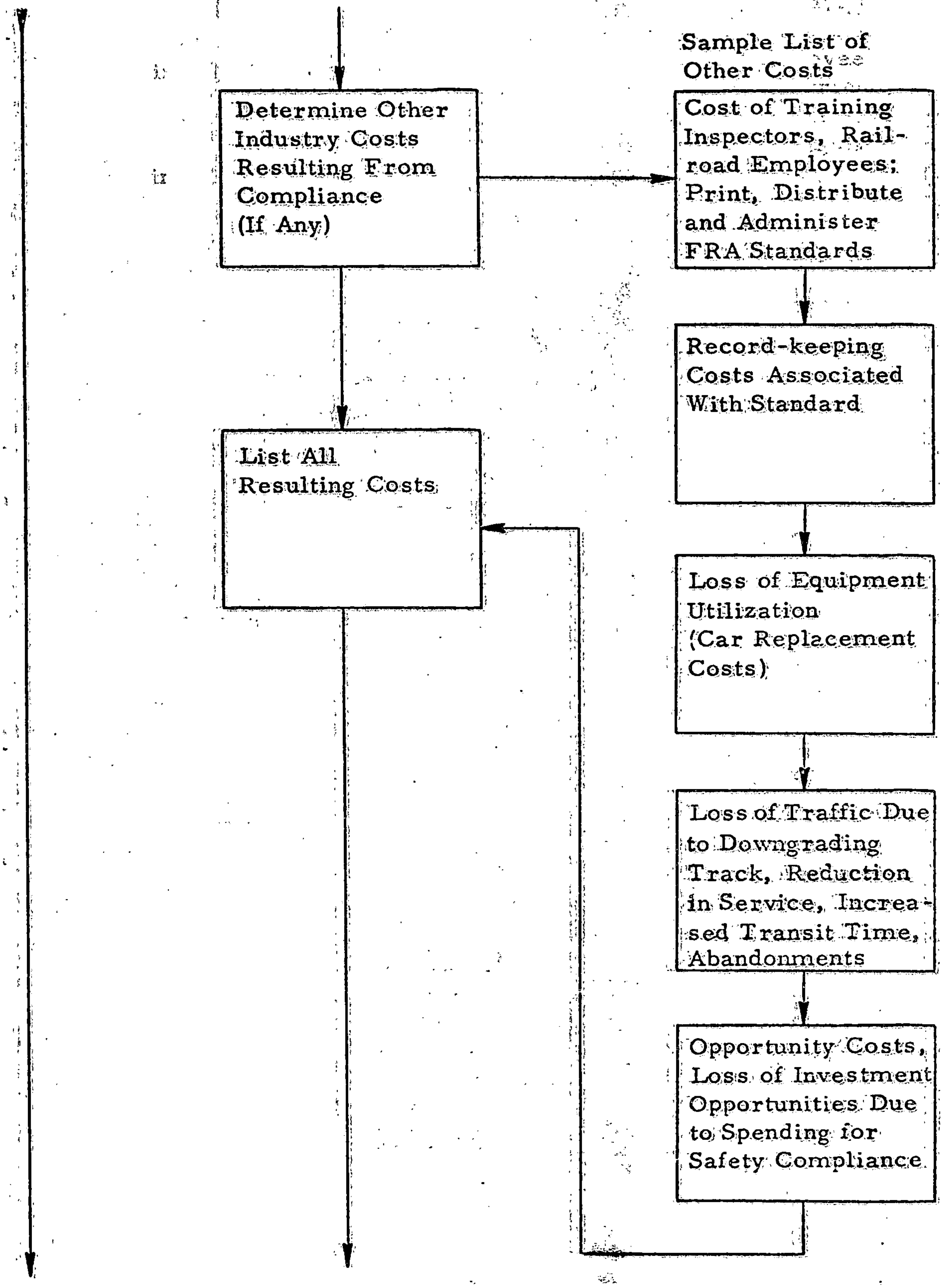


FIGURE 2 (continued)



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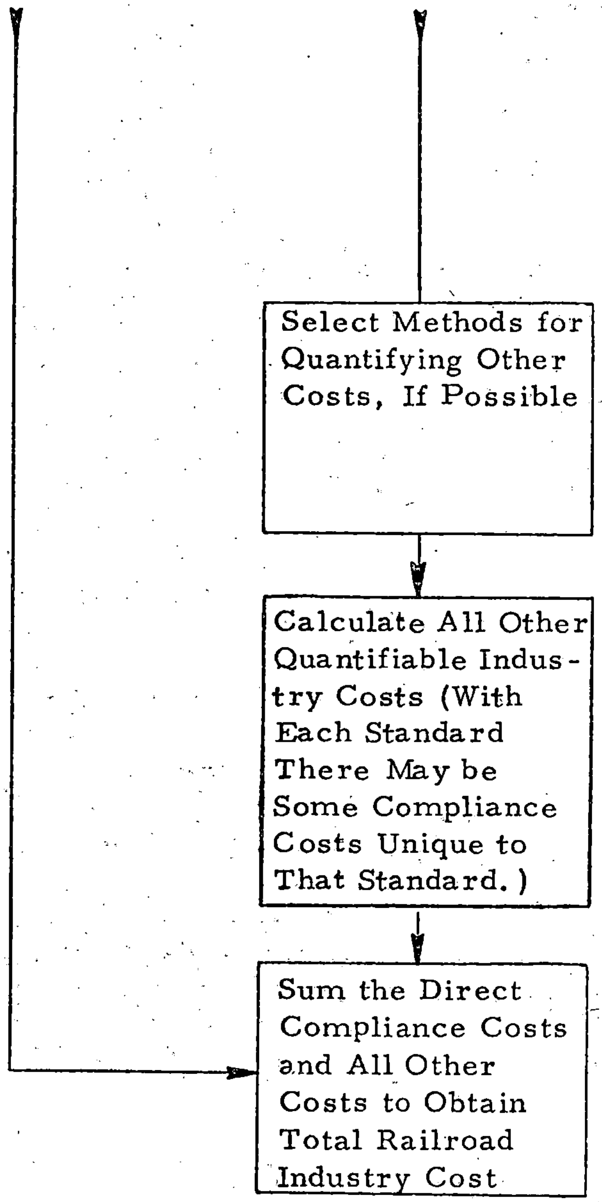


FIGURE 3
Flow Chart for Cost-Effectiveness
Methodology: Societal Costs

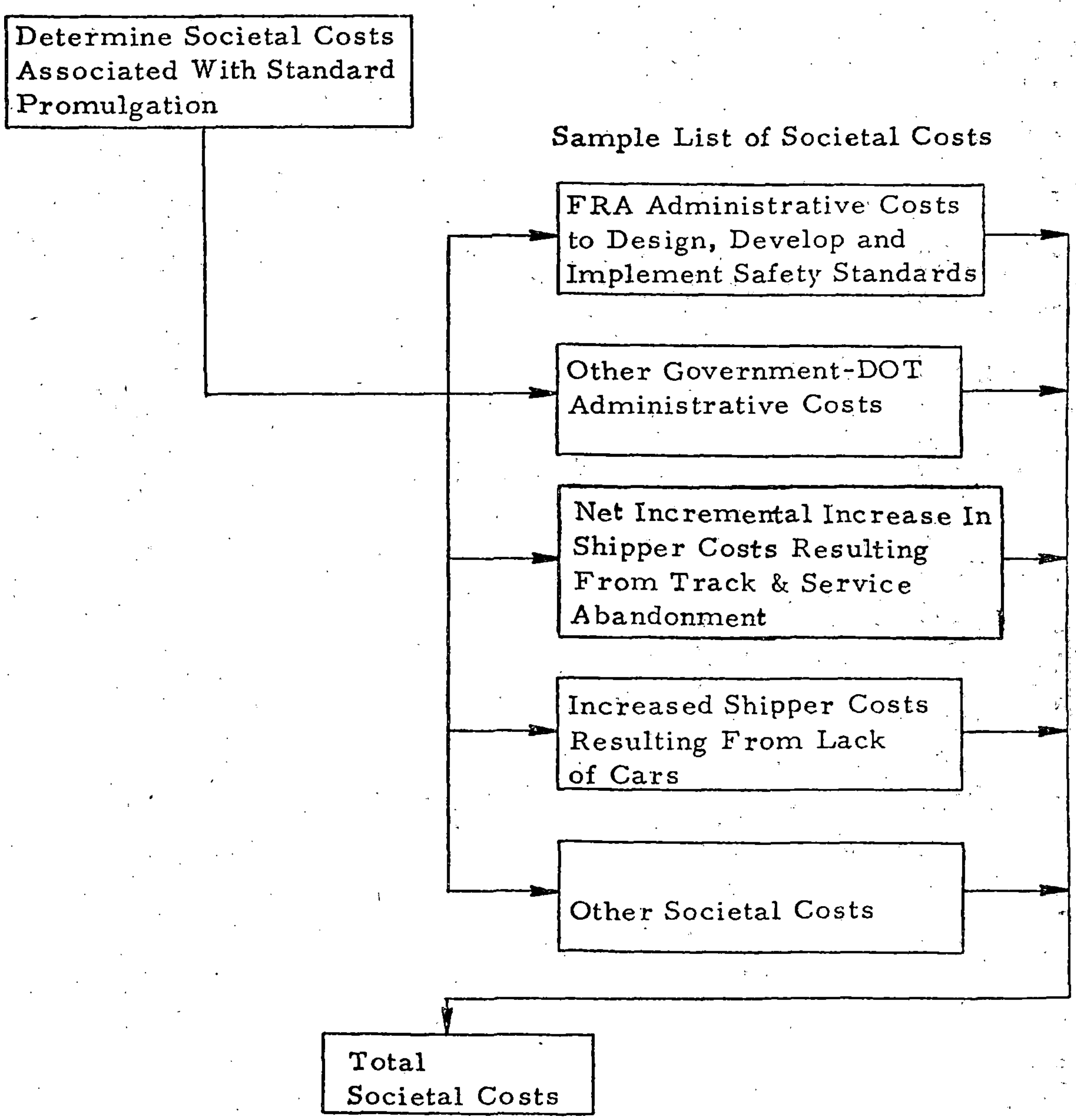


FIGURE 4
Flow Chart for Cost-Effectiveness Methodology: Accidents

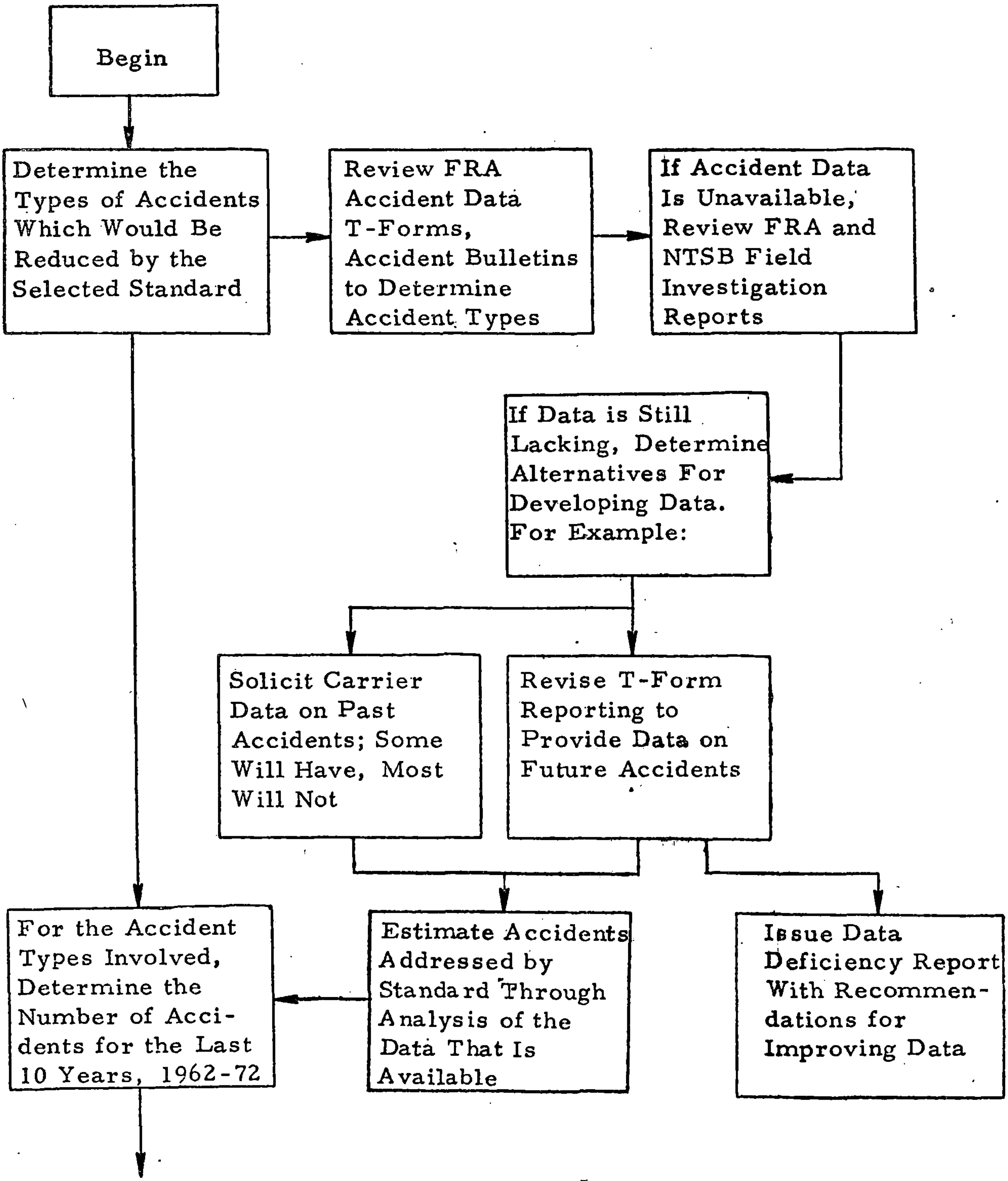


FIGURE 4 (continued)

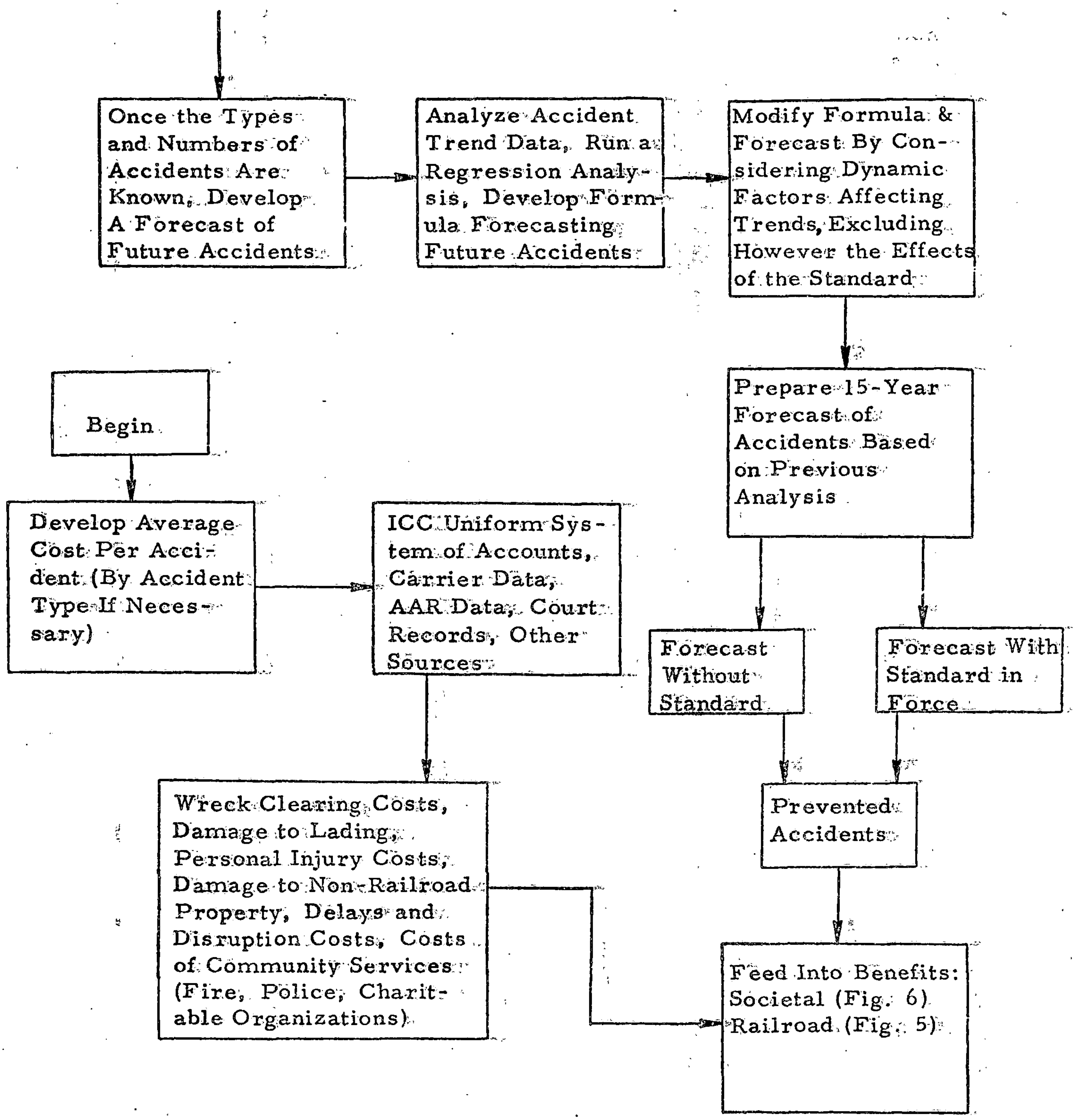


FIGURE 5
Flow Chart of Cost-Effectiveness
Methodology: Railroad Benefits

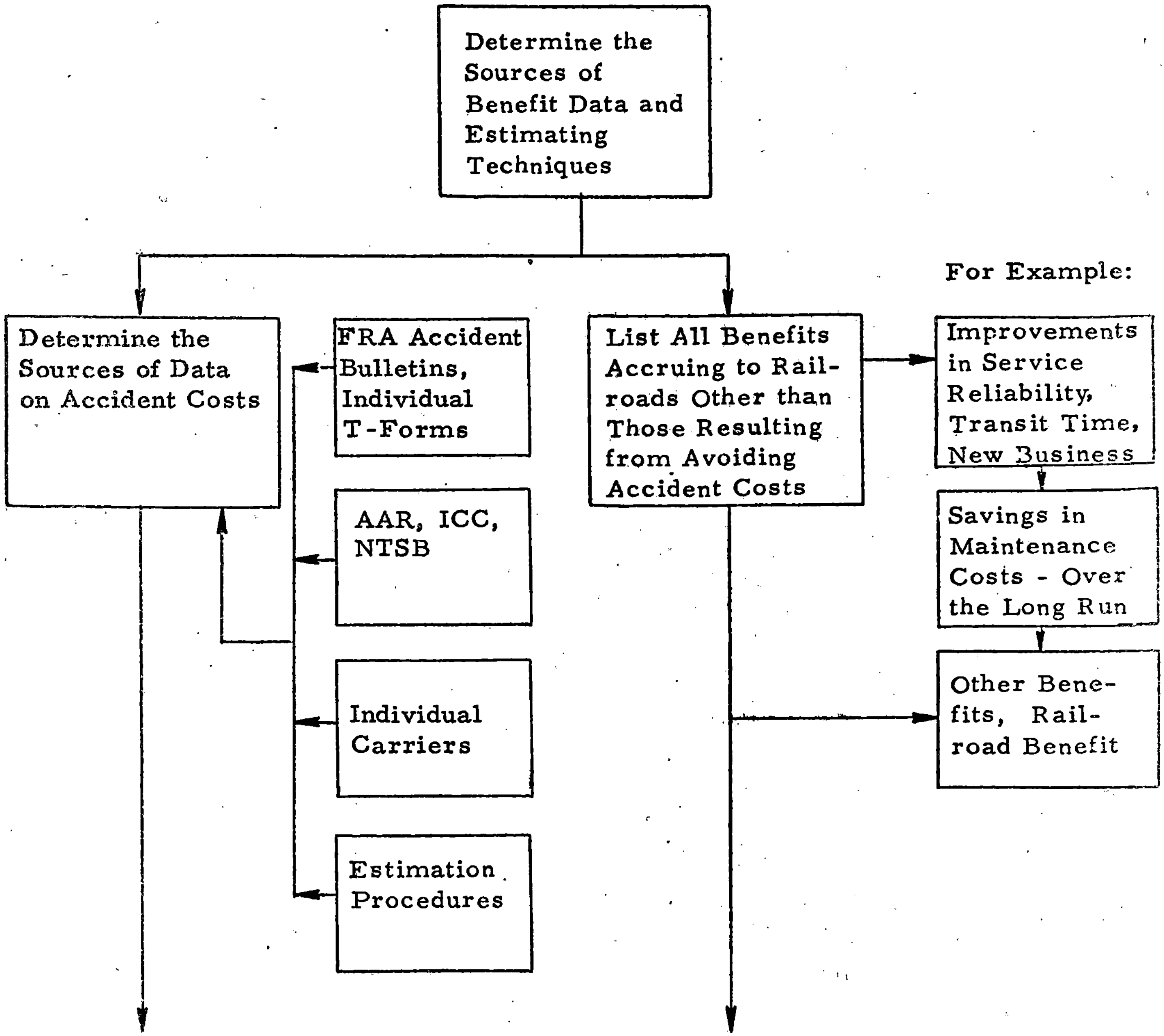
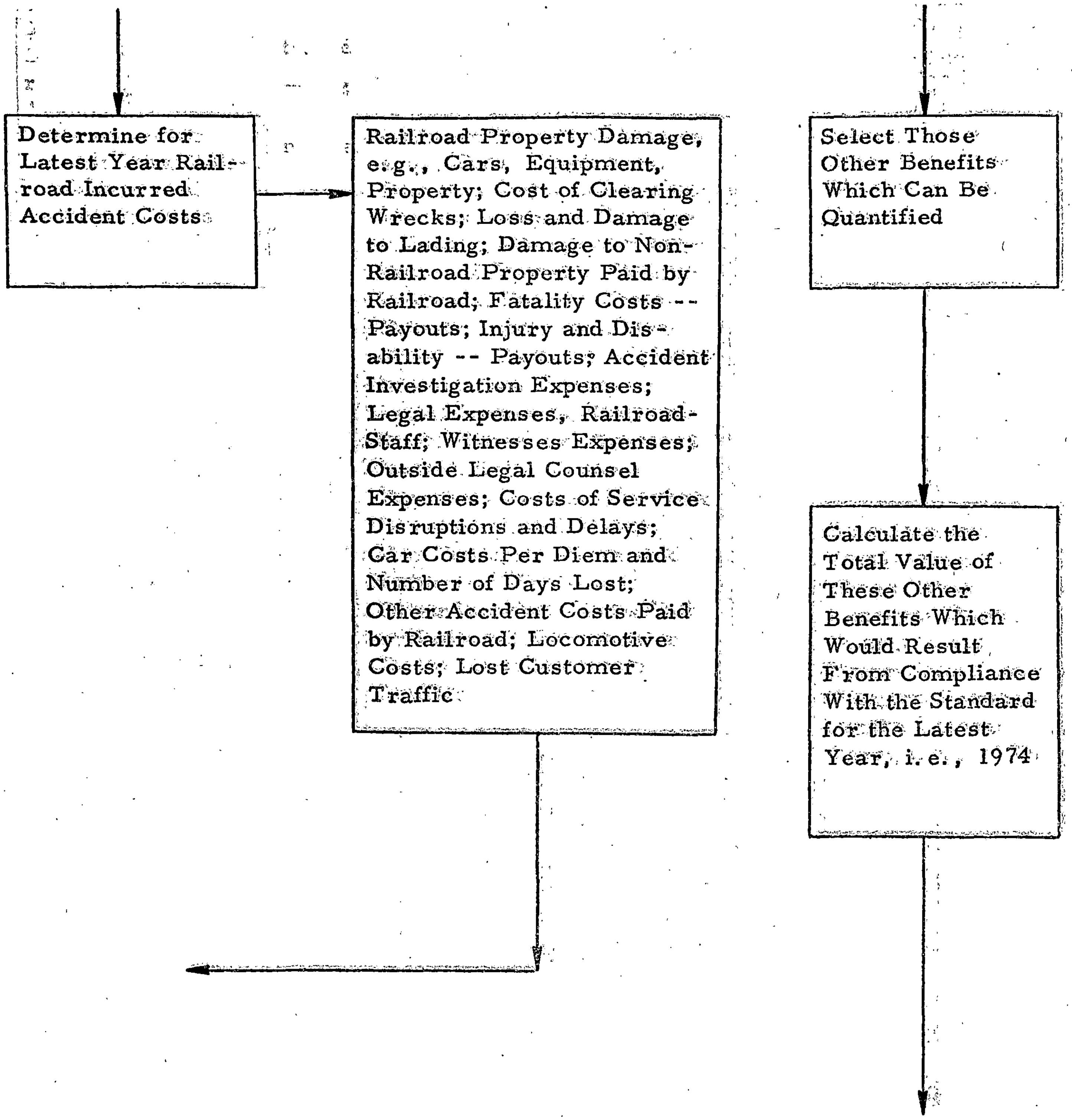


FIGURE 5 (continued)



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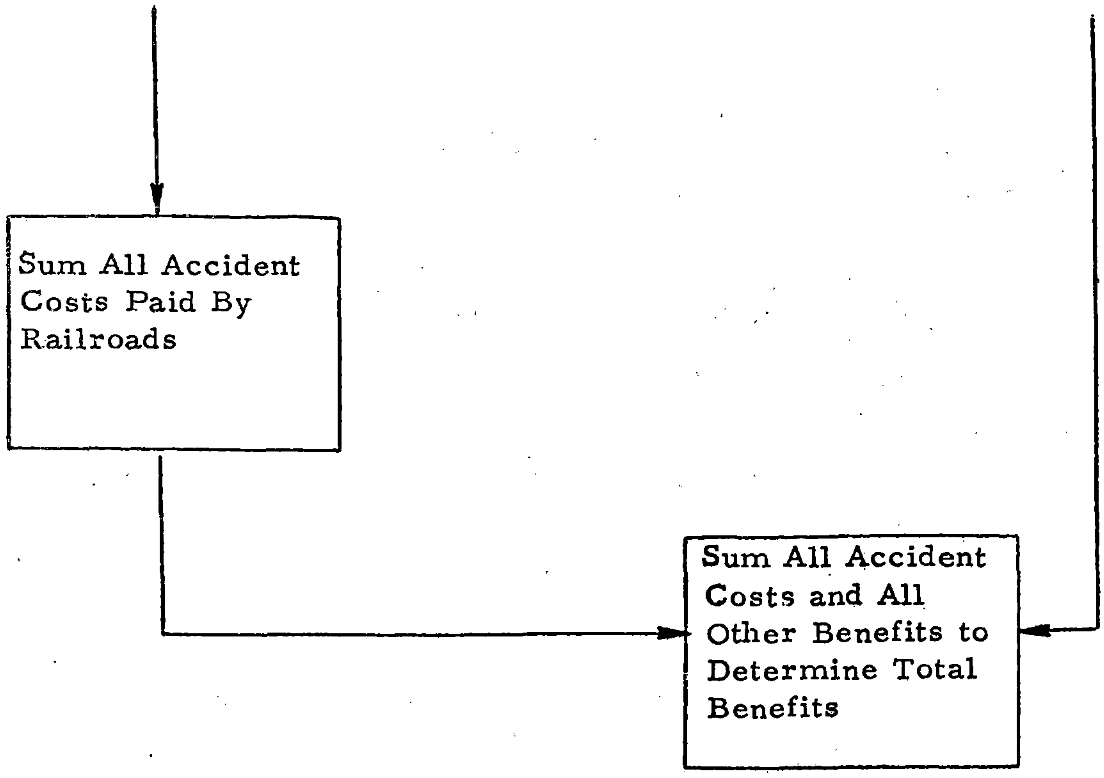


FIGURE 6
Flow Chart for Cost-Effectiveness Methodology: Societal Benefits

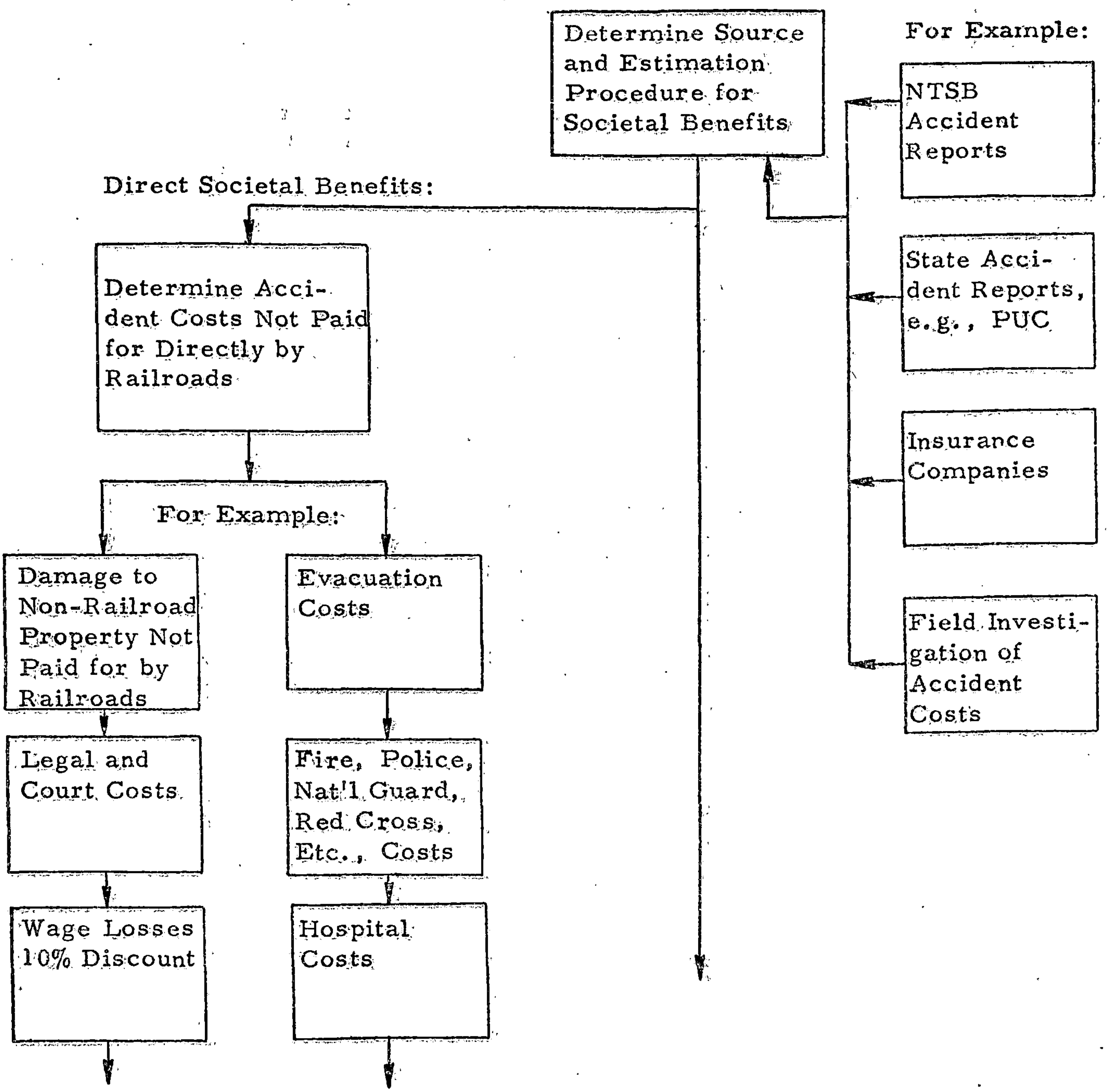


FIGURE 6 (continued)

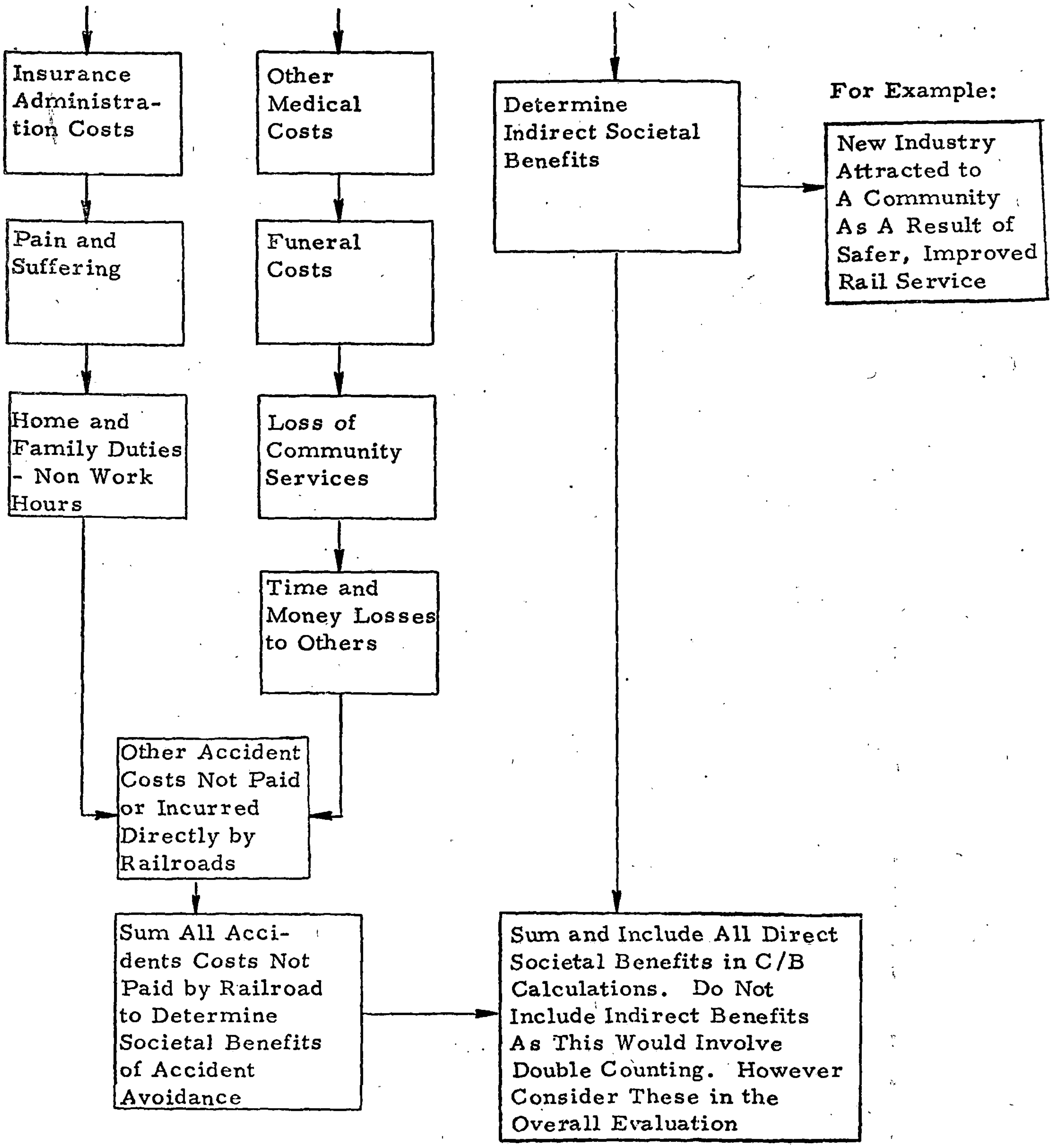


FIGURE 7
Flow Diagram for Calculating Initial Costs and Benefits

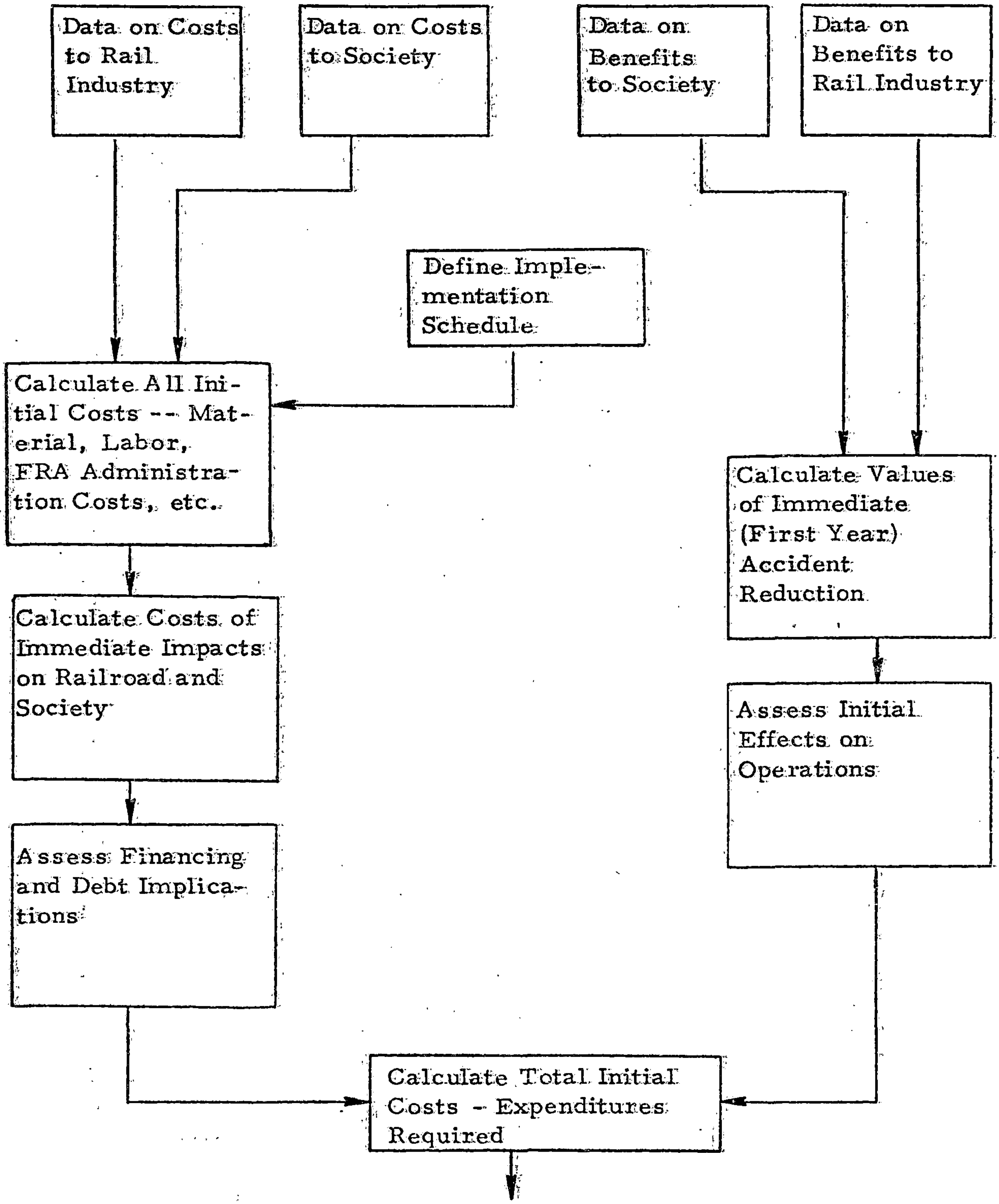
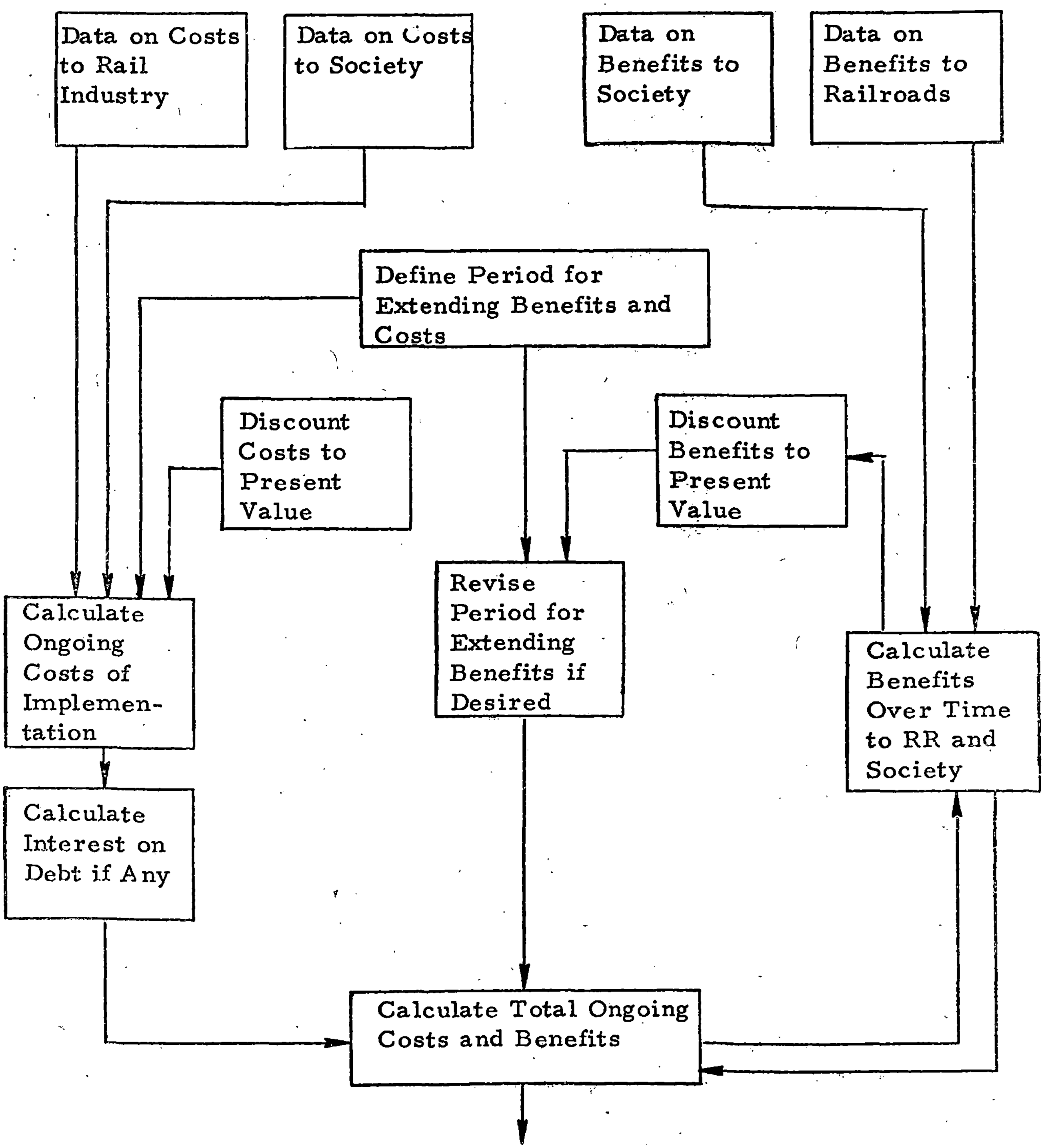


FIGURE 8
Flow Diagram for Calculating
Ongoing Costs and Benefits



3.0 ECONOMIC IMPACT METHODOLOGY: DETAILED DESCRIPTION

The major factors which are pertinent to railroad safety standards are costs and benefits, both to railroads and also to society. In the preceding section, an overview of the economic impact methodology for railroad safety was presented, with diagrams to show how various separate procedures and calculations are necessary to assemble all of the benefits and costs which are realistically associated with railroad safety and accidents. In the following sections, segments of this overall methodology are explained more fully. Sample calculations are included also, using rough estimates of labor and material costs, and estimates of various railroad and societal benefits. These estimates lack the precision which will be obtained when each type of cost and benefit is specified for the years during which they are expected to occur.

The following sections do not in any way intend to produce a complete total cost or total benefit to be obtained from any one safety standard, or from several standards. The calculations use estimates to illustrate how concepts and procedures necessary for a complete analysis can be applied. Since information on accidents, a principal measure of safety conditions, is an important part of both cost and benefit calculations, this topic is treated in detail.

3.1 Background of Economic Impact Analysis

There are no hard and fast rules for determining which factors are relevant and which factors are irrelevant to a particular economic analysis. Since the type of methodology which is best for comparing costs and benefits depends on the particular study, this review was performed to determine which techniques are most applicable to the assessment of railroad safety standards. The literature sources, many of which are listed in the annotated bibliography in Appendix A, fall into three major groups:

- The general literature on economic impact studies,
- Cost-benefit studies made of automobile and highway safety standards, and
- Cost-benefit and cost-effectiveness studies associated with the railroads.

In the case of railroad safety standards, there are four assessments to be made: the costs and benefits to the railroad industry and also to society at large. In this section, a discussion is given of these assessments and of other considerations which are part of an economic impact analysis. Detailed procedures are discussed later.

3.1.1 Terms and Approaches

The definition of cost-benefit analysis is made difficult by an array of terms which are used interchangeably and have different meanings for different groups of people. These terms include "cost-benefit," "benefit-cost," "cost-effectiveness," "cost utility," "systems analysis," and "operations analysis." Since there is no commonly accepted terminology in cost-benefit analysis, it is desirable to discuss briefly the meanings of the various terms before proceeding to discuss particular methodologies.

Cost-benefit analysis and benefit-cost analysis are interchangeable terms. Both terms refer to a systematic examination and comparison of alternative courses for the achievement of a specified objective in some future period. Critical examination of alternatives typically involves two major considerations: first, the assessment of cost and, second, the assessment of benefit pertaining to each of the alternatives being compared. The assessment of cost and the assessment of benefit are usually expressed in terms of dollar values, although other measuring units can be used.

Various approaches are possible; for example:

- Fixed benefit approach --- For a specified level of benefit, the analysis attempts to determine that alternative or feasible combination of alternatives likely to achieve the specified level of benefit at the lowest economic cost.

- Fixed budget approach --- For a specified budget level to be used in the attainment of some given objective, the analysis attempts to determine that alternative or feasible combination of alternatives likely to produce the highest benefit for the given budget level.

Either or both of these approaches may be used, depending on the context of the problem and it is often useful to move from one to the other in order to determine which program of safety features is optimum.

With any approach, a major difficulty, especially in the sphere of safety, is in quantification of such things as human life, peace of mind, and goodwill. If all the non-quantifiable, intangible, and secondary effects are dealt with satisfactorily in some way,* there are still problems with the quantifiable factors.

In a cost-benefit evaluation of the quantifiable effects of safety standards, there are two ways to procede. The first is to compute the net benefit of each safety standard and then to select that alternative with the highest net benefit. The net benefit is obtained by subtracting the cost of implementing the safety standard from the gross benefit obtained from the safety standard. Both costs and gross benefits are discounted at the recommended discount rate to determine their present worth. The second approach for comparing alternative safety standards is to compute the ratio of gross benefits to costs and then to select that alternative with the highest benefit-cost ratio.

In comparing the merits of the benefit-cost ratio with that of the net benefit criterion, it is useful to make a few preliminary observations.

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*For example, the number of lives saved may be the same under each candidate safety standard.

If gross benefits exceed costs then the net benefit will be positive and the benefit-cost ratio will be greater than one. An alternative to the ratio of gross benefits to costs is sometimes used. This is the ratio of net benefits to costs. If the net benefit is positive then the ratio of net benefits to costs will be greater than zero. The ratio of net benefits to costs can always be derived from the ratio of gross benefits to costs by subtracting one from the ratio of gross benefits to costs. If for any alternative the gross benefits are B and the costs are C then the net benefit is B − C. The ratio of gross benefits to costs is B/C. The ratio of net benefits to costs is $(B - C)/C = B/C - 1$.

When either the level of benefits or the level of costs is fixed, it is possible to consider each alternative safety standard with respect to the criterion of the benefit-cost ratio. However, if the level of benefits or costs is not fixed as is most often the case then the use of the benefit-cost ratio leads to results which are difficult to interpret. Consider the following hypothetical illustration:

	Benefit (B)	Cost (C)	B/C	B − C
Alternative A	40	20	2	20
Alternative B	400	200	2	200

Here, the benefit-cost ratio is the same for each alternative (B/C = 2), but the net benefit is different for each alternative. For alternative A, the net benefit (B − C) is $20, whereas for alternative B, the net benefit

(B - C) is $200. If the benefit-cost ratio is used as the criterion of choice the FRA would be indifferent between alternative A and alternative B. If net benefit is used as the criterion of choice then FRA would choose alternative B.

The benefit-cost ratio provides no information as to the scale of the benefits and costs involved in the analysis and as can be readily seen, the scale or value of the benefits and costs will be of prime importance to the FRA in selecting alternative safety standards for implementation.

There is another reason for rejecting the benefit-cost ratio as a criterion for choosing a particular alternative safety standard. It is often not clear whether an item should be considered as a benefit or as a cost savings. For instance, where do you allocate a savings in maintenance costs? Is the savings a benefit or a reduction in cost? If it is a benefit then the savings in maintenance cost increases the numerator of the benefit-cost ratio. If the savings in maintenance cost is a reduction in cost then the denominator of the benefit-cost ratio will be decreased.

These two methods will not lead to the same numerical result, thus reducing the validity of the benefit-cost ratio as a consistent criterion of choice. Elaborate accounting rules would have to be devised to keep analyses comparable. No similar ambiguity is present when using net benefits as long as the algebraic sign and the year in which benefits and costs accrue are known. The net benefit criterion is particularly useful when the fixed costs approach to cost-benefit analysis is taken for then it is possible to state the problem as one of maximizing net benefits subject to cost and budgetary constraints. Finally, net benefit can be presented as the quantifiable (in dollars) portion of a cost-effectiveness evaluation in conjunction with other quantifiable measures (such as number of lives saved) and the non-quantifiable factors. All of the items comprise the economic impact of each candidate safety standard.

Cost utility analysis often has the same meaning as cost-benefit analysis. It should be noted, however, that the utility value of benefits may be different from the monetary value of benefits. This distinction arises from the recognition that money has a different value or utility to different segments of society. An added dollar of wealth may have considerably more meaning to a poor man than to a rich man. Similarly, an increase in safety standards on the railroads may be worth more to one group of customers or employees than to another such group. While recognizing these differences in utility to different people, cost-benefit analysis considers that the determination of benefits in general is already inexact and that the inclusion of utility considerations would not lead to a better estimate of the benefits to society.

Indeed, comparison of utility between different people is impossible to perform in a non-arbitrary manner and will be excluded from the methodology proposed for this study.

Cost-effectiveness is a term which often is assigned the same meaning as cost benefit. Occasionally, however, it is used to mean a process of evaluation in which a final dollar value is not placed on the benefits to be derived from, say, introducing improved safety standards on the railroad. In this form of cost-effectiveness, the candidate safety standards are compared on the basis of cost and different factors of effectiveness such as lives saved, reduction in the number of accidents, etc. No attempt is made to combine these factors of effectiveness into a single measure of the benefits to be derived from the safety standards; neither is an attempt made to measure the total benefits in terms of dollar value. Proponents of this approach to cost-effectiveness consider the objective measurement of many forms of effectiveness as unfeasible and hence not reducible to a single dollar value.

Gross Benefit, Cost, Net Benefit and Consumers' Surplus

In the private sector of the economy, the prices of goods are determined in well-developed markets through the interaction of the supply of, and the demand for, those goods. However, for goods provided by the public sector, there is no market structure which establishes price. Moreover, for public goods -- goods such as national defense or television transmission which can be consumed by more than one person at a given time at no additional cost and for which the exclusion of potential customers involves significant costs -- the creation of such a market structure is undesirable, if not impossible. Unfortunately, in the absence of a reasonably competitive market for a particular good, no direct test of the economic justification for the provision of the good is available. Rather, indirect methods must be devised to evaluate the desirability of these goods.

Safety standards for railroads are public goods in that, first, they provide protection on the same basis to all individuals who are potentially affected by railroad accidents and, second, the exclusion of any individual from this protection is clearly impractical. Consequently, direct market tests cannot be relied upon for the economic evaluation of these standards. Therefore, the remainder of this section will be devoted to the development of an indirect methodology for performing this evaluation.

The first step in this development is the establishment of some basic terminology. The <u>gross benefit</u> obtained by an individual from his consumption of a good or service is the maximum amount of money that he would be willing to pay for the quantity of the good or service that he receives. The <u>cost</u> to the individual of this good or service is the expenditure that he actually makes. The <u>net benefit</u> is the gross benefit less the cost. For a public good, or any other good which commands a market price of zero, the net benefit and gross benefit are equal. In general, a consumer will purchase a good or service only when the net benefit to him from doing so is positive (that is, when a net benefit exists). The total net benefit derived by society from the consumption of the good or service -- the sum of the net benefits obtained by the individuals consuming the good or service -- is referred to as the consumers' surplus.

An improvement of safety standards on the railroad will generate a benefit to society in three parts. First, there is an increase in the net benefit to the present customers and employees of the railroad. Second, the new safety standard may encourage more customers either to travel by the railroad or to transport their goods on the railroad as a result of improved, more reliable service. Finally, non-customers will experience an increase in their net benefit from the decrease in the risk that they will be involved in or adversely affected by railroad accidents. The sum of the net benefits to existing customers plus the net benefit produced by attracting more customers to the railroad plus the net benefit obtained by non-customers who are potentially affected by railroad accidents is the consumers' surplus associated with the safety standards.

In order to measure the net benefit or the consumers' surplus of a public good such as safety, it is necessary to know how much people are willing to pay to have this public good available. It seems reasonable to measure the value of increased safety as the willingness to pay for increased safety by the beneficiaries of the safety improvement. For example, a railroad carrying 100 people safely from point A to point B theoretically should be operating at an equilibrium point where the cost of marginal safety improvement (a reduction in the probability of an accident occurring) is just equal to the sum of the amounts that each of these 100 people would be willing to pay for this improved safety. However, since there is no market structure for public goods, it is difficult to determine how much people are willing to pay for safety. Modal split, which is a measure of ridership preference under existing terms and conditions, is a function of many factors, only one of which is safety. Opinion surveys, in which a sample of affected persons are asked what they are willing to pay for safety, are expensive and notoriously inaccurate.

Consequently, the determination of how much people are willing to pay for a particular good often has to rely on estimates derived from similar situations. For example, it may be possible to infer some approximate estimates of people's willingness to pay for improved railroad safety from the dollar amounts which they have spent voluntarily for safety standards on automobiles and from the involuntary expenditures which they have tacitly accepted.

3.1.2 Costs and Benefits

In an economic impact analysis, we are concerned with the costs and benefits of a public good such as railroad safety standards. A public good is often supplied in a large quantity to society or it is not supplied at all; hence, it often has effects which go beyond the immediate area of introduction. These effects (externalities) can be both beneficial and costly to different segments of society. For instance, the externalities of an airport can represent benefit to the community which it serves, and also a cost to those members of the community who are affected by aircraft noise. The aircraft noise is a societal cost which should be considered by an airport planning agency.

The benefits derived from safety standards on the railways can be subdivided into three major categories: (1) decreases in property and railway car damage, (2) decreases in loss of life or injury caused by railroad accidents, and (3) increased level of satisfaction of railway employees, customers, and other members of society as a result of the first two categories.

To determine the gross benefit derived from these three major categories, it is necessary not only to measure the changes in the probability of their occurrence but also to be able to attribute dollar values to each category and subcategory. The problem of attributing dollar values to fatalities, injuries and changes in satisfaction has been dealt with in recent years and is currently employed by many agencies of the government as an evaluative tool. Current cost-benefit methodology suggests that such intangibles as psychic satisfaction and a reduction of pain and suffering should be listed as a benefit in any economic analysis.

In addition to the external costs imposed upon society through the introduction of a public good, the establishment of railroad safety standards imposes an opportunity cost upon all members of society. The development, promulgation, and enforcement of safety standards cannot be accomplished without the application of some societal resources. Since the funds available for the provision of public goods are limited, the funding of railroad safety standards necessarily will absorb resources which alternatively could be devoted to other public or private programs. The value of these foregone programs constitutes the opportunity cost of introducing the standards. This cost, in addition to the externality costs discussed previously, must be considered as a component of societal costs.

As a further example of such costs, consider the decision to abandon a railroad serving a particular community and the subsequent substitution of motor carrier, bus, and automobile transportation for rail transport. The main societal costs which arise in this instance are:

- Those related to passenger trips or freight traffic diverted to other forms of transportation. This includes the higher incremental costs of the alternative transport mode and costs associated with the value of additional transit time, where such additional travel time is involved.

- Those costs which arise from products no longer transported and available to the community. This is a direct loss to the community.

- Those costs imposed on other members of the community. For example, there is a cost imposed on motorists and other road users due to the added congestion and maintenance of highways which is created by the additional motor vehicle traffic.

It is important to recognize that neither the decrease in revenue earned by the railroad nor the increase in expenditures upon other carriers directly constitutes a societal cost. This shift in expenditure patterns is primarily a transfer of benefits from one segment of the community to another segment of the same community and does not affect the overall level of societal cost. Only if the increased expenditures on other carriers exceeds the reduced expenditures on railroads is there a net loss to society.

In a similar manner, as a result of the abandonment of the railroad, certain factories and industries may decide to close down or relocate. While this constitutes a loss to the individual community affected, it may not be an additional loss to society as a whole. If other communities benefit from the closing through employment of either the displaced resources or an equivalent amount of previously unemployed resources, the inclusion of the losses incurred by the first community as a portion of societal cost in the analysis would result in double-counting.

One community's cost may be another community's gain, and one individual company's losses may likewise be another's benefit. Consequently, in computing societal costs, it is necessary to include each member of society, thus to guard against purely distributional effects of benefits and costs. While it is desirable to take distributional effects into account when choosing between alternatives, the results will not affect the overall dollar value of costs and benefits.

Yet, the sheer enormity of the task of accounting for <u>all</u> direct and indirect effects of a particular public policy upon <u>each</u> member of society makes the conducting of a comprehensive cost-benefit analysis of an issue as far-reaching as the imposition of railroad safety standards impractical if not impossible. At some point, the increased precision of the analysis which results from the evaluation of any remaining indirect effects fails to justify the efforts required to accomplish the evaluation. At this point, further analysis is unwarranted. For this reason, the methodological test included in Section 5 of this report which studied the economic impact of the imposition of journal bearing standards concentrated only on the direct costs and benefits attributable to these standards. Thus, the analytic technique employed in this study can be described more accurately as cost-effectiveness analysis than as cost-benefit analysis.

In addition, it is this restriction of the analysis which necessitates a choice between net benefit and the benefit-cost ratio as a criterion for decision-making. If all benefits and costs can be isolated and evaluated, the two criteria become indistinguishable. Thus, an expansion and standardization of the collection of information describing the causes and effects of railroad accidents, the direct and indirect costs and benefits of compliance would cause the existing distinctions between alternative efficiency criteria to fade and would permit the conducting of a cost-benefit analysis of railroad safety standards.

3.1.3 Selection of the Time Period for Evaluation

The time period for the evaluation of the effectiveness of the safety standards employed on the railroad depends on three main factors: (1) the time span of reasonable predictive ability, (2) the service life of the safety standards, and (3) the anticipated period of application of the safety standards.

The time span of reasonable predictive ability depends in a large part on events external to the railroads per se. As predictions are made farther into the future, the reliability of the predictions decreases. There could be a change in the demand for rail transportation through the emergence of a competing form of transportation. For instance, magnetic levitation and linear induction propulsion may render current forms of rail transportation and railroad safety standards obsolete. Hence, it is desirable to restrict the time span for calculations to about 15 years which is within the limits of reasonable predictive ability.

While safety standards are generally felt to be ongoing in nature and of indefinite length, the service life of the safety standards depends both on the technological life of the major physical components that it addresses and the limits of the useful life of the safety standards due to changes in the demand for that mode of transportation.

The anticipated period of application of the safety features is a third restriction on the time period for evaluation. It may be desirable to make an assessment of the contribution and cost-effectiveness of the safety standards after a short period of time. If the safety standards are not cost-effective, then they need not be renewed for future periods of time.

3.1.4 Sensitivity Analysis

Since most important decision problems involve major elements of uncertainty, an analysis of such problems must provide for explicit treatment of uncertainty. Suppose in a given analysis there are a few key variables about which the analyst is uncertain, then instead of using a "typical expected value" or a "best estimate," the analyst may use several values (optimistic, mean, pessimistic) in an attempt to see how sensitive the results (the ranking of the alternatives being considered) are to variations in the uncertain variables.

For instance, in determining the present value of human life, it is possible to use a figure corresponding to the immediate costs of death (medical services, funeral costs, etc.) and another figure which in addition to the immediate costs of death includes the present value of future expected earnings and measures for the costs of pain and suffering, etc. The analysis can be performed twice to determine how sensitive the safety standards evaluations are to differing estimates for the cost of death. If the occurrence of fatalities is extremely low compared to the occurrence of property damages per track mile, then it is likely that the computation of net benefits will not be sensitive to the value placed on human life.

A good example of the use of sensitivity analysis is presented in Section 5. Since quite a bit of uncertainty exists about some of the parameters (for example, the percent of freight cars which have stabilized bearings), these parameters were varied over a wide range of values. This exercise is useful at several stages in a study; in an early stage, it can be used to indicate the accuracy necessary in each parameter. Also, in many cases (as in Section 5), if a computer program is written to perform the basic arithmetic in the analysis, the sensitivity analysis can subsequently be done by simply rerunning the program with the changed parameters.

3.2 Railroad Costs

The safety standards to be implemented under the Federal Railroad Safety Act of 1970 (PL 91-458) are required to cover all areas of railroad safety. The FRA has developed safety standards in the areas of track and equipment, thus providing a basis for analyzing the costs to be incurred by the railroad industry in implementing these standards in situations where track and equipment presently do not meet the new and proposed standards.

The types of costs likely to be incurred by the rail carriers include material costs, labor costs, and administrative and managerial costs. Since the new and proposed standards are stated in terms of existing technology, such costs as research and development and reorganization are assumed to be negligible. The types of costs will vary in size among different rail companies, but some costs will generally be higher than others, as indicated in Table 1.

The discussions in this section are keyed to the methodology flow chart in Figure 2.

3.2.1 Guidelines for Calculations

Many problems arise in calculating the exact costs carriers will bear as a result of the new standards, because any carrier is expected to integrate additional inspections, repairs, or administrative work with his present operations.

TABLE 1
Estimated Relative Size
of Implementation Costs*

		Materials	Labor	Administration/ Management (includes record keeping and overhead
Track	Inspection	Low	High	Moderate
	Repair/ Replacement	Moderate	Moderate	Moderate
Equipment	Inspection	Low	Moderate	High
	Repair/ Replacement	Moderate	Moderate	High

*"Low," "High," and "Moderate" are terms relating to costs generally borne in the regular day-to-day railroad operations. In other words, the above assessment is intended to reflect the additional burden likely to be incurred by the carriers due to the standards.

Since many of the requirements of the standards are likely to be merged with existing procedures, it will be important to monitor implementation and effects carefully to assess whether implementation costs are, in fact, in line with estimates resulting from the cost-benefit methodology.

One of the most important steps for insuring the overall reasonableness and accuracy of the analysis is the determination of exactly how railroads will, in the aggregate, comply with the standards. For example, in calculating inspection costs, it will be necessary to ascertain how railroads will likely conduct the inspection -- <u>what</u> items will be inspected and <u>how</u> they will be inspected (visually-dismantling). It is also important to estimate the extent of the railroad industry's compliance with a standard. The early experience of the FRA has been that the railroads slip into delinquency especially if a particular standard is more stringent than the appropriate interchange rules. If less than full compliance will be tolerated, then the railroad industry's cost should be based on this amount of compliance. If penalties are provided for non-compliance, then these are part of the costs borne by the railroads.

Although benefits from safety rules are generally conceded to extend into perpetuity, a 15-year period has been established for the present study. This assumption means that all costs must be extended over a 15-year period also. Since some of the costs of implementing the standards will be borne over a much shorter period, the costs and benefits must be equalized in terms of comparable dollars. The procedure for this equalization involves calculating specific year-by-year values for each cost and each benefit. Estimates not obtained by this annualization procedure are not strictly comparable.

3.2.2 Implementation Costs

Implementation cost estimates can be verified by data obtained from a series of procedures and sources, as indicated on the methodology flow chart in Figure 2:

- FRA field inspection reports,
- Sampling maintenance records and other records kept by carriers,
- Results of special studies performed by AAR, RPI, and others,
- Modelling the costs of standards using engineering data on components plus other data on costs and procedures, and
- Obtaining more reliable estimates from a joint FRA and rail industry task force or panel to provide ongoing feedback on costs.

It would be even more desirable to obtain implementation cost data from a series of two or more of the above procedures. Describing in detail a program for the use of these procedures is, however, outside the scope of the present report.

The FRA-Industry Joint Task Force is a concept by which representatives from the railroad industry, unions, and FRA would meet to provide expert opinion and recommendations for FRA in the cost-benefit analysis of safety standards. This concept was suggested by one of the railroads interviewed and has been reviewed with other railroads and union officials in subsequent interviews, and has received vigorous approval, along with indications that participation would be widespread.

For specific technical problems, other specialists and technical representatives from AAR, RPI, and various firms would be included. In any case, a determination of the effectiveness of a given standard in reducing accidents will require a high degree of technical competence, an understanding of accident causes, etc. This is an important and sensitive calculation in the cost-benefit analysis of safety standards, and one for which expert opinions should be sought wherever possible.

In addition, the Task Force could act in a consulting capacity during the rule-making procedures to work out changes and definitional problems in proposed standards before they are issued.

The serious lack of data on safety is another problem that the Joint Task Force could also address, and perhaps through the auspices of participating members, additional data requirements could be defined and mutual action undertaken to insure effective development.

3.2.3 Inspection Costs

The costs to rail carriers of implementing new and proposed safety standards have, for the purposes of this study, been divided into two major cost categories: inspections and repair/replacement. The reason for this division is clear from the present form of the new track standards, and from the proposed equipment standards. Both sets of rules have specific inspection requirements which must be met independent of other rules.

The inspection costs for both track and rail standards have been divided further into "direct costs" and "other costs." Direct costs are the costs of actual inspections of either track or equipment consisting primarily of labor costs. Other costs are those associated with the hiring and training of inspectors, transportation of the inspector to the track to be inspected, movement of freight cars to and from the repair track, and the lost car utilization resulting from the inspection. It is assumed for this study that the time lost in utilization of track while it is being inspected is negligible.

"Other costs," as opposed to direct costs, are discussed in the following section. "Direct costs" involve only inspection time, and crude estimates of these costs are to be obtained by estimating the number of man-hours of inspection time required for an appropriate unit and multiplying it by the total number of units (cars, track miles, etc.) to be inspected. The total annual cost of inspection for all units is then projected by the estimated average number of inspections required each year over a 15-year period and a 15-year total cost obtained.

In both the track and the equipment standards, two types of basic units are defined, based on the type of service in which they are employed. Thus, main line track is distinguished from yard and switching tracks, and high utilization cars are distinguished from other cars. Separate inspection costs must be calculated for each category of track and cars.

Actual time spent on inspections may vary widely depending on the item or unit being inspected and on the inspector's experience. For freight cars, estimates of the time required to periodically inspect all truck components plus couplers and draft systems have ranged from 12 man-hours to 30 man-hours.* These estimates generally assume that some car components such as journal bearings and wedges would have to be physically dismantled to properly gauge wear and condition. In the case of track, a rule-of-thumb of 20 miles per day was mentioned, but actual times might run from one mile per hour to five miles per hour, or from eight to 40 miles during an eight-hour day. A sample

*Visual inspections can naturally be accomplished in a matter of minutes.

calculation for inspection of main line track is shown in Table 2. These calculations are only rough estimates for illustration purposes only, because separate calculations were not made for each year in the 15-year period and the costs were not discounted.

The number of personnel assigned to track and equipment inspection now varies considerably among railroads. It can be assumed, however, that each railroad may find it necessary to hire and train additional track and equipment inspectors and other personnel in order to comply with the standards. Although there is little formal structure for such training at present, it is possible to calculate how much such a program would cost, based on the assumption that the major expense would be the time of the instructors and the trainees. Some railroads might merely assign trainees to existing inspection personnel.

3.2.4 Average Industry Condition

To calculate costs of implementation of standards, an estimate must be made of the extent of substandard track and equipment in the present system. Also, age and wear data must be used to determine when track and equipment will, in the future, fall below the proposed standards. Estimates of the track and equipment which must be upgraded or replaced in order to achieve compliance with the proposed FRA standards can then be made.

TABLE 2

Sample Calculation of Inspection Costs Over 15 Years

Note: Figures are preliminary estimates of yearly (undiscounted) costs.

	Actual Time of Inspector Per Unit	Cost of Unit Inspection at $14.24 Per Hour*	Frequency of Unit Inspection	Frequency Multiplied by Unit Cost to Get Total Cost/Unit	Total Fifteen Year Cost (undiscounted)
Track Inspections	8 hours per 20 miles (2.5 miles/hour). For 205,000 miles of main line, there are 10,250 20-mile units.	$113.92	Twice per week for main line track, with 24-hour period between inspections. There are 780 weeks in a 15-year period.	Unit cost per week: $227.84 Unit cost per 15 yrs: $227.84 x 780 = $177,715	$177,715 x 10,250 = $1,821,581,000

*This is the AAR billing rate for general labor charges as of August 1, 1974.

The maintenance costs resulting from compliance activities are not likely to be known before formal adoption of the standards, and therefore these amounts must be estimated for inclusion in the total implementation cost of the standards. The estimating procedure requires some assessment of the degree or level of substandard track and equipment which presently exists in the rail system and the extent to which the railroad industry will upgrade its condition. Making this assessment is simplified when the proposed safety standards are similar to the rules* which the rail industry (AAR) has already promulgated, as in the case of the proposed track and equipment standards. In these instances, the AAR may have ongoing reports or test results which will measure the condition of the items and the extent of industry compliance with the recommended practice. This information can be of enormous help to the FRA in estimating the general industry condition or probable numbers of defective units.

The results of the inspections required by the new safety standards should provide carriers with a clearer picture of which conditions on their railroads are leading to accidents. The averred intent of the

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*While the AAR interchange rules have not been legally binding on the carriers, they have served over the years as guides as to when items and components should be repaired and replaced. These maintenance guidelines have been established by the FRA as minimum safety standards.

proposed standards, and of the Federal Railroad Safety Act of 1970, is to ameliorate these conditions and thereby reduce the occurrence of accidents. Since accidents, having remained at moderate levels over the past 15 years, are recently increasing, it is likely that significant amounts of additional maintenance investment will be required to achieve the objectives of the Act.

3.2.4.1 Track Condition

The general procedure for determining present condition of track and roadway and its future condition is illustrated by the work of the Labor and Management Committee Task Force II on Track and Roadway (April 13, 1971). The overall cost of the program recommended by this report is $208 million per year for tie replacement, and $325 million per year for rail replacement. The report recommends that the tie replacement program be implemented for at least a six-year period, and the rail replacement program for ten years.

Although the program outlined by the Track and Roadway Task Force is designed to produce a very high quality rail system, with 98 percent of main line track being converted to welded rail, not all of that program would be necessary to achieve compliance with the FRA track standards. Nevertheless, the procedure employed by the Task Force is suitable for use in the recommended cost-effectiveness methodology. Some changes must be made in parameters such as average tie replacement cost, now substantially higher than in April, 1971, and in overall objectives, since safety considerations alone do not require the same degree of improvement as is required for maximum, as well as safe, operating performance.

3.2.4.2 Equipment Condition

The present philosophy underlying FRA safety standards activity is that the reduction of accidents to be expected from the proposed equipment standards will occur because of increased inspections and the immediate replacement of worn components. Under present practices, defective equipment parts are not necessarily discovered before failure, and even when a worn part is discovered, it is not necessarily replaced immediately, because of time, labor, facility, and capital constraints. This philosophy is reflected in the following prominent features of the equipment standards:

- The proposed standards are defined for wheels, axles, bearings, couplers, and draft systems. Other components are referred to in a "miscellaneous" standard. In other words, the standards for equipment apply to rail car components.

- The standards are defined according to industry standards already in use and widely accepted. These standards generally involve measurements of components to determine wear and potential failure.

- In spite of present standards and inspections, a substantial number of component failures occur. Additional inspections are required with the intent of detecting components which are worn below standards.

The main purpose of this discussion is to estimate how many more components of certain types will be found to be worn than are presently found, and how many of these will be replaced under the proposed standards.

Much of the data on equipment components must be estimated on the basis of the following factors:

- Age of freight cars in service (UMLER File),
- Age of installed components where known or recorded (carrier records),
- Present and expected inspection rates,
- Usage or service rates of freight cars (dedicated unit trains, free running, local captive movements),
- Replacement and repair parameters such as man-hours, component costs (carrier records).

The first step in developing the needed estimates is to summarize the types of service in which freight cars are employed. The reason for this approach is to derive a range of wear for a freight car of a given age and a mean or most likely estimate for a given class of service. Because freight cars in service vastly outnumber the passenger cars, the present report will deal with freight cars only.

The types of service vary widely along at least five dimensions:

- Speed,
- Axle weight,
- Track (including track condition and terrain),
- Climate, and
- Annual car mileage (high vs. low utilization cars).

There are other dimensions, of course, but these five are necessary at least to adequately describe freight car operations.

The proposed FRA equipment standards separate the types of service for freight cars into heavy and light, or high utilization and low utilization. A high utilization car is defined to be a car that is designed to carry trucks or trailers, or is one which operates on a continuous round-trip cycle, or travles more than 50,000 miles annually. The frequency of periodic inspection requirements originally proposed by FRA and the most recently revised requirements are shown in Table 3 on the following page.

These periodic inspection requirements need not add to the scheduling problems of freight car usage because the proposed FRA rules do not require that each freight car be inspected exactly at the end of 150,000 miles, or exactly every 50,000 miles. Thus, the inspections can be accomplished at any time a car is on a repair track. However, the required scheduling of inspections may add to the time that cars are in shops and may result in increased repair and replacement costs, since more worn and defective components may be detected.

The calculations, presented in Table 4, illustrate a method of estimating the distributions of worn components in the freight car fleet. The parameter values are hypothetical and the results apply only in the aggregate--the life of any one component on one particular freight car cannot be estimated in this manner. The assumptions are:

TABLE 3
Inspection Frequencies for Freight Cars

Originally Proposed Standards, Federal Register, September 22, 1972, Vol. 37 No. 185

	New		Reconditioned	
	Initial	Subsequent	Initial	Subsequent
High Utilization	Once during first 150,000 miles	Once every 50,000 miles	Once during first 150,000 miles	Once every 50,000 miles
Normal Utilization	Once during first 7 years or 150,000 miles	Once every 2 years or 50,000 miles	Once during first 7 years or 150,000 miles	Once every 50,000 miles or 2 years

Revised Standards, Federal Register, November 21, 1973

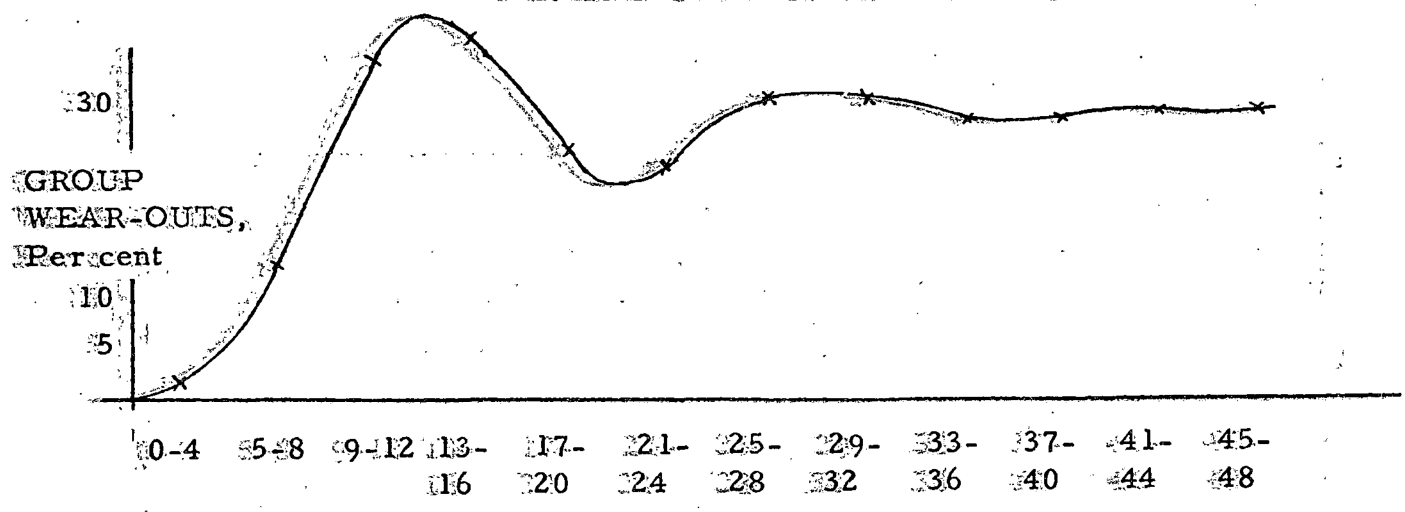
	New		Reconditioned	
	Initial	Subsequent	Initial	Subsequent
High Utilization	Once during first 2 years	Once every year	Once during first 2 years	Once every year
Normal Utilization	Once during first 8 years	Once every 4 years	Once during first 8 years	Once every 4 years

TABLE 4

Hypothetical Distribution of Worn Freight Car Components

Age of Car In Years	Statistical Distribution of Draft Systems Failures (%)*	Statistical Distribution of Failed Roller Bearings (%)**	Statistical Distribution of Failed Wheels (%)***	Total Wheel Wear-Outs in Each Age Group (%)
0-4			2.0	2.00
5-8			14.0	14.04
9-12	3.0		34.0	34.56
13-16		2.0	34.0	37.34
17-20	15.0	14.0	14.0	25.33
21-24		34.0	2.0	24.24
25-28	32.0	34.0	All Replaced or Rebuilt	30.48
29-32		14.0		30.44
33-36	32.0	2.0		27.65
37-40		Replaced or Rebuilt		27.70
41-44	15.0			29.04
45-48				28.96
Over 48	3.0			

FREIGHT CAR WHEEL WEAR-OUTS



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*All entries are the percents of the original components which fall in the indicated time period. It is assumed that 6% of all new draft systems have failed at the end of 15 years.

**Assume an average life of 500,000 miles and a yearly mileage of 20,000 miles.

***Assume the mean wheel life is 13 years and the wear occurs in a normal distribution.

- In 1971, the average freight car traveled about 20,000 miles per year (Railroad Facts, 1971), and
- The mean period of time to reach maximum allowable wear levels was:

Wheels	13 years,
Draft systems	25.5 years, and
Roller bearings	25.0 years.

The percent figure for each of these components show what percent of the remaining components from the original group (population) would be expected to fail inspection during the time periods shown in Table 4.

In other words, the freight car fleet can be viewed as a collection of components which were new when each individual car was bought and placed in service. As the cars continue in service, the total collection of all components begins to wear. Some components of a given type (wheels, journals, etc.) wear out fairly early, and must be replaced. By the end of the mean lifetime of any type of component, about 50 percent have become worn, and of that 50 percent, most of those components that have been detected have been replaced.

The components that have been replaced also begin to wear out, and under the same operating conditions, it is assumed for estimation purposes that wear is a constant factor. By knowing the approximate age and class of service for a given car and probable operating conditions, and the mean service life components, an estimate of the component wear can be made. By summing the individual car estimates, an estimate for the entire fleet can be derived. Finally, from the distribution of worn components for the entire fleet, and an analysis of the condition of failed components, the probability of component failure can be calculated.

Therefore, it is possible to roughly estimate the percent of worn components in any age group of railway cars. According to the percent shown in Table 4, two percent of the wheels are worn in the group less than four years of age. Fourteen percent of the wheels are worn in the five-to-eight year group, but two percent of the wheels in this group have already been replaced. These new wheels form a new younger group with the same wear distribution as the original group. Hence the worn wheels in the five-to-eight year group are 14 percent of the original group and 2 percent of the new group for a total of 14.04 percent of all the universe of wheels, as shown in Table 4. There are now three different age groups, each with identical wear distributions. Continuing in this fashion the probable wear-outs for the entire fleet in each age group are given in the last column of Table 4. These numbers are also plotted underneath Table 4 to show that the wear-outs are approaching a constant rate of about 7 percent per year.

In order to calculate the distribution of worn components in the fleet, the following alternatives should be considered:

1. Computer process the AAR UMLER File to determine the age of cars by car type and estimate wear factors, considering probable service environments.

2. Use individual carrier records to determine the average age of cars and probable condition of components. This can be done with FRA/carrier cooperation.

3. Examine carriers' shop records to ascertain the frequency of repair and replacement of given components. The carriers' replacement rates can be used as a rough approximation of industry defectives. Obviously, the more carriers that can be included in the base estimate, the better.

4. Query suppliers who have marketing information, including projections. Large suppliers have a good idea of the total market also and can sometimes either verify or contradict the railroads' data.

5. The ideal, but perhaps most expensive method for determining the average industry condition of given components is to field sample a sufficiently large number of cars to produce statistically reliable estimates of the distribution of worn components. FRA could treat their own field inspection reports of carriers' compliance as a broad representative sample of component conditions/wear which could be used to establish the approximate distribution of worn components for the entire rail fleet.

6. It may also be possible to approximate such a distribution by a computer simulation, providing sufficient data can be obtained on the age and operating environments of cars and components. This technique will often provide a cost savings over field sampling.

In the methodological test which is discussed in Section 5 of this report, the data on component condition, that is, the number of freight cars with plain bearings (versus roller bearings) and the split of the plain bearing population between stabilized and unstabilized bearings, were estimated in various ways. The AAR provided a fairly rough estimate, individual roads provided very rough (different) estimates, and data from initial reports of FRA field inspectors' forms a somewhat random but limited sample of 337 cars. Projections of the United States freight car fleet composition used similar sources with the addition of a major bearing manufacturer who disagreed emphatically with a claimed 6,000 conversion per year from plain bearings to roller bearings. Data on bearing failures came in by much the same sources.

It is important to realize that there are great differences in operating philosophies, record keeping activities, and willingness to share information among railroads, among suppliers, and among agencies and committees. Even within an individual supplier, for example, projections will sometimes come from the marketing department and sometimes from the metallurgical or some other department.

3.2.5 Compliance Costs

The Labor and Management Committee Task Force II on Track and Roadway presented a report on April 13, 1971, on a recommended upgrading program. Their results, summarized in Table 5, illustrate the costing procedure and provides a comparison for the FRA track standards cost. The FRA standards require a more modest program aimed at safety rather than better operating performance. Neither

TABLE 5
Comparison of Track and Roadway Requirements: Task Force II Program versus FRA Standards.

Program		Objectives	Maintenance Required and Cost Per Year	Minimum Number of Years Program Required	Total Mainte-nance	Total Cost
Track and Roadway Task Force II	Rail	98 percent of main line must be welded rail	Relay 7,500 miles per year and convert to welded rail; $325,000,000	10	75,000 miles of rail	$3.50 billion
	Ties	All ties must be less than 35 years of age	Replace 26,000,000 ties per year; $208,000,000 Normal maintenance; $160,000,000	6 4	236 million ties	$1.9 billion $5.4 billion
FRA Track Standards	Rail	Rail is maintained in condition to comply with standards	Replace rail which is worn below standards and improve overall maintenance; $180,000,000	Annually (continuous)	30,000 miles of rail	$1.8 billion in 10 years
	Ties	Ties are maintained in condition to comply with standard	Replace 20,000,000 ties per year at $8/tie; $160,000,000 per annum	Annually (continuous)	20 million ties	$1.6 billion in 10 years $3.4 billion in 10 years

programs' total costs are discounted but they are somewhat comparable over the ten years since both are rougly annual costs. However, at the end of ten years, the Task Force's program is finished; and expenditures can drop to a maintenance level. The FRA program continues.

The main point of Table 5 is not a cost comparison but the illustration of compliance cost calculations which are more completely described in the Task Force II report.

Compliance costs for equipment are calculated in much the same way. For freight cars, for example, labor and material costs are fairly easy to get. A good source is AAR billing allowances which are arrived at by polling the major roads and calculating average costs. A railroad is motivated to neither overstate nor understate a charge because they are alternately producers and recipients of the charge. The schedules of charges by car manufacturers and renovators provide a verification of how closely the AAR billing charges come to actual costs (see Table 6).

There are other costs associated with safety standard compliance, of course. For example, taking a car out of service (an average of three days for shopping a car) incurs a per diem charge of $4.20 per day against the road shopping the car. Setting off the car costs two man-hours and $55. A large intangible "cost" is the wrath of a customer whose shipment is delayed those three days.

TABLE 6
Approximate Unit Costs of Freight Car Component Replacement

	Materials ($)	Labor ($)
Wheel	112	20
Axle (100 ton)	209	20
Journal bearing	15-30	20
Roller bearing	75-104	10-23
Coupler	126	15-20
Draft gear	100-198	15-20

Source: Interviews with car manufacturers and renovators.

3.2.6 Other Costs

As noted previously, a number of other costs are associated with inspections, and most of these costs have similar components in the repair and replacement category of safety maintenance. Some overlapping or duplication occurs, which will reduce the actual cost, as, for example, in the case of record keeping. Although records may be required to be kept of freight car inspections, the same recording procedures that now exist to handle interline repair billing can be employed.

Further examples of indirect costs are loss of equipment utilization, loss of revenue from downgraded service on substandard tracks or eliminated service on abandoned tracks, and loss of investment opportunties due to use of capital for achieving compliance with safety standards. An example of intangible cost is the wrath of the shipper whose order is delayed because a car is shopped for compliance with a safety standard. Undoubtedly other costs will be added to the overall methodology for calculating the total cost of implementing a specific standard as experience with cost-effectiveness evaluations of such standards is gained. Although these are important costs, they will not be as high as the basic repair and replacement costs, and their overall importance in the cost-effectiveness analysis may well be left to the judgment of policy decision-makers.

3.3 Societal Costs

The societal costs resulting from the promulgation of rail safety standards are defined to be those direct and indirect costs that are incurred by society as a result of the development and implementation of safety standards. In the context of this analysis, they refer to any costs not borne directly by the railroad industry. This definition excludes societal or governmental lost opportunity costs, that is, what the alternative returns would have been had funds invested in rail safety standards been invested in other areas, for example, highway safety. For discussions of lost opportunity costs with respect to government investments, see Dorfman* and Margolis.**

Examples of direct societal costs are FRA's administrative costs to develop and promulgate the safety standards, and expenses of state governments and/or commissions in conjunction with this effort. Calculating these costs for an individual safety standard will require determining what portion of the total FRA expenses will be spent developing a particular standard and proration of general expenses which cannot be attributed to any specific standard.

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*Dorfman, Robert (ed.), Measuring Benefits of Government Investments, Washington, D.C., The Brookings Institute, 1963.

**Margolis, Julius (ed.), The Analysis of Public Output, National Bureau of Economic Research, 1970.

The current and projected salaries and expenses of all FRA field inspectors and state inspectors required to police and implement the safety standards should be included in the societal cost calculations, along with any other direct costs not specifically borne by the railroad industry.

Consideration should also be given to indirect societal costs which would result from the promulgation of safety standards. However, these costs are frequently a transferral from one sector of society to another, having a negative benefit for one and positive benefit for another. For example, the costs of stringent track safety standards may result in successful efforts by railroads to abandon certain branch lines with the following non-railroad costs:

- Increased shipping costs due to higher transportation costs for those affected,
- Certain businesses may be forced to close due to higher transportation costs,
- Local communities may have difficulty attracting new businesses due to the lack of rail service, and
- Individuals living in the community may suffer some diminution in their total welfare due to the absence of rail transportation.

On the other hand, this same abandonment may have the following positive effects:

- Increased business for motor carriers, and/or other transportation companies,
- Increased business for other competitive companies resulting from the failure and closing of the affected companies,
- Stimulation of the development of other regions due to the increased business afforded by the inability of the affected community to compete, and
- Individuals served by the rail carriers in other communities and areas may benefit as a result of financial strengthening of the carrier.

Since the list of indirect societal costs and benefits affected by the issuance of rail safety standards is rather long, only the major indirect costs and benefits should be considered. In calculating the net cost-effectiveness of a given safety standard, if indirect items are included, care must be taken to avoid double-counting.

3.4 Accidents and Accident Data

Safety and safety standards encompass more than accidents. Adequate safety is lacking in the case of a shop worker's gradual hearing loss even though no "accident" occurs. Similarly, battered cargo results from exposure to an unsafe environment. However, since the major impact of most safety standards will be on accidents, accident data will be the principal measure of economic impact. As indicated in Figure 4, these data will form the basis for calculating the principal benefit component, namely, the reduction in total accident costs. It will be necessary to determine the total costs of all accidents addressed by the proposed standards, keeping separate those costs that railroads are paying for directly and those that they do not pay for, namely, the societal costs. The principal sources for this data are naturally the railroads themselves who are recording far more information than is currently being reported to the FRA. Based on current reporting rules, only those accidents are reported which result in the death of a person, or an injury which incapacitates a person for more than 24 hours, or which incur $750 or more in damages to railroad property, excluding wreck-clearing costs.

Thus, some rather important cost elements necessary for cost-effectiveness analysis are as follows:

- The total number and cost of non-reportable accidents,
- The cost for clearing wrecks,
- The cost of loss and damage to lading,
- The personal injury costs resulting from fatalities and injuries,
- The costs of damage to non-railroad property,
- The costs of service disruptions and delays,
- The costs of community services provided (fire, police, Red Cross) for major railroad accidents, and
- Damage to structures, other than track.

The accident investigation reports of the NTSB provide some measure of total damages and do enumerate the numbers of persons injured or killed in major railroad accidents. However, since 1967, only 18 such reports have been issued, providing good, but limited, data on the costs of railroad accidents. Several states, California, Oregon, Iowa, Missouri, Illinois, and Pennsylvania, accumulate statistics on railroad-highway grade crossing accidents but do not cover other types of railroad accidents.

The Interstate Commerce Commission (ICC) publishes in Account 415* the costs of clearing wrecks and in Account 420* the costs of injuries to persons which include claims, legal fees, witness expenses, etc. These cost figures are useful for establishing an average wreck-clearing expense and an average injury cost for all accidents. Investigations of accident costs, however, reveal that certain types of accidents, e.g., those resulting from journal bearing failures and wheel failures, are significantly more expensive than other types of accidents, e.g., passed couplers, and therefore the use of a broad average would tend to introduce inaccuracies in the cost-effectiveness analysis.

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*Interstate Commerce Commission, <u>49 C.F.R.-Part 1201, Uniform System of Accounts</u>, Railroad Companies, October 1, 1973.

The AAR publishes freight loss and damage figures for train accidents but, since this information is not broken down by accident type, it is of limited use in the consideration of a specific safety standard.

3.4.1 Wreck Clearing Costs

The total cost for clearing wrecks in 1971 amounted to $38,477,000 for all railroads.* Since this is a major cost component of accidents, it is essential that it be included in any cost-effectiveness analysis of safety standards. On request, a number of carriers supplied data on their average wreck clearance cost, which, in 1971, amounted to $1,500/car including material and labor. This average figure overstates costs for single car derailments, which constitute the majority of accidents, and greatly understates costs on more severe accidents. For calculation purposes, it is recommended that an overall average cost on cars be developed for each category of accidents being considered and that FRA obtain such estimates from cooperating carriers.

3.4.2 Loss and Damage to Lading

AAR reports a total of $36,782,768 in freight loss and damage due to train accidents in 1971. This information is currently developed by all carriers and is reported on a regular basis to the AAR. There is often a significant delay, however, between the time of an accident

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*ICC Account 415.

and the settlement of all claims. Therefore, it may be necessary to use fairly old data and compensate with inflators.

3.4.3 Personal Injury Costs

Personal injury costs are possibly the largest and most significant component of rail accident costs. While current FRA accident reporting requirements provide the number of persons injured or killed in an accident, the costs of the injuries are not provided for a given accident. Included in these costs are the following items:

- Compensation: actual claims paid to survivors and relatives of the deceased, or injured parties,
- Accident investigation expenses,
- Legal fees and administrative expenses,
- Witnesses - outside counsel,
- Claim personnel, administrative expenses, and
- Other personal injury expenses borne directly by the railroads.

There is considerable sensitivity about providing this information on a regular basis and strong feelings on the part of the carriers that some aggregation would be necessary to avoid disclosures which would divulge average settlement costs. Considering these reservations, and the time delays which will necessitate matching claim settlements and other personal injury costs against past accidents, it is recommended that an estimating procedure be followed for developing personal injury costs.

Through interviews with the carriers and by careful perusal of Federal court records, average settlements can be established for each category of injury. For example, our interviews produced the following data from one carrier:

Average cost per employee death	$33,922
Average cost per employee injury	$ 5,756

and from another carrier:

Average legal expenses per accident	$ 3,000
Average witness expense per witness	$ 200

and from another carrier:

1972	Number Injured and Killed	Total Compensation Payment
	867	$5,300,000

Construction of an average personal injury cost table for fatalities, permanent total disabilities, and permanent partial disabilities, would thus provide a means for estimating the personal injury costs of the different accident categories addressed by the safety standards in question.

3.4.4 Damage to Non-Railroad Property

The cost of damages to non-railroad property, for which the railroad may or may not make compensation, should be entered in the economic impact calculations of any rail safety standard. The vast majority of property damage and personal injuries are paid for by the railroads. However, minor or incidental costs arising from accidents are often ignored. The costs of community services such as fire and

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3.4.5 Service Disruption and Delays

In reviewing the fact that accidents may frequently tie up cars, locomotives and trains, a number of carriers pointed out that these costs should be taken into consideration in a cost-effectiveness analysis. The cost items should include not only the immediate equipment involved in the accident, but all other trains and cars that were held up or delayed by reason of the track being blocked. Often, the effects of an accident are very widespread, especially if it occurs where alternate routing options are few. One interview respondent suggested some railroad managers really had little idea of just how much an accident can affect its overall costs. In his words, "We may be paying now for an accident that occurred ten days ago." However, these delay costs are significant and, for this reason, one carrier regularly develops this information as part of its internal accident reporting system.

Loss of goodwill is more difficult to assess. Several interview respondents stressed that shippers react swiftly and substantively to delays. Revenue loss may amount to 1% or more of the total accident cost.

3.5 Rail Industry Benefits

Most of the benefits to the rail industry from safety standards will come from reduced accident costs. The procedure for assessing these benefits is outlined in Figure 5. Different types of accidents will require different techniques for analysis.

The FRA system of tabulating accidents on railroads uses the categories "train", "train service", and "non-train" to designate the three basic types of accidents. It is not likely that the FRA track and proposed equipment standards will reduce the accidents in the non-train category, so this study will concentrate on train and train service accidents. Train accidents are classified as either derailments, collisions, or other, and it is likely that the track and the equipment standards will directly affect these categories.

Train service accidents are an important category because it includes most highway grade crossing accidents. However, the standards thus far proposed and promulgated for track and equipment are not likely to directly reduce this specific type of accident. Train service accidents in which employees of railroads are victims should experience reduction in number and severity because of the safety standards presently defined. As standards are later developed for more areas of railroad operations, reduction of a greater number and variety of accidents should occur.

3.5.1 Pertinent Data

For the types of accidents likely to be reduced by the track and equipment standards, both reduction in injuries, as well as reduction in property damages, will result, and the benefits from these reductions will accrue directly to the rail carriers in a large number of accidents. It is not known what proportion of the cost of accidents are eventually paid by the railroads, or by their insurance funds, but those claims paid by the railroads are known to be high. At least one type of property damage, i.e., damage to railroad-owned property, is tabulated in the FRA Accident Bulletin.

Other types of data which reflect benefits to be gained from accident reduction have been discussed previously, and it is likely that some proportion of the cost of any type of accident damage accumulating over a period of time will be paid by one or more carriers. In other words, whatever type of damage occurs, there will be some occasion on which a carrier must bear the cost of this damage. Even though the actual claims paid by carriers may be difficult to obtain, some notion of the average size of such claims is obtainable by a survey of court transcripts and newspaper files.

Other sources of accident cost data which can be used for calculation of benefits are:

- Costs of Clearing Wrecks -- This variable was described previously and can be estimated from the carriers' most recent experience ($1,500/car). The ICC's Account 415 can also be used to construct gross estimates for all accidents to use as a benchmark or check of costs derived from carrier estimates.

- Loss and Damage to Lading -- The vast majority of this damage is paid for by the railroads, and data is available from ICC accounts and from the American Railway Car Institute.

- Damage to Non-Railroad Property Paid by Railroad -- This damage will be difficult to divide between that portion borne by the railroad and that portion borne by society. Here, a survey of court records and newspaper files may be necessary.

- Fatality Costs -- the Number of fatalities is tabulated by FRA, and a standard value or range of values can be assigned to each life.

- Injury and Disability Payouts -- The number of injuries by type is tabulated by AAR, and standard insurance company values can be used in assigning dollar values.

- Accident Investigation Expenses -- Many railroads maintain an accident investigation staff, and by determining budgets for these staffs and the number of accidents investigated, an average value for the investigation of an accident, and possibly of accidents of different types can be calculated.

- Legal Expenses -- Again, budgets for legal staffs can be ascertained, and the number and type of accidents requiring their attention can be compared to these budgets. Similar values, such as witness expenses and non-staff legal expenses, can be obtained in interviews with railroad legal personnel.

- Costs of Service Disruption -- There are likely to be several components to the costs arising from service disruption, including the loss of use of the freight cars and locomotives delayed, the delays to passengers, and the freezing of the capital represented by the freight. In the last case, an estimate of the cost per year can be obtained by applying an interest rate to the value of the average freight shipment. The period of delay for a mainline accident is estimated by assuming that for each collision, two trains were delayed for one day each. An alternate approach calls for estimating the customer and customer traffic lost as a result of accidents and accident-induced service delays. This approach was utilized in the cost-effectiveness test of journal standards.

- Locomotive Costs -- The value of a locomotive-day will be multiplied by two and used as the value of the loss of the locomotives' time in delays from collisions.

- Lost Customer Traffic -- A complete assessment of lost customer traffic would require an analysis of accidents and declining ton-miles on specific routes, or at least on a large number of railroads. The latter analysis can be performed to test the relationship between loss of traffic and accidents of different types. The cases of declining ton-miles can be converted to revenue losses.

3.5.2 Allocation of Benefits to Types of Accidents

Types of accidents for the purpose of cost-effectiveness analysis include the train accidents as attributed to various causes in the FRA Accident Bulletin. The types of accident causes are summarized in Table 4 (page three of the 1973 Bulletin), and are shown in detail in Tables 102, 103, and 104. These causes are all subdivisions of the train accidents classification, which in 1973 totaled 9,375 accidents.

The three basic causes are negligence of employees, failures of equipment, and improper maintenance of way and structures.

Based on the proportions of each type of accident cause relative to the total number of train accidents, the value of damages and other dollar amounts has been allocated proportionally among accidents by type of cause, so that an estimate can be made of the losses and damages due to bearing accidents, draft gear accidents, etc. In some cases, the total losses due to accidents must first be allocated among the broad categories of train, non-train, and train service accidents, before dividing the damages among types of causes, which are only provided in the Accident Bulletin for train accidents. This procedure will provide a rough estimate of the accident costs for given categories of accidents and thus provide a check or benchmark for the other more specific aggregated cost data.

An example of how such data on damages and expenses can be allocated to accidents of various types is shown in Table 7. Although this figure only shows percentage allocations for the three basic types of accidents, the allocations could be applied for types of accident causes within the broader categories. The expenses of clearing wrecks would not be associated with non-train accidents, so the figure tabulated by the ICC in Transport Statistics is allocated to train and train service accidents. The "Injuries to Persons" data are figures of total personal

TABLE 7
Sample Allocation of Railroad Costs of Accidents, 1971

	Total Accidents	Fatalities and Injuries (and percent)	Wreck Clearing Expenses ($)	Injuries to Persons ($)
Train Accidents	7,304 37%	865 (4%)	14,236,490 (37%)	4,722,080 (4%)
Train Service Accidents	12,562 63%	13,963 (67%)	61,074,603 (63%)	79,094,840 (67%)
Non-train Accidents	*	6,154 (29%)	*	34,235,080 (29%)
TOTALS	19,866	20,982	$38,477,000	$118,052,000

*Non-train accidents omitted because total accidents figure is not relevant to costs of clearing wrecks.

injury and fatality awards in rail accident cases, also published by the ICC. These data are allocated among the three major types of accidents.

3.5.3 Estimation of Reduction in Accidents

Research thus far has revealed that the cost-effectiveness approach to evaluating rail safety standards is not limited at this time by deficiencies in analytical methodology. Rather, the principal limitations are the lack of substantive information on the nature, costs, and causes of railroad accidents. Unfortunately, there is no set of procedures that will provide exceptional penetrating power or reliable approximate answers to problems characterized by incomplete or poor data and large uncertainties.

In completing any cost-effectiveness analysis, perhaps the single most sensitive calculation required is the determination of the probable numbers of accidents that will be prevented by a given safety standard, since this calculation will determine the magnitude of benefits to be derived from promulgation.

The ability to measure overall effectiveness and indeed to prescribe effective safety standards in the first place, is governed to a large extent by the degree of understanding of what is happening in accident situations. A considerable amount of descriptive information is required before diagnosis and remedial action can be put on an objective policy. Developing a clear picture of the detailed cause and effect relationships, the interacting of multiple causes in a typical accident creates demands for quantitative information and relevant data which must be satisfied.

In order to calculate the root causes of railroad accidents, it will be necessary to formulate hypotheses and measure the relationship and association between factors found in the accident environment. Observation data must, as a consequence, consider human factors, the actions taken by participants -- crew members, environmental factors -- weather, visibility, etc., operating conditions -- speed, track condition, train dynamics, etc., and equipment or component conditions. Interactive conditions must be identified; the classic example in railroad accident analysis is perhaps the case of a worn wheel picking a worn switch point. Much of the present understanding of such interrelationships is inadequate and consequently, the data tasks must be completed in order to provide a foundation for subsequent analysis. Once established, a number of techniques can be followed in diagnosing accident causes. Briefly summarized, they are:

- Descriptive Modeling,
- Regression Analysis,
- Designed Experimentation,
- Computer Simulation, and
- Use of Expert Opinion-Delphi Approach.

Descriptive Modeling can help to explicate the association that exists among accident types, contributing factors, and remedies, but such a process can reveal that many elements are unrelated to others, and that the number of interconnections is generally too high to permit the postulation of simple relationships. Direct measurements, as a consequence, become difficult as many of the relationships are often non-linear in character.

Regression Analysis can be used to measure the strength of relationships of variables to accidents. In the early stages of this project, CONSAD developed a method for predicting accident reductions from the promulgation of a safety standard by using regression analysis to relate numbers of accidents to a "condition ratio," which is explained later. Since the input data required to use the equations in a predictive mode were difficult, if not impossible, to come by, the technique could not be relied upon as the principal technique for predicting standard effectiveness. Nevertheless, in many situations, particularly in the cost-effectiveness analysis of track standards, this technique can be applied as there is considerable data available from the ICC on railroad expenditures in given track and roadway categories (ties and rails, for example). Accordingly, a general description of how the technique was used in compiling the numbers of accidents prevented is presented in the new few paragraphs.

As noted previously, the additional effort in maintenance will result in additional maintenance expenditure, whether in track or equipment or other categories of railroad operations. If traditionally, accidents of specific types have been reduced by making increased expenditures in the maintenance category, then it should be possible to predict the number of accidents that will be prevented by using increased maintenance expenditures as the basis for the prediction. The number of accidents to be prevented would be a statistical prediction, i. e., it would have some error or uncertainty associated with it, but at least it would serve to identify an approximate degree or rate by which accidents would be reduced as maintenance expenditure increased.

To identify the relationship of accidents to maintenance expenditure in the past, a third factor must be considered: the use rate or work performed by the track and equipment. Consideration of this factor is necessary because it is a measure of the forces working in opposition to maintenance effort. In other words, in order to reduce accidents, the effort exerted must overcome the work and wear imposed on the system, and must improve the system condition enough that failures are reduced.

The work imposed on the system divided into the maintenance effort is a measure of the relative intensity of the two factors, and is referred to as the "condition ratio." The measure of work used in the example that was considered is the number of ton-miles travelled by the trains on a rail system. (Alternatively, work can be measured in train-miles.)

The general form of the equation is:

$$\begin{matrix}\text{Total Number of Accidents} \\ \text{Due to Failures in Track} \\ \text{in Any Given Year}\end{matrix} = A - B \cdot \left(\frac{\begin{matrix}\text{Total Investment in} \\ \text{Track in That Year}\end{matrix}}{\text{Total Ton-Miles}} \right)$$

This expression states that an increase in the magnitude of the condition ratio (either more maintenance dollars or less work) will increase the subtractive term which produces fewer accidents. The equation is valid only over a limited range; obviously, a large enough investment will not produce a negative number of accidents as the algebra would indicate.

When accidents, investments, and work have been determined for past years, regression procedures are applied to determine the relation of maintenance to the occurrence of accidents. The regression procedures produce a series of equations which can be used to predict the reduction in accidents on the basis of increased maintenance expenditure, providing a reasonable forecast of work can be made. These equations will give a rough estimate of how many dollars must be invested in maintenance for each ton-mile, or for each train-mile, for a given level of accidents.

There are several other problems with this application of regression analysis. One of these is the lag in the effects of track and road investments. Deferred maintenance, in some cases, will take several years to impact safety. However, this regression methodology is a powerful tool if the associated problems are handled satisfactorily.

Designed Experimentation can be used to estimate the effectiveness of any proposed safety standard. However, actual establishment of field experiments may be costly depending on the nature of the standard involved and may be risky to undertake. In the real world, the establishment of failure conditions may involve the deliberate exposure of people and goods to high-risk situations.

Laboratory experiments, on the other hand, while very safe, often lack some of the ingredients which are instrumental in certain types of accidents. For example, the switchover from cotton waste to manufactured pads improved the lubrication environment considerably for plain friction bearings on freight cars. But it also increased the pilferage rate from journal boxes because the pads burn for hours in stoves and grills. "Missing pad" is a standard hot box "cause" on many railroads' reporting forms.

Computer Simulation, a far safer approach, and one often used by military planners, is to simulate the various processes of interest in order to measure overall effectiveness. With this technique, input elements can represent single functions or distributions that can be measured unambiguously and by random sampling to generate accident situations, "the failures or accidents" can be counted under trial exposure conditions. Accident severity distributions can be included as part of the sampled elements. In this manner, many sequences of designed experiments can be carried out, rapidly and economically, listing a variety of parameters in the process.

Use of Expert Opinions -- Due to the many deficiencies in existing information concerning the effectiveness of various factors that bear in accidents, it may be difficult, if not impossible, to determine relative effectiveness of any standard strictly on the basis of objective analysis and scientific evidence. In practice, reliance on expert opinion is often necessary, and may be the best approach for FRA to consider in determining overall effectiveness. The Joint Task Force, discussed in previous sections, is one manner in which a body of expert opinions can be established and utilized in the determination of standard effectiveness.

The experts opinions can be drawn by using a Delphi approach which has evolved as a fairly systematic method for the solicitation and collection of informed judgments on a specified topic. It has a high communication content, especially of a feedback nature, which is enhanced by a high degree of anonymity on the part of the participants.

3.5.4 Summary

The preceding discussion has reviewed how the various benefits to be obtained by railroads from accident reduction can be measured in the recommended cost-effectiveness methodology. These benefits can be measured in dollars, or in number of accidents avoided, and they can be related directly to types of maintenance, in both the way and structure and in the equipment categories when regression techniques are employed. The criteria for selecting the most appropriate techniques would naturally be determined to a great extent by the standard being evaluated, the data available, the complexity of the accident environment, and normal budgetary constraints.

3.6 Societal Benefits

Societal benefits are defined to be the total sum of all benefits which society receives from the promulgation and implementation of rail safety standards. This sum does not include those benefits which accrue directly to railroads. Calculating these benefits is one of the most important features of the methodology outlined here, inasmuch as past resource allocation decisions made by FRA, DOT, and Congress, with regard to railroad safety, may have been limited to evaluations based on direct out-of-pocket costs. This approach has conceivably resulted in an underutilization of funds for safety and a misallocation of resources among various types of safety programs.

In principle, all conceivable costs and benefits should enter into the evaluation of railroad standard tradeoffs, in practice, however, there are major barriers to doing so. The principal barrier is the danger of double-counting or listing an item as a cost element and then listing it again as a benefit element. In order to avoid double-counting, we have included, in the design of our methodology, the calculation of all direct and indirect railroad industry costs, along with the direct societal costs and benefits. (A direct societal benefit is, for example, the avoidance of accident costs.)

The inclusion of indirect societal benefits was rejected to avoid double-counting. For example, a particular safety standard will require a railroad's purchasing additional material and hiring additional personnel to effect compliance. This represents a direct cost to the railroad and an entry in the cost side of the cost-benefit ledger. These same expenditures, however, represent indirect societal benefits to the material suppliers and those that are hired. However, by including these indirect societal benefits in our compilation, we would be double-counting.

Since economic activities are largely circuitous and double-entried, the more complete the enumeration of costs and benefits, the more difficult it is to avoid double-counting -- which is why a line must be drawn at some point to minimize this possibility. This is not to say that the indirect societal benefits should not be calculated and considered by the evaluator. Indeed, we think it of paramount importance that recognition be given to the potential indirect benefits that railroad expenditures will have on labor, railroad industry suppliers, and other potential beneficiaries. For many public decisions, the sole justification is in the distribution of indirect benefits. However, for the purpose of rationally evaluating the overall cost-effectiveness of alternative standards, we cannot permit double-counting.

In summary, all direct and indirect railroad costs will be calculated, along with all direct societal costs and benefits. Indirect societal costs and benefits will be taken into consideration by the evaluator but would not be entered into the calculations of costs and benefits summations.

In the light of the above discussion, the major part of societal benefits are really the benefits that will result from the elimination of accident costs. Therefore, in the ensuing discussion, when societal accident costs are referred to, we are really describing potential societal benefits. There are, of course, other benefits that society will receive as a consequence of promulgating railroad safety standards, and other safety countermeasures. However, the elimination of accident costs is by far the largest and most important potential benefit.

It was the recognition of the societal costs of railroad accidents that prompted Congress to pass the Railroad Safety Act in 1970. The catastrophic consequences of the rash of accidents that occurred in 1969 dramatically registered on the public consciousness the costs of serious railroad accidents and mandated some type of corrective legislation action. Often the real societal costs of smaller, less spectacular, accidents go unnoticed in comparison, but they are nonetheless real and far more numerous. Consider, for example, the pain and suffering of those injured, or the grief and bereavement of families that have lost loved ones, a father, mother or child in railroad accidents. These are important societal costs that must be considered by the FRA in properly fulfilling its responsibilities to the railroad industry and the public-at-large.

It is well recognized that it is impossible to place a value on a human life and no less difficult to truly gauge the losses resulting from injuries or disabilities. Undoubtedly, the value that any individual places on his or her life is infinite. Nevertheless, for cost-effectiveness analysis, some measure of the economic losses to society of railroad casualties is necessary. Our approach has been to identify all known societal costs and then present quantitative estimates of as many of the losses associated with railroad accidents as is possible. Even if data are lacking, we feel it essential to provide some reasonable dollar estimate of the cost, inasmuch as a failure to include some cost would imply that a zero (quantitative) cost is assumed.

A complete enumeration of all societal costs was considered necessary in order to:

- Facilitate the determination of funds to be spent improving railroad safety,
- Assist in determining the most cost-effective safety standards among the many possible candidates which have been, and are being, developed, and
- Enable previously established standards to be reviewed in light of their cost-effectiveness.

In interviewing the railroads, the existence of societal costs resulting from accidents was never questioned, rather, the question was raised as to the extent to which the industry could afford or should afford to pay for these costs, and the dollar values that should be assigned to each component.

We have not attempted to determine who should pay for railroad safety nor to debate the relative merits or issues involved. Obviously, it could be argued that these societal costs result from railroad accidents and therefore the industry should bear the brunt of all costs to eliminate or reduce such accidents. However, this would ignore the critical financial condition of the industry and its importance to the nation as a whole. By any economic measure, a further weakening of the railroad industry through the imposition of safety standards that are grossly cost-ineffective could not be countenanced. It is rather the responsibility of the FRA to determine the delicate line between what is too much and what is too little to pay for safety, having before it a complete and comprehensive cost-effectiveness analysis of the standards involved.

3.6.1 Comprehensive List of Accident Costs

Reduction or elimination of accident costs is the principal benefit inuring to society as a consequence of safety standard implementation. The following list of accident costs was developed to insure that no societal costs would be overlooked in the analysis of safety standards.

Societal Benefits - Summary Table
(Societal Accident Costs)

Property Damage to Non-Railroad Property
(Not Paid for by Railroads)

Community Costs (Not Paid for by Railroads)
- Evacuation Costs
- Fire, Police
- National Guard
- Other

Personal Injury and Fatality Costs (Not Paid for by Railroads)
- Wage Losses -- Railroad Employees
- Wage Losses -- Non-Railroad Employees: Adult, Child
- Hospital Costs
- Other Medical Costs
- Funeral Costs
- Insurance Administration Costs
- Pain and Suffering
- Home and Family Duties
- Time and Money Losses to Others
- Community Services
- Assets

Societal Benefits - Summary Table (continued)

Total Personal Injury and Fatality Costs
Less Railroad Payouts (Compensation)
Total Societal Costs -- Personal Injury and Fatalities

3.6.2 Data Sources

For the most part, data for measuring the societal costs of railroad accidents is limited, thus constituting an important data gap affectting implementation of the economic impact methodology. Regularly published data appears in the yearly FRA Accident Bulletin and the individual railroads' Annual Reports to the ICC, both of which publications have been mentioned previously. These cost data, however, represent only a portion of the direct railroad property losses and damage incurred in railroad accidents. Thus, the real potential benefits to society and to the railroad industry of safety improvements are obscured by a lack of statistics measuring the total societal costs of railroad accidents, as well as certain categories of direct costs which the railroads must bear, e.g., cost of clearing wrecks.

There is some information provided in the National Transportation Safety Board's accident investigation reports under the headings "Damages" and "Casualties," but it is also limited, and covers only a few of the major accidents that occur during a year. State statistics on railroad accidents are largely confined to data on railroad-highway grade crossing accidents and insurance companies have, as far as we could determine, little information which would measure societal costs.

The AAR collects information on personal injury or fatality compensation; however, due to economy measures, the AAR was forced to abandon its collection activities for several years. The AAR has resumed collection of these data at the request of a number of railroads, and anticipates having payout data on a regular basis. While this information is useful for measuring the railroad settlement costs for personal injuries and claims, it does not provide any measure of the societal costs involved. Obviously there are many cases where employees are killed or injured through no fault of the railroad but through their own negligence, and in these cases, the railroad may make only a token settlement or contribution to compensate for the employees total losses. Other measures and data sources are thus required.

The National Highway Traffic Safety Administration (NHTSA) has produced a preliminary report on "The Societal Costs of Motor Vehicle Accidents" which was helpful in reviewing the types of societal costs pertinent to railroad accidents. We have used their estimates of the less tangible accident costs, where applicable, in lieu of alternative available data. NHTSA's estimates are largely derived from highway accident cost data, and were in some instances based on studies which would not permit precise estimation. Cautious use should be made of their estimates since:

"It is clear that current data are inadequate for precise estimation of societal costs. There are problems of comparability, reliability, and comprehensiveness with the studies that have produced data on the various components. Therefore, the estimates produced for this analysis should be viewed as interim measures and subject to revision as new data and methodology become available."*

In view of the scarcity of data on societal costs of railroad accidents, greater reliance has been placed on estimation techniques in our methodology. However, it is recommended that a research program be initiated to determine the nature and extent of railroad accident costs. This recommendation will be discussed subsequently in greater depth.

3.6.3 Property Damage to Non-Railroad Property

In determining this cost, it is important to recognize that railroads are already paying for a portion of the total damage to non-railroad property, and consequently, it will be necessary to determine those damages for which no compensation is made. A careful review of the FRA accident statistics and T-Reports, along with the NTSB reports, should be undertaken to determine the relative size and cost of the accident types under consideration. Generally speaking, the larger the accident, the greater the probability that there will be some societal property damage.

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*U. S. Department of Transportation, National Highway Traffic Safety Administration, The Societal Costs of Motor Vehicle Accidents, p. 8.

Additional queries can be made of railroad safety, operating, and claims personnel familiar with accident circumstances to ascertain the extent of non-railroad damage and degree of compensation rendered by the railroad. In most cases, it will be desirable to question local officials familiar with the accident and the non-railroad parties directly affected to determine the extent of uncompensated losses. In this manner, an estimate of the extent of societal property damage can be developed for each accident type, along with a measure of the amounts involved in the typical accident. This information can be used to calculate an average cost for societal property damage for that specific accident category. In the methodological test, which will be discussed in Section 3 of this report, the societal costs associated with accidents due to journal failures were developed through extensive phone interviewing of individuals involved or familiar with the accident circumstances. This proved to be a highly successful method for determining the nature of non-compensated accident costs and based on the responses, it was felt that FRA would have equal success in measuring societal accident costs using this technique.

3.6.4 Community Services

Large railroad accidents frequently require assistance from local police, fire, and other groups like the Red Cross and/or National Guard. In our railroad interviews, we learned that some of these costs may be paid by the railroad but more frequently are absorbed by the local community. As an example, one of the carriers being interviewed discussed a recent accident that necessitated the evacuation of an entire town: "The decision to evacuate the town was made by local officials as a general safety precaution; Why should we have to pay for this?"

In order to develop some measure of the economic costs of community services expended in rail accidents, it will be necessary to follow the procedures outlined in the previous section on non-railroad property damage, examining all available reports on the accident in question, and then following up with on-site investigations to determine the extent of compensation for community services. The results of the methodological test suggest that while railroads often make some restitution for the costs of community services engaged in a rail accident, in many cases, no compensation is made.

3.6.5 Personal Injury and Fatality Costs

As an introduction to discussing how the societal costs of personal injuries and fatalities can be calculated, it is instructive to consider in how many ways a railroad accident which fatally injures a person can diminish social welfare. Consider the following example, given in the NHTSA study on "The Societal Costs of Motor Vehicle Accidents," of an individual fatally injured in an accident:

TABLE 8
Personal Injury Costs

Cost Component*	Fatality	Permanent and Total Disability	Partial Disability	No Permanent Disability
Hospital	$ 787	$ 5,618	$ 1,798	$ 129
Other Medical	478	3,146	1,348	225
Funeral	1,011	---	---	---
Legal and Court	2,921	3,034	843	112
Insurance Admin.	4,382	4,157	4,157	449
Losses to Others	1,461	11,236	1,348	112
Employer Losses	1,124	1,124	---	---
Community Services	7,865	7,865	2,022	---
Pain and Suffering	11,236	56,180	11,236	112
Home and Family Duties	37,079	39,326	10,112	56
Assets	5,618	2,247	---	---
Total, Per Occurrence	73,962	133,933	32,864	1,195

*The values in the table are estimates of 1973 costs per accident. The assumption is made that railroad accident costs are similar to automobile accident costs.

"1. The individual was a producer of goods and services. The value of his output can be measured by his wages. With this income, he and his family derived welfare through the consumption of goods and services.

2. As a result of the accident, there were medical fees, vehicle repairs, insurance and legal costs, time and money spent by friends, and relatives, etc. These are all losses in welfare and can be defined in terms of opportunity costs. The vehicle repairman could be building schools, the doctor could be treating illnesses and diseases, the lawyer could be engaged in some welfare-producing activity such as consumer protection.

3. The individual experiences pain and suffering, and his family and friends grieve. His children now lack parental guidance and companionship. There is no way of accurately measuring these very real and very significant losses to societal welfare. However, a very gross approximation of how society values such losses can be derived by what preferences have been revealed in the past. Court awards for pain and suffering are an example.

It should be made clear that changes in societal welfare have little if any relevance to the gross national product (GNP).

Also, the incidence of a welfare loss has not been a consideration in this analysis. Although an individual may be more than adequately compensated by his insurance company and he feels that he is now even better off than before the accident, there has still been a loss to society -- the incidence in this case is on those paying insurance premiums. Additionally, it is not relevant that some losses are compensated by insurance payments or court awards and others are not. The loss has occurred in both instances."

Each of the basic components of personal injury costs which should be initiated in a cost-effectiveness analysis of proposed safety standards has been itemized and will be discussed in turn.

3.6.6 Wage Losses

The largest single societal cost component resulting from railroad accidents is the value to society of the lost earnings that the individual would have received had he lived or continued in an uninjured state.

In order to calculate the value of these earnings, we recommend that three categories of people killed or injured by railroad accidents be utilized: adults, children, and railroad employees. The latter breakout is suggested inasmuch as average railroad employee earnings are somewhat higher than the median incomes for all other types of workers and their wage losses to society would be greater. In addition, FRA accident statistics readily distinguish between employee and non-employee injuries so that this data is available to facilitate these calculations.

In computing the value of wages lost, it is necessary to determine first the average number of working years available to the individual had he lived. We have assumed the mean age of all railroad employees killed in rail accidents to be 45 years, corresponding to the mean age of all living railroad employees.* Consequently, the fatally injured employee will have had an average of 20 years of productive life remaining. Computations of future wage earnings should consider possible increases in real income-productivity increases, and we have assumed a 3 percent increase per year based on an extrapolation of past productivity increases.

In addition, the future flow of earnings should be discounted to present values to reflect society's time preference for the immediate return versus the less certain future return. The rate selected for discounting future wage losses to society is the most important single factor in the earnings calculation, since a slight change in the discount rate can make a major difference in results. We have utilized a 10 percent discount rate, which is considered rather high by many experts, but is the rate currently recommended by OMB to be used to calculations of this nature. As illustrated in Table 9, the discount factor tends to concentrate 75 percent of the lost wages into the first 12 years.

A similar approach is being followed to calculate the average value of lost earnings for employees who are permanently or partially disabled, and for adults and children that are killed or injured as a

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*Data provided by Railroad Retirement Board.

TABLE 9
Cost of Lost Wages

Year	Probable Average Income - Assuming a 3% Net Gain Due to Productivity Increase	Discount Factor 10% - Recommended by OMB	Present Value of Lost Future Wages
1973	13,000	-	-
1974	13,390	x .909	= 12,172
1975	13,792	x .826	= 11,392
1976	14,206	x .751	= 10,669
1977	14,632	x .683	= 9,994
1978	15,071	x .621	= 9,359
1979	15,523	x .564	= 8,755
1980	15,989	x .513	= 8,202
1981	16,469	x .467	= 7,691
1982	16,963	x .424	= 7,192
1983	17,472	x .386	= 6,744
1984	17,996	x .350	= 6,299
1985	18,536	x .319	= 5,913
1986	19,092	x .290	= 5,537
1987	19,665	x .263	= 5,172
1988	20,255	x .239	= 4,841
1989	20,863	x .218	= 4,548
1990	21,489	x .198	= 4,255
1991	22,134	x .180	= 3,984
1992	22,798	x .164	= 3,739
1993	23,482	x .149	= 3,499

TOTAL $139,957

result of railroad accidents. These calculations will be presented as tables in the cost-benefit manual being prepared for FRA personnel to facilitate calculating the societal costs of lost wages for each category of accident being considered.

3.7 Special Problems and Methods

In performing economic impact analyses, some special problems arise. For example, all dollar amounts should be compared as of the same point in time; this requires discounting. Also, to avoid the consideration of events into the infinite future, a realistic time span must be chosen. These and related problems, along with recommended solutions, are discussed below.

3.7.1 Initial Costs and Benefits

In the case of implementing the safety standards, some railroads will choose to capitalize much of the compliance cost through long-term financing, while others will choose to cover the entire cost of the implementation from their annual operating budgets (expensing). In order to enable the cost-effectiveness methodology to be applicable to a variety of plans, the assumption is made that some of the costs of implementation are treated as immediate capital costs, and some are treated as ongoing operating costs. The immediate capital costs are called the inital costs, and the recurring operating costs are treated as ongoing costs. A procedure for assessing immediate or initial costs and benefits was outlined in Figure 7.

Even in the case of the immediate capital costs, these may be "long-term" if the capital is obtained specifically from bonds or long-term loans. For estimating a relatively severe cost which might accrue to a railroad which had difficulty securing long-term financing, for example, the cost-effectiveness methodology is designed to consider a portion of capital costs as immediate. Some costs will probably require long-term financing of some form (equipment trust certificates, conditional sales agreements, mortgage bonds) as, for example, the cost of replacing all freight cars over 50 years of age. Even if the railroad industry as a whole replaces all the obsolete cars fairly soon, the costs will be spread over many years. For this reason, the replacement of obsolete cars has been listed under ongoing costs in Figure 16.

The distinction between immediate and ongoing benefits is even more difficult to draw than for costs, but it is safe to assume that all benefits will not begin to be received immediately after implementation of the safety standards. Inspection of a large portion of the track and of the freight car fleet will have to occur, and then some portion of the replacement and repair will be necessary, before benefits are felt. If the implementation of equipment standards takes about two years, as has the implementation of the track standards, it is reasonable to assume that much of the benefit will be appearing at the end of the second year, and all of these benefits will have reached a stable level by the end of the fourth year.

FIGURE 9
Distinction Between Immediate and Ongoing Implementation Costs

<u>Immediate</u>

Track	Equipment
Hiring and training new inspectors	Hiring and training new inspectors
Replacing ties and rail	Replacing components

<u>Ongoing</u>

Track	Equipment
Maintenance to track	Replacing obsolete cars
Inspections	Inspections

3.7.2 Ongoing Costs and Benefits

Based on estimates of some carriers to acquisition rates for freight cars which are normally depreciated for IRS purposes over a 15 year period, we have selected this time horizon for calculating all continuing costs and benefits. The procedure for these calculations was outlined in Figure 8. Certain improvement costs resulting from compliance activities such as relaying rail and replacing ties and reconditioning of equipment can be expected to continue indefinitely, hence, beyond the 15 year period, as will the corresponding benefits derived. Nevertheless, this planning horizon will provide sufficient time for most replacement and repair and for benefits to reach their long-term stable level. Extending the period of calculations further into the future raises the uncertainties of longer-term financing and the effects of technological shifts on operating and marketing patterns. In 20 years, railroads may be operating in a completely different environment with substantially altered technology which may or may not be affected by safety standards developed today. Thus, limiting the calculations of costs and benefits to 15 years is a reasonable compromise between long-term uncertainty and the need to measure fully the beneficial effects of the safety standards.

3.7.3 Discounting Future Benefits

Some of the risks of costs and extended benefits for an indefinite period of time into the future can be compensated for by discounting future flows. Economic impact analysis is concerned with recommending whether specific investments should be undertaken here and now in order to gain benefits in the future. Safety standards are introduced in the present so as to gain the benefit of reduced accidents in the future. Two major reasons exist for discounting the future flows of costs and benefits derived from introducing safety standards: (1) to reflect a societal preference for earlier over later benefits, and (2) to reflect the opportunity cost of investing in safety rather than in other possibilities. Each of these two reasons are discussed in more detail in the following two paragraphs.

Individual consumers in our society are continually faced with the problem of whether to spend their money now or whether to invest their money for a greater future benefit. If the future benefit gained through investment is not in excess of the present benefit gained through spending, then consumers in general will spend their money now. Similarly, society will only invest funds to gain future benefits if these future benefits exceed the present benefits from using the funds here and now. If society makes an investment now and has to wait a long time for a return, then the value to society of the benefit is normally regarded as less than if it were available earlier. The discount rate used to discount the value of future flows of benefits is commonly assumed to reflect society's preference for present benefits as opposed to future benefits. The OMB recommends the use of a 10 percent discount rate to discount the future flows of benefits arising from the application of railroad safety standards.* This implies that society is indifferent between, say, $100 million of benefits today and $110 million of benefits next year. The higher the discount rate which is employed to discount the future flows of benefits, then the more weight which is given to the earlier benefits of public investment and the less weight which is given to benefits expected in the more distant future (say 10 to 30 years from now).

The decision of society to invest in safety standards for the railroads generates an opportunity cost for society in that funds allocated for safety standards are no longer available for using here and now nor for making other investments. Society has limited funds at its disposal which it needs to allocate in such a way as to maximize the benefits to society. Investment in safety standards for railroads is an investment to obtain benefits to society over a relatively long period in the future. The discount rate is chosen so as to reflect the opportunity cost of investing in safety standards for the future rather than of investing in another project whose benefits are realizable sooner.

*DOT 5000.1, OMB, 6-30-72.

3.7.4 Discounting Future Costs

Not only is it necessary to discount future benefits to their present value, but the same procedure must also be applied to the flow of costs incurred over a multi-year period. The reasons for discounting costs down to their present value are similar to those given for discounting benefits. Not only is the money being used for a purpose other than earning interest, but also the costs incurred at present appear higher than costs incurred in the future.

Thus, if track and equipment maintenance costs are expected to be an amount of X dollars in the future, the amount appears smaller than if the X dollars had to be spent at once. To calculate the total cost of the maintenance program over several years, the cost for each later year must be added to the first year's cost, but they must be added in dollars the same size as those spent in the first year, which appear larger than those to be spent later. Therefore, the later costs are reduced by discounting.

A separate factor in the size of costs and benefits is inflation, which has the effect of raising costs and benefits over time. Because goods and services in the future become more expensive and valuable, the dollars paid and received for them are more than if they were bought or sold at present. If the rates of inflation for both costs and benefits are the same, then actual increases are not calculated in the impact analysis procedure. Under a single inflation rate assumption, all future dollar amounts may be expressed in constant dollars and the present value may be obtained by the use of a single discount rate such as the 10 percent recommended by OMB.

3.7.5 Net Cost-Effectiveness

Two further steps will be necessary before the cost-effectiveness methodology will yield a specific comparison between costs and benefits. First, the expected number of accidents must be projected 15 years into the future (1988). This projection will be done on the basis of an analysis of past trends coupled with a forecast of dynamic factors influencing the future trends, without the satety standards. The expenses associated with the projected accident rate will be calculated, but the important result will be the difference between the projected "undisturbed" number of accidents, and the number expected with the safety standards in effect. The reduced number will be calculated using the procedures discussed earlier.

The second important step thus is the calculation of savings from the reduced level of accidents. These savings will be calculated using the procedure described earlier, in which a specific amount of dollars to be saved from a specific type of accident was determined. In other words, the total number of accidents avoided is allocated to a series of types of accidents and the value or expense associated with each type of accident is added to those of all types of accidents to produce a total amount expected to be avoided. For each type, after the total benefits over the 15 year period are calculated, the total costs will be obtained, and then it will be possible to calculate the difference between the two, the net savings or net cost-effectiveness. The results of this calculation for a given safety standard can then be compared to other similar cost-benefit results to determine the most cost-effective safety standards. The entire procedure is outlined in Figure 10.

FIGURE 10 Net Cost Effectiveness Procedure

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total 15 year costs	Total 15 year benefits
	initial costs							ongoing costs									
COSTS																	
track replacement																	
tie replacement																	
equipment components																	
inspections																	
freight car replacement																	
total costs discounted to present value →																	
BENEFITS																	
accidents																	
without standards																	
with standards																	
prevented accidents x cost/accident (rail industry plus societal)																	
total benefits discounted to present value = →																	
NET COST EFFECTIVENESS (total benefits less total costs) →																	

4.0 SUMMARY DATA DEFICIENCIES: RECOMMENDATIONS FOR CORRECTION

In previous sections, the principal data components necessary for cost-effectiveness analysis have been discussed and recommendations have been made for developing or estimating data not otherwise available. This section will briefly summarize the principal data deficiencies that have thus far been identified, and will recapitulate the recommendations for development. It is obvious that data derived from estimation techniques are oft times poor substitutes for exact figures; nevertheless due to the shortage of certain data components some estimating procedures must be followed.

We have arranged the listing of data gaps in three groups corresponding to that which is readily available, little available, and relatively unavailable. Certain types of data that are readily available to carriers or perhaps the AAR may have been categorized as unavailable, if it was felt that the FRA would not be able to secure them. Thus, the ordering and identification of data deficiencies required a subjective evaluation of the extent to which FRA could develop the necessary information.

In the far right hand column of the following summary Table 10), we have listed recommendations for either estimating or developing the data components. If all of the data requirements for conducting a cost-effectiveness analysis of safety standards were met, the actual calculations could be performed in a simple, straight-forward manner with a minimum expenditure of time and manpower. Thus, the cost of conducting cost-effectiveness analysis is directly related to the data available for making the basic calculations.

Our research thus far has shown that little of the necessary data is immediately available to FRA and that substantial additional data development is necessary in order to perform complete cost effectiveness analysis with minimal expenditure of funds. FRA, by virtue of its legislative mandates and powers, does have the authority to correct most of the data gaps through revisions in the accident reporting system. We recommend that this authority be exercised, not just to provide information for cost-effectiveness analysis, but to provide the basic data necessary to quantify what railroad safety really means to the railroad industry and to the country as a whole. The relative costs of providing this information, which must be borne directly by the railroad industry, should naturally be taken into consideration before making any revisions in accident reporting.

TABLE 10 DATA DEFICIENCIES

Availability of Data to FRA	Description of Data Deficiency	Recommendations for Correction of Data Deficiencies
Relatively Unavailable	Number of defectives, equipment components, track components,	Field sampling program to determine any condition.
	Component failure that cause accidents, manufacturer name, date of manufacture, serial number of part, type, etc.	Revise T-form reporting criteria, urging the the identification & description of components that have failed.
	Rates on equipment components, expected life, expected mean time to failure.	Joint research program funded by FRA, AAR, and RPI.
	True accident causes	Expanded accident information system; Accident diagnostic analysis; multi-disciplinary accident investigation teams.
	Societal property damage.	Revise reporting criteria, carrier to provide estimate of damage on T-form.
	Societal personal injury costs.	Estimation, procedure.
	Societal costs, community services (fire, police, etc.).	Estimation, research NTSB reports.
	The number, type, and costs of non-reported accidents.	Estimation, develop multiplier.
	Age of non-employees involved in rail accidents.	Revise reporting criteria for T-form.
	Cost of service disruptions and delays to railroads.	Revise reporting criteria for T-form, have estimated total delays, in car and locomotive days reported by carriers.
Little Available	Installation costs (labor), replace defective components.	Can be readily estimated based on data provided by carriers.
	Cost of clearing wrecks.	Revise reporting criteria, report on T-form.
	Loss and damage to lading.	Revise reporting criteria, report on T-form.
	Cost of personal injuries and fatalities paid by railroads.	Develop estimates through carrier assistance and research of court settlements for individual accident types.
Readily Available	Loss and damage to railroad property (cars, roadway).	
	Cost of replacement parts, track equipment, etc.	
	Nature of fatality and injury in rail accidents.	
	Age and description of employees.	
	FRA costs to develop standards.	

4.1 Specific Data Deficiencies, and Recommendations

Some examples of problems encounted during this task are given below. The problems are illustrative in nature and are not meant to be definitive.

The method used in determining what accidents involving hazardous materials were caused by failed journals was tedious and time consuming. Every time a railroad experiences an accident involving hazardous materials such as explosives, flammable liquids or gases and poisonous liquids or gases, the carrier must file a Hazardous Material Accident Form, independent of the T-form, to the FRA. This form is filed and information from it and from a subsequent investigation if found necessary, is condensed and logged in a summary book or bibliography of Hazardous Materials Accidents. Nowhere, in this summary of accidents is the cause of the accident listed. As a result, it was necessary to review the T-forms for friction bearing accidents, record the date, location and Hazardous Accident Summary in order to determine what accidents involving hazardous materials were caused by friction bearing failures. This work would have been enormously simplified with the addition of the accident cause code to the Hazardous Materials Summary and/or some cross-referencing to the applicable T-form. After locating these accidents in the summary, the corresponding hazardous material file was reviewed to determine if any societal costs had occurred because of the accidents. Finally, after the accidents with these potential societal costs were located, an investigation of the major accidents was made to determine the extent of the societal costs that resulted. It is recommended that the Hazardous Materials Summary be revised to include the accident cause (code), or, at least, a cross reference to the T-form or the new Rail Equipment Incident Report.

For any kind of cost effectiveness study it is important to have all the costs of an accident. For example: The total cost for clearing wrecks in 1971 amounted to $38,477,000 for all railroads.* Since this is a major cost component of accidents, it is essential that it be included in any cost-effectiveness analysis of safety standards. It is therefore recommended that this information be included on Incident Reports by the railroads, and that the reporting criteria be revised accordingly. All railroads have this data readily available due to ICC reporting requirements and should be able to furnish it at minimal additional cost.

Wreck clearance costs are another piece of information which is lacking except from carriers' estimate of averages. This average figure overstates costs for single car derailment which constitute the majority of accidents, and greatly understates costs on more severe

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*ICC Account 415.

accidents. For calculation purposes, it is recommended that an overall average cost on cars be developed for each category of accidents being considered and that FRA obtain such estimates from cooperating carriers.

AAR reports a total of $36,782,768 in freight loss and damage due to train accidents for 1971. This information is currently developed by all carriers and is reported on a regular basis to the AAR. It is recommended that the reporting criteria be revised to include freight loss and damage estimates on the Rail Equipment Incident Report. Even though there is often a significant delay between the time of an accident and the settlement of all claims, the initial estimate would provide a basis for estimating eventual costs.

It is not recommended that personal injury costs, other than as reported on the Railroad Injury and Illness Summary, be reported. Personal injury costs are possibly the largest and most significant component of rail accident costs. While current FRA accident reporting requirements provide the number of persons injured or killed in an accident, the costs of the injuries are not provided for a given accident. Included in these costs are the following items:

- Compensation: actual claims paid to survivors and relatives of the deceased, or injured parties,
- Accident investigation expenses,

- Legal fees and administrative expenses,
- Witnesses - outside counsel,
- Claim personnel, administrative expenses, and
- Other personal injury expenses borne directly by the railroads.

This information could conceivably be provided by carriers on an annual report summarizing all personal injury expenses by accident codes. However, frequent revisions of the personal injury costs for each type of accident would have to be made as claims generally take an average of two years to be settled according to the railroad claims agents interviewed. In addition, the submission and publication of this data opens up the risk of inadvertently divulging figures which may be used against the railroads. There is considerable sensitivity about providing this information on a regular basis and feelings on the part of the carriers that some aggregation would be necessary to avoid disclosures which would divulge average settlement costs. Considering these reservations, and the time delays which will necessitate matching claim settlements and other personal injury costs against past accidents, it is recommended that an estimating procedure be followed for developing personal injury costs, rather than have carriers make estimates on the Incident Forms.

Similar reasoning applies to damages to non-railroad property. It is felt that limited description in NTSB reports and individual carriers' data will provide better information than would estimates made at the time of an accident.

In reviewing the fact that accidents may frequently tie up cars, locomotives and trains, a number of carriers pointed out that these costs should be taken into consideration in a cost-effectiveness analysis. One respondent suggested some railroad managers really had little idea of just how much an accident can affect its overall costs. In his words, "We may be paying now for an accident that occurred ten days ago." In order to provide a means of quantifying the effects of service delays caused by accidents, it is suggested that the total car and locomotive days lost, as a result of the accident be entered on the Rail Equipment Incident Report (Item 31 presently lists number of units involved).

This estimate can be then used by FRA to compute, using per diem averages, a measure of the economic costs of service delays. In estimating this figure, the carriers should include not only the immediate equipment involved in the accident, but all other trains and cars that were held up or delayed by reason of the track being blocked. One carrier regularly develops this information as part of its internal accident reporting system. It is recommended that the reporting rules be adjusted to develop this important accident cost component.

Another useful item would be the age of both employees and non-employees killed or injured in railroad accidents. This information which could be provided on the Annual Summary Report of Railroad Injury and Illness (Form FRA 6180.56a), facilitate calculation of the mean age of all persons killed or injured in railroad accidents which will improve the preciseness of lost wage and earnings calculations.

4.2 Summary Total for Accident Costs

It is strongly recommended that a summary table of all accident costs be developed for inclusion in the Accident Bulletin, along with appropriate individual tables listing total accident costs by carrier and by type of accident. Our reasons for making this recommendation are as follows:

- The real costs of railroad accidents need to be established and published in such a way as to provide guidance to management and governmental planners.

- Efforts to improve safety funding frequently founder on the lack of knowledge of total costs of rail accidents and thus the potential benefits of safety efforts. Some of the carriers' safety personnel made the comment that if their managements really knew how much accidents were costing them, they would give safety greater emphasis. Many expressed the idea that safety is difficult to sell because it's an intangible thing, but by being able to show the total costs of accidents, they felt safety efforts would be strengthened.

- By providing a summary of all accident cost, FRA can heighten public awareness of rail safety and the improvements that are being made.

- Individual carriers and FRA, through cost-effectiveness analysis of safety programs, can determine those measures which will be most cost-effective. Tables providing cost data on individual accident categories will greatly facilitate this analysis.

A sample summary table which has been constructed for illustrative purposes is given in Table 11.

4.3 The Reporting Threshold

In early interviews with Bureau of Safety personnel, it was learned that consideration had been given to revising the $750 reporting threshold for all accidents. It was believed that with the continuous rise in prices over the last 10 years, a substantially greater percentage of total accidents was being reported each year and thus there would be some justification for raising the reporting threshold in order to provide more uniform year-to-year reporting. Furthermore, by raising the reporting threshold, it would cut down on the number of reports the carriers would have to make to the FRA and hopefully improve the quality of the accident reporting.

There is no question that a fixed dollar threshold will distort any year-to-year comparisons or statistical analysis of accident trends due to inflationary price increases. If this were the only problem with the $750 threshold, it could be resolved by inflating the cutoff point for

TABLE 11 Sample Table Recommended for Inclusion in the Accident Bulletin
1971 Railroad Accident Costs (Illustrative)

	Railroad Industry Costs	Societal Costs	Total Costs
Property Damage	109,784,045[1]	5,000,000[7]	114,784,045
Wreck Clearing Cost	38,477,000[2]	500,000	38,977,000
Loss and Damage to Lading	40,000,000[3]	500,000	40,500,000
Personal Injury and Fatality Costs			
Est. Fatalities	15,000,000	334,000,000[8]	349,000,000
Est. Injuries	60,000,000	284,580,000	344,580,000
Other, Legal Fees, Etc.	43,052,000	--	43,052,000
Total	118,052,000[4]	618,580,000	736,632,000
Delays and Service Disruptions	7,000,000[5]	1,000,000	8,000,000
Community Services	1,000,000[6]	4,000,000	5,000,000
Non-Reportable Accidents: Property Damage Losses	22,500,000	100,000	22,600,000
Total	336,813,045	629,680,000	966,493,045

*This table, which is provided as an illustration for a Cost of Railroad Accidents Table to be included in the Accident Bulletin, includes the costs of rail highway grade crossing accidents, which account for an estimated 60% of the total fatality costs, 17% of the injury costs, and 3% of the property damage, wreck clearing, and loss and damage to lading costs.

[1]Reported to FRA on T-forms.

[2]ICC Account 415: Wreck Clearing Expenses.

[3]AAR reports a total of 36,782,768 in freight loss and damage due to train accidents for 1971. We have added 3,217,232 as an estimate of the loss and damage resulting from unreported accidents that was listed under the headings of Improper Handling and Concealed Damage.

[4]ICC Account 420: Injuries to Persons, estimated 15,000,000 fatalities; 60,000,000 injuries; 43,052,000, other legal, administrative expenses.

[5]Rough estimate based on percent of all carloads being delayed due to accidents. 25,000,000 carloads x 1% = 250,000 carloads. The average car is delayed four days at $5/per diem; 250,000 x 20 = $5,000,000. Locomotive delays at $2,000,000 = 100,000 hours x $20/hour.

[6]Estimate based on brief review of NTSB reports and other FRA accident reports.

[7]Estimated non-compensated property damage losses resulting from each accident.

[8]2,000 x ($200,000 - $33,000 railroad payment) = $167,000 x 2,000 - 334,000,000 fatalities; 18,972 injuries x 20,000 - 5,000 railroad payments) = 15,000 x 18,972 = 284,580,000. Note: these are very rough preliminary valuations. We have, therefore, excluded fatalities in the last row of the table so that the reader can make this comparison.

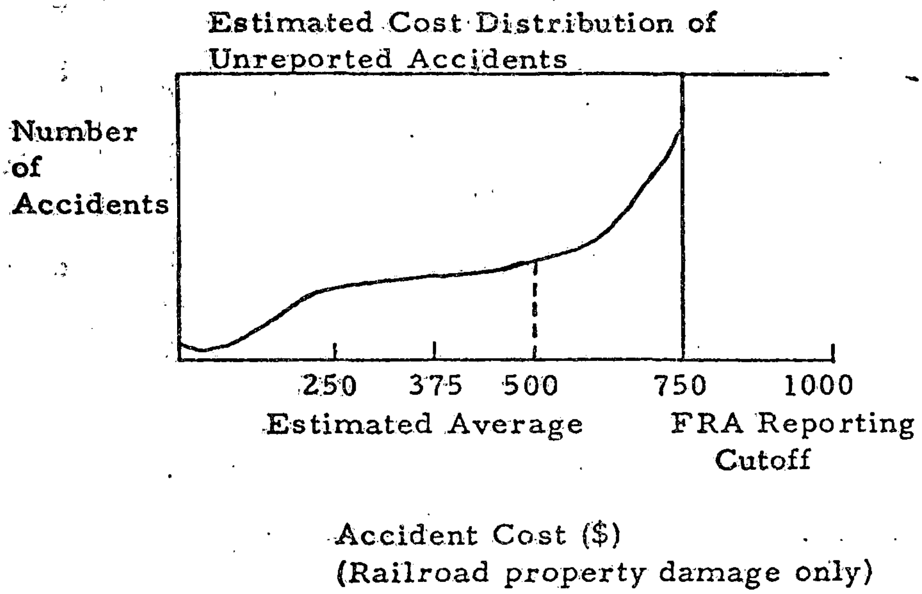
succeeding years by an approximate price inflator, and then adjusting the total accidents reported, based on the inflated cutoffs. In this fashion, the $750 reporting figure could be retained; however, only the figures exceeding the adjusted cutoff would be reported in the accident bulletins, providing a more realistic base for year-to-year trend analysis. Future tables and graphs presented in the accident bulletins could reflect this price adjustment.

However, a far more serious question is the extent to which the $750 cutoff masked and obscures the true safety picture. Put more succinctly, "Just how may accidents occur in the $750 and under category and what is the total cost of these accidents?" In order to determine the answers to this question, CONSAD sought in each railroad interview to determine the total number of accidents occurring on each railroad as reported internally and the total number of accidents reported to FRA in order to calculate what percentage of total accidents are now being reported. Based on the figures provided in this limited sample, the results indicate approximately 15 percent of all accidents are reported, while 85 percent are unreported. One carrier provided us with a complete listing of all accidents by cause which indicated that human and track failures were the principal types of accidents occurring on their road, while equipment failures were a relatively small component.

Other examples of significant but unreported accidents occur at railroad-highway grade crossings. A train may demolish a $5,000 unoccupied automobile with little resulting damage to railroad equipment. Such an accident is unreportable. In a Report to Congress on Railroad-Highway Safety in August, 1972, by the FRA and the Federal Highway Administration, it was pointed out that, while 3,377 vehicle-train accidents were reported by the railroads to FRA during 1970, an estimated total of 12,400 vehicle-train accidents occurred at grade crossings, based upon information available from police reports and other sources.

Utilizing the total train accidents reported in 1971 as a base (7,304 accidents), we calculated that total unreported train accidents for 1971 amounted to 48,700 accidents. In order to estimate the dollar value of these unreported accidents, we calculated the average cost of each accident to be $1,000, based on the following assumptions:

- In our interviews, we found that a number of carriers actually discouraged reporting accidents that were slightly over the $750 cutoff by requesting that the accident circumstances be carefully reviewed by the individual making the assessment to insure that the estimates were accurate. Invariably, the accident was not reported. Thus, instead of using an average cost of $375 for unreported accidents, we have estimated the figure to be approximately $500 per accident, as illustrated in the following graph.



- This $500, of course, only covers the loss and damage to railroad property -- cars, equipment, track and roadbed. It does not cover the cost of clearing the wreck (rerailing cars, hiring mobile cranes, etc.) nor does it cover any losses and damage to lading or losses resulting from track tie-ups and delays. We suspect that some portion of the freight loss and damages reported by carriers to the AAR under the headings, "concealed damage" and "improper handling not otherwise provided for," resulted from unreported train accidents. Therefore, we have estimated per accident costs of loss and damage to lading to amount to $225, the costs for wreck clearance at $200, and the average cost of disruption to service and delay at $75. These estimates seem conservative since many of the unreported accidents described to us by carriers were considerably more costly. In certain accidents, there is very little damage done to cars _per se_, but nevertheless considerable expense involved in clearing the wreck, but under the current reporting rules, these accidents go unreported. The estimated total cost of unreported accidents amounts to $1,000 per accident, broken down as follows:

Estimated Unreported Accident Costs Per Accident

Damage to railroad cars, track, equipment, etc.		\$ 500
Wreck clearance costs		\$ 225
Loss and damage to lading		\$ 200
Disruption to service delays, etc.		\$ 75
	Total	\$1000

Estimating the number of unreported accidents for 1973 at 45,000, the total cost of unreported accidents would amount to \$45,000,000. This figure is sufficiently large to warrant consideration of eliminating the \$750 reporting threshold entirely, and is the first of three alternatives which will subsequently be explored:

- By requiring carriers to report all accidents, the volume of accident reports being submitted to FRA would increase by a factor of seven, necessitating increases in FRA personnel and a redesign and streamlining of the accident reporting system. In addition, there would be an increasing in the railroad costs for collection and preparation of the reports, although perhaps not as much as might be expected inasmuch as most of the railroads interviewed are already preparing reasonably complete accident reports for their own management information.

- An alternative to eliminating the \$750 reporting threshold would be to determine which accident types are generally excluded by the reporting criteria, in order to develop a multiplier to calculate the total number of accidents involved from the sample being reported. In this manner, reasonable estimation procedures could be followed, based on sampling carrier accident reports to determine the total number of unreported accidents.

- Lastly, the reporting criteria can be kept as is (at $750), recognizing that the total cost of unreported accidents may account for as much as 40 percent of the reported costs.

We recommend that the second alternative be pursued in view of obvious need to develop more complete information on unreported accidents, the probable budgeting limitations that may minimize expansion of Bureau of Safety personnel, and the potential distortion in the cost-benefit results that would result from their exclusion.

The new threshold of $1750 still retains all of the problems discussed above. The provision of a yearly adjustment to this threshold does make year-to-year data comparisons a little more meaningful but all of the other objections stated above remain.

4.4 Concluding Remarks

Any serious effort to prevent or reduce accidents has as a fundamental prerequisite for success, the establishment of clear-cut cause-and-effect relationships. Throughout all of the interviews with carriers, FRA, AAR, and others, a considerable number of questions were raised concerning the accuracy of the data provided on T-forms, the potentials for coding errors, the question of multiple accident causes, difficulties of correctly perceiving all accident causal factors, and the political nuances affecting what was and was not reported. We have not attempted to highlight any of these difficulties as we have found that their cognizance is widespread and well understood, and has been summarized in previous research work completed for FRA. It is clear that every effort should be made to improve the quality and timeliness of the accident-reporting system and indeed substantial efforts are now underway to accomplish this goal.

The need to provide more complete data on equipment and track failures is obvious and we can only add our endorsement to suggestions that have already been made for expanding the reported data. Information on equipment that has failed, thus causing an accident, such as the manufacturer's name, date of manufacture, serial number of the part, and/or type, is essential in order to establish such things as mean time to failure, average life expectancy, etc. This information can be summarized and analyzed to determine the relative cost-effectiveness of alternative equipment makes and designs. There is a well-recognized need in the railroad industry for component failure data which would enable railroads to improve their planned maintenance activities and purchasing effectiveness through prediction of failure, wear rates and costs per unit of service. The provision of identifying data on accident reports could enable FRA to publish this information for industry use.

The potential for substantial progress in accident cost reduction is still very real in the railroad industry and the commensurate benefits attending improvement in railroad safety and maintenance effectiveness are likewise real. But progress in reducing accidents is dependent on knowing what action should be taken, and the current accident reporting system provides far too little data with which these decisions can be made. The suggestions offered here for improvement do not seek to totally replace the basic reporting system as it now exists, rather a more complete reporting is recommended, especially of component failure information.

5.0 TEST OF THE COST-EFFECTIVENESS METHODOLOGY

This section describes a test of the cost-effectiveness methodology described in this report. The safety standards chosen are those addressed to plain journal bearings on freight cars and are detailed in the November 11, 1973 issue of the Federal Register as amended in the July 11, 1974 issue.

This test exercise follows the flow charts presented in Section 2 using the procedures discussed in Section 3. In the following sections the scope of the test/cost-effectiveness analysis is defined and background information on journal failures is provided. Subsequent sections follow the major procedural steps outlined previously, namely, the computation of:

- Railroad Cost of Compliance with the Standard,
- Societal Costs,
- Railroad Benefits,
- Societal Benefits,
- Determination of the Number of Accidents Prevented, and
- Summary Evaluation.

Throughout the discussion, numerous references will be made to the procedures followed in completing the analysis in order that the reader may correlate the activity with the principal methodological steps.

5.1 Study Scope

In considering what standard would be most suitable for testing the cost-effectiveness procedures, preference was expressed by FRA for evaluating one of the newly proposed, but as yet unofficially prescribed, equipment standards. Mutual agreement between FRA and CONSAD centered on the desirability of testing those standards addressing journal failures on cars equipped with friction bearings, inasmuch as these failures presently cause more damage to railroad property and equipment than any other single accident cause.* Accidents caused by burned off journals (an undetected hot box) are generally known to be more serious than other types of accidents (a passed coupler for example) and more likely to result in third party damage (societal costs), which, in terms of the analysis, would exercise more of the recommended methodological steps. This was an important consideration in selecting a representative standard for testing. It was also anticipated that there would be better data available on the causes of journal bearing failures, which would in turn help overcome the acknowledged deficiencies in accident data necessary for cost-effectiveness analysis.

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*In terms of loss of life and damage to non-railroad property, rail highway grade crossing accidents are the most severe; however, in terms of the immediate costs to railroads, accidents caused by journal failures are singularly most damaging.

These data deficiencies, which were summarized in Section 4, represent potentially serious constraints limiting FRA's ability to complete realistic cost-effectiveness analyses.

The proposed safety standards initially considered in this cost-effectiveness analysis were an integral part of the overall minimum safety standards proposed by FRA for railroad freight cars, and published in the Federal Register of September 22, 1972.

Basically, these equipment standards were organized into eight sections with Subpart A covering the application, scope, definitions, responsibility for compliance, movement of defective cars for repair, civil penalties, designation of qualified persons, and waivers. Subpart B, 215.23 prescribed requirements for visual inspections and Section 215.25 detailed the requirements for periodic inspection. This latter section also defined high and low utilization cars and the unique inspection requirements for each, and further specified that each railroad submit a program outlining how it will bring its rolling stock into compliance on or before January 1, 1976.

Subparts C through H covered the specific equipment standards for wheels (C), axles (D), journal bearings (E), other truck components (F), couplers (G), and draft systems (H).

The specific standards initially evaluated were those contained in Subpart E, applicable to cars equipped with friction bearings. It was understood that the FRA was considering a lubrication standard which would require all plain bearing cars (both unstabilized and stabilized) to be repacked on a 24 month cycle. The AAR interchange rule was, and is, a 24 month repack requirement for unstabilized cars and a 30 month repack requirement for stabilized cars.

However, the proposed lubrication standards published in the November 17, 1972 issue of the Federal Register allowed a 30 month repacking interval on the stabilized bearings.

The rule making process for railroad freight cars is nearly completed and is stated in the November 21, 1973 issue of the Federal Register with amendments stated in the July 11, 1974 issue of that publication. The standards (which are effective as of January 1, 1974) which are pertinent to this methodology test are:

Subpart E-Journal Bearings

215.81 Scope

This subpart prescribes minimum safety requirements for journal bearings on railroad freight cars.

215.83 Defective plain bearing boxes

A plain bearing box is defective if it has any of the following conditions:

(a) It does not contain free oil.

(b) The box lid is missing, broken, or otherwise not preventing contaminants from entering the box.

(c) It contains any foreign matter which has a detrimental effect on the lubricant.

(d) The box is cracked or has holes so as to permit leakage.

215.85 Defective journal lubricating system

A journal lubricating system is defective if a lubricating pad is missing or has any of the following conditions:

(a) An exposed core or metal part contacting the journal.

(b) The pad is not contacting the journal.

(c) A scorched or burned area.

(d) Glazing over half the pad surface.

(e) Deteriorated or decayed fabric.

(f) A tear along the top, front, back, or side more than half the length of the pad.

215.87 Plain bearings and wedges required

Each railroad freight car must be equipped with the full number of plain bearings and wedges for which it is designed.

215.89 Defective plain bearings

A plain bearing is defective if it is not located in its design position or has any of the following conditions:

(a) A break, or crack.

(b) Overheating as evidenced by--(1) melted babbit; (2) smoke from hot oil; (3) journal surface damaged; or (4) journal temperature of 400°F or more.

(c) Wear at either end which reduces its length more than one-fourth inch.

(d) Combined wear that reduces its length more than three-eights inch.

(e) A lug worn more than one-eighth inch.

(f) Combined wear on both sides of the lug extension more than one-fourth inch.

(g) A loose lining or section of lining broken out.

(h) Lining worn through to brass more than three-eights inch above the lower edge of the brass sidewall.

215.91 Defective plain bearing wedges

A plain bearing wedge is defective if it is not located in its design position or has any of the following conditions:

(a) A bend, break, or crack.

(b) Wear measured at the contact surfaces which reduces its overall length more than three-sixteenths inch.

(c) A bottom surface unevenness of more than one-sixty fourth inch.

(d) Wear on top beyond the following limits:

Nominal journal size, inches	Wear limit flat lengthwise, inches
4 1/4 by 8	3 1/4
5 by 9	4
5 1/2 by 10	4 1/2
6 by 11	5
6 1/2 by 12	5 1/2

Subpart B --Inspection

215.21 Scope

This subpart prescribes requirements for inspection of railroad freight cars.

215.23 Safety inspection required

(a) After May 31, 1974, each railroad freight car in a train must be given a safety inspection, in accordance with instructions approved by the Federal Railroad Administrator, by a qualified person designated under 215.15 at the point where the car is placed in the train. However, except at the point where the train is originally made up, if a qualified person is not on duty at the point where the car is placed in the train but the car is inspected by available personnel for conditions adverse to safe movement, the safety inspection may be performed at the next point en route where a qualified person is on duty.

(b) Before February 1, 1974, each railroad that is in operation on January 1, 1974, and operates railroad freight cars to which this part applies shall submit to the Federal Railroad Administrator for approval under 215.29 three copies of its instructions for safety inspections of railroad freight cars required by this section. Each railroad that commences operations after January 1, 1974, shall submit its instructions to the Administrator for approval at least 90 days before the date it commences operations. Instructions submitted to the Administrator for approval must include procedures to be followed by qualified persons to assure compliance with all applicable requirements of this part.

215.25 Periodic inspection required

(a) After December 31, 1976, a railroad may not operate a railroad freight car unless:

(1) In the case of cars other than high utilization cars, the car was inspected as prescribed by 215.27 within the preceding 48 months or was originally constructed or reconditions within the preceding 95 months; and

(2) In the case of high utilization cars, the car was inspected as prescribed by 215.27 within the preceding 12 months or was originally constructed or reconditioned within the preceding 24 months. However, a high utilization car for which a railroad maintains and makes available to the Federal Railroad Administration a mileage record sufficient to show that the car traveled less than 25,000 miles during the preceding 12 months may be operated if that car meets the inspection requirements of paragraph (a) (1) of this section and is stenciled in accordance with 215.11(c)(6).

(b) For the purpose of this section, a "high utilization car" is a car:

(1) Specifically equipped to carry trucks, automobiles, containers, trailers, or removable trailer bodies for the transportation of freight; or

(2) Assigned to a train which operates in a continuous round trip cycle between the same two points.

(c) Before June 1, 1974, each railroad that is in operation on January 1, 1974, and has in service railroad freight cars to which this part applies shall submit to the Federal Railroad Administrator for approval under 215.29 three copies of a program to bring all those cars into compliance with paragraph (a) of this section by January 1, 1977. Each railroad that commences operations after Januayr 1, 1974, shall submit a program to the Administrator for approval at least 90 days before the date it commences operations. Each program submitted to the Administrator for approval must include procedures to be followed by inspection personnel to assure compliance with all applicable requirements of this part.

215.27 Periodic inspection: suspension and draft systems

Each inspection under 215.25 must include an examination, by a person designated under 215.15 to determine that all components of a railroad freight car's

(a) Suspension system, including wheels, axles, bearings, adapters, and truck components; and

(b) Draft system, including couplers, cushioning units, center sill, body bolsters, and center plates -- comply with the requirements of this part.

The major impacts of the new standards are effected through the visual and periodic inspections. The visual inspections, effective November 11, 1973, are mandatory every time a train is made up. The depth of the inspection depends upon the equipment and personnel available. The periodic inspections, effective December 1, 1976, are required every year for high utilization cars and every four years otherwise. While a visual inspection can be performed on a yard track, a periodic inspection requires that the car be shopped. These inspections, especially the periodic type, will be a significant cost item for the railroad industry. On the other hand, since journal failures can occur as a result of overheating which in turn can result from excessive wear or failure of a component part, lack of lubrication, etc., the inspections mandated by these standards are prescribed so that visual detection of the worn or failed components is possible. Thus the standards are designed to prevent accidents from occurring by detecting incipient failure conditions.

Even though the repacking intervals for plain bearing cars are identical to those of the AAR interchange rules, the FRA standards will impose additional costs on the railroad industry. These costs stem from the civil penalty provision stated in the November 21, 1973 issue of the Federal Register:

215.19 Civil Penalty

Any railroad that operates a railroad freight car in violation of any requirement prescribed in this part is liable to a civil penalty of at least $250 but not more than $2,500 for each violation. Each day of each violation constitutes a separate offense.

The FRA is presently thinking in terms of $750/day for repacking overdate violations. Thus, presumably, if it could be proven that a car ten months overdate (not a rare event) had been operated the entire preceding ten months by one railroad, that railroad could be fined a quarter of a million dollars.

Although extenuating circumstances, such as a railroad's past safety record and its overall financial condition will be taken into consideration in assessing civil penalties, the financial risk will highly motivate railroads to comply with the standards.

The impacts of the inspection standards and the mandatory nature of the repacking standards will be investigated in detail below. This exercise will constitute the test of the cost-effectiveness methodology described in this report.

5.2 Background: Accident Trends

In order to better understand the analytical discussion which will follow, it is desirable to review the nature and circumstances surrounding plain bearing failures.

As can be seen in the following table, reported journal failures over the last twelve years have varied from 557 in 1961 to the present lows of 305 for 1972, and 323 for 1973.

TABLE 12: Accidents Due to Journal Failures Reported to the FRA (Codes 2318 and 2319)

Year	No. of Accidents	Year	No. of Accidents
1961	557	1967	441
1962	408	1968	495
1963	483	1969	561
1964	539	1970	449
1965	529	1971	355
1966	452	1972	305
		1973	323

These are only the reported failures (on the FRA T-Form reports); total failures were 566 in 1972 and 377 in 1973. The decline in failures over the years is the result of the following factors:

(1) Introduction and application of roller bearings to the fleet in 1954 -- as illustrated in the following table.

TABLE 13: Fleet Phase Over to Roller Bearings

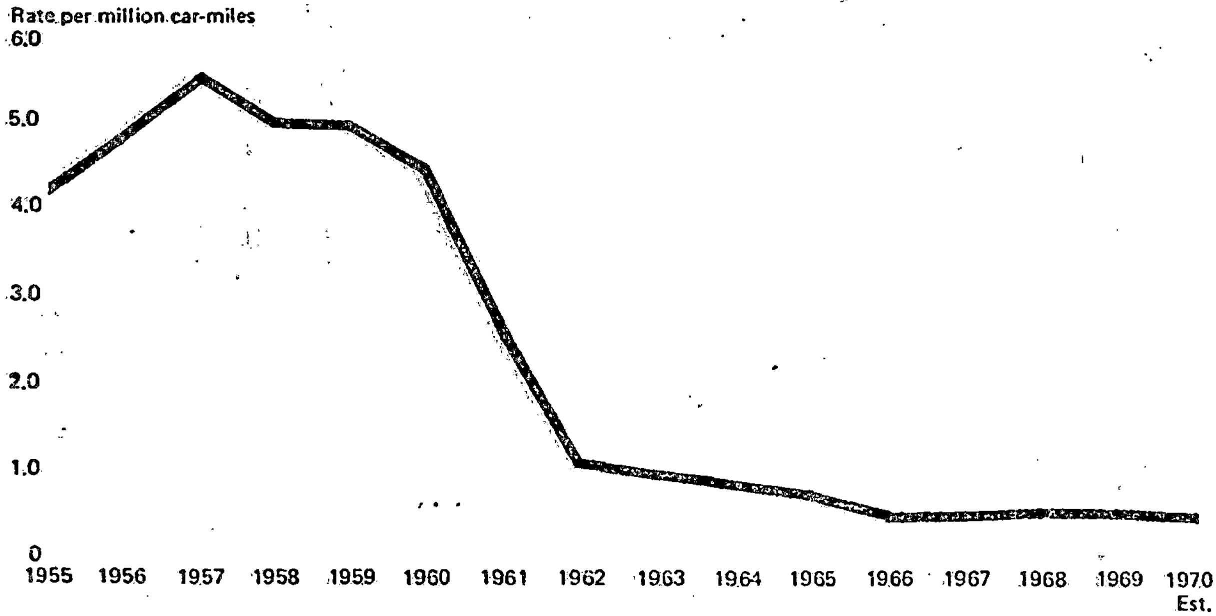
Year	Total Freight Car Ownership	Freight Cars Equipped with Roller Bearings	% of Freight Cars Equipped with Roller Bearings
1971	1,759,223	730,750	41.54
1970	1,784,181	656,911	36.45
1969	1,791,736	580,385	32.34
1968	1,800,375	505,740	28.09
1967	1,822,381	450,714	24.73
1966	1,826,499	367,464	20.12
1965	1,800,662	273,455	15.19
1964	1,796,264	209,007	11.64
1963	1,814,193	156,721	8.64
1962	1,850,688	121,280	6.55
1961	1,905,268	97,114	5.10
1960	1,965,486	76,674	3.90
1959	1,980,531	47,286	2.39
1958	2,031,181	38,420	1.89
1957	2,054,311	34,661	1.69
1956	2,009,764	27,352	1.36
1955	—	—	—
1954	—	—	—

AAR estimates that, as of April 1973, 55 percent of the freight car fleet was equipped with roller bearings. Other surveys and opinions of bearing suppliers and individual carriers indicate a 50 percent split as more realistic.

Roller bearings have contributed significantly to the reduction in lost train and car time as reflected in the following chart.

FIGURE 11

Freight Car Set-Outs Per Million Car-Miles, 1955-70



Source: Association of American Railroads.

Since 1970, set outs have been farily constant 1/2 car set out per million car miles.

2. The establishment by the AAR of the requirement that, effective August 1, 1966, all new cars and rebuilt cars of 100 ton capacity must be equipped with roller bearings. This was later changed, effective August 1, 1968, to require that all new cars, regardless of capacity, be equipped with roller bearings.

3. Continuing improvement in the nature and type of lubrication devices designated acceptable by the AAR, especially in the lubricating and wearing qualities of pads. As the number of plain bearing cars decreases because of retirement and conversion, the shrinking

lubricator pad market has squeezed out the "cheapies". AAR surveys and subsequent recommendations have also helped educate the railroads in the economics of lubricator pad qualities.

4. The development of the "stabilized journal box" dictated by AAR order effective August 1, 1966, to all rebuilt cars equipped with plain journal bearings given general repair (150 man hours). Some time ago, the frequency of cocked brasses and wedges led to the introduction of stabilizers (also called "journal stops") for standard bearings and also led to new stabilized bearings. Opinions on stabilizers range from "probably effective" to "just take up oil room" and "sometimes get wrapped around the axle". New stabilized bearings, which are effective, perform the stabilizing function by lugs on the brass and wedge. There are two types of stabilized brasses, the flat back and the HI-HAT. Stabilization also implies front (journal box lid) and rear seals which reduce oil loss.

5. The AAR requirements, effective June 1, 1972, that new lubricator pads should be used on all periodic repacks.

6. The introduction in 1960 and subsequent growth in numbers of hot box detectors.

7. The gradual discontinuance of stepped journals and bearings. The trend is to discard worn journals rather than turn them undersize and use a smaller diameter brass.

Counteracting the improvements resulting from the aforementioned items, and tending to retard the net reduction in accidents were factors affecting the journal operating environment. Simply stated, journals and journal bearings have had to work much harder and longer due to heavier and longer cars, greater dynamic loads, and increasing daily car mileage. Possibly the greatest single offsetting factor has been the reduction in inspections during train movement due to restrictions over the last ten years in maintenance of way personnel.

The net balance of physical improvements less those counteracting forces produced the reductions in failures that have been effected in the last few years. Nevertheless, the present rate of journal failures indicates that the absolute number of serious accidents will still be significant.

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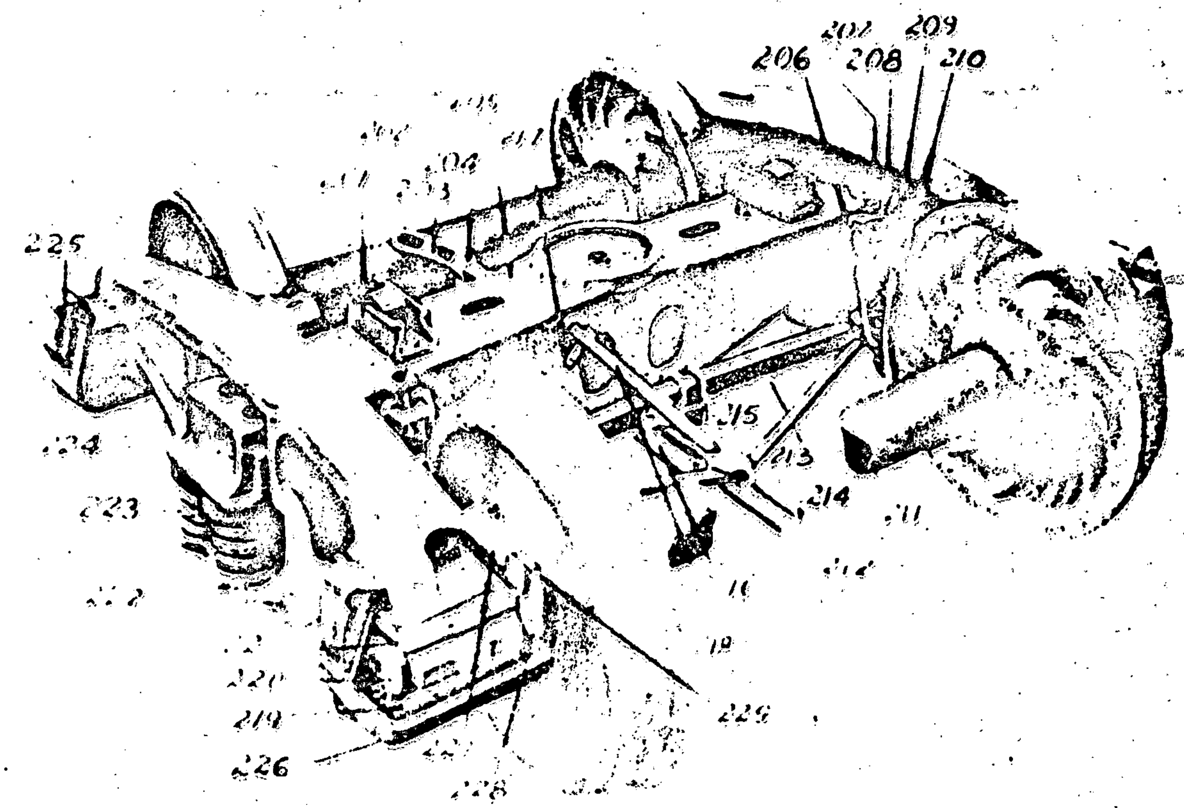
*Journal Failure Report, Engineering and Accident Analysis Division, Office of Safety, FRA, October, 1972, p. 9.

5.3 The Plain Journal Bearing

A freight car truck is shown in a cut away view in Figure 12. The load of the car is on the center plate which distributes it along the bolster, through the springs to the side frames and thence to the top of each box. The load is then distributed through the wedges and brasses to the journals, axles and wheels.

The typical friction journal bearing, sketched in Figure 13, is essentially a concave piece of brass (the bearing), supporting part of a car's weight, riding on a smooth part of the axle journal. Lubrication is provided by a pad resting in a pool of oil and pressing against the bottom of the axle. The brass's function is to distribute the load over a large portion of the journal. The brass, in turn, is supported in the box by a wedge which, being rounded at the top, allows for slight misalignment. When this wedge flattens, misalignment damages the brass and journal leading to failure. It is interesting to note that many freight car components are merely "sitting" on each other. If a car is raised by the coupler, the truck remains on the track. If the truck journal side frame is raised, the wheel and axle remain on the track, squashing down on the lubricator pad, and the brass and wedge fall out (or can be tapped loose). All of these items rely on gravity to stay together. This assembly explains how brasses and wedges get cocked and sometimes get spit out of the box entirely.



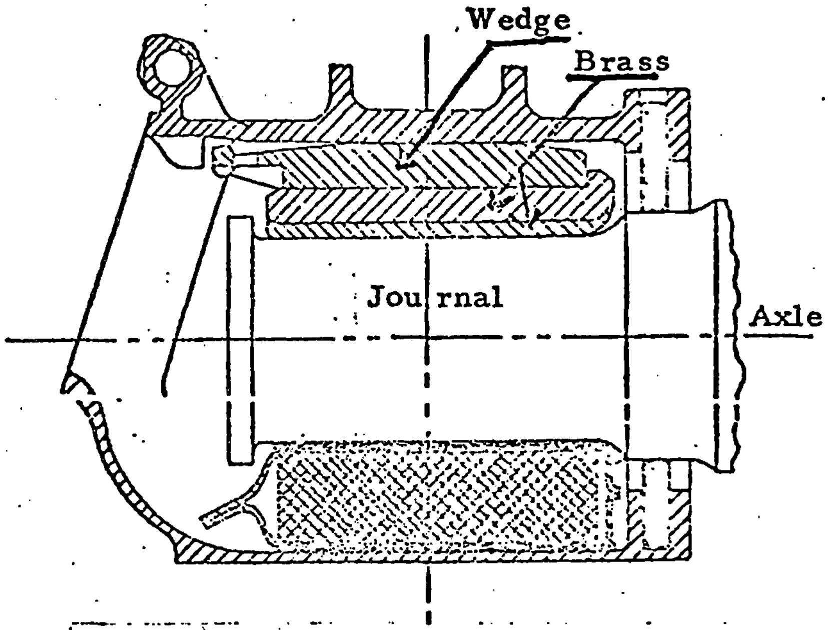
A A R [illegible]

Names of Parts

201	[illegible]	211	[illegible]	221	[illegible]
202	[illegible]	212	[illegible]	222	[illegible]
203	[illegible]	213	[illegible]	223	[illegible]
204	[illegible]	214	[illegible] Connection	224	[illegible]
205	Truck Bolster	215	[illegible] Support	225	[illegible]
206	Brake Hanger	216	[illegible] Support	226	[illegible]
207	Brake Hanger Key	217	[illegible]	227	[illegible]
208	Brake Hanger Wear Plate	218	[illegible]	228	[illegible]
209	Brake Shoe Key	219	[illegible] Waste	229	[illegible]
210	Brake Shoe	220	Journal [illegible]		

Figure 12 Freight Car Truck With Cut Away Journal To Show Parts

FIGURE 13: Plain Bearing Details



Journal and Bearing Side View

JOURNAL BEARING IDENTIFICATION TABLE

Nominal Size Journal	A-1 Bearing Size (in.)	Stamped on lug end or top of bearing	A-3 Bearing Size (in.)	Stamped on lug end or top of bearing	A-5 Bearing Size (in.)	Stamped on lug end or top of bearing
5 x 9	5.015	5.02	4.890	4.89	4.765	4.77
5½ x 10	5.515	5.52	5.390	5.39	5.265	5.27
6 x 11	6.015	6.02	5.890	5.89	5.765	5.77
6½ x 12	6.515	6.52	6.390	6.39	6.265	6.27

Banned

*Source: AAR Lubrication Manual.

Journals and bearings come in different sizes with the mating surfaces differing about 0.02" in diameter. Stepped journals and bearings represent attempts to maintain close tolerances by turning worn axles to standard undersizes and using off-the-shelf undersize brasses (bearings). Dimensions are shown in Figure 13. The industry trend seems to be away from stepped sizes, although some roads attribute part of their outstanding "record" to them. The A-5 undersize has been banned and inventory costs and achievable journal tolerance may not justify stepped sizes. A better philosophy may be that a badly worn journal should be replaced (knock off the wheels and put them on a new axle).

Plain friction bearings fail for many reasons, usually beginning with a hot box. On carriers' hot box report forms, there are listed as many as 34 causes, including "other" and "unknown". Some are simple: the lubricator pad was making poor contact with the journal and the mating parts ran out of lubricant. Some are really results of previous events: a broken off side bearing (between the car underbody and the truck bolster) will allow the car's load to shift and overload the bearings on one side of the truck. The immediate hot box cause then may be listed as "worn brass." A broken spring can produce the same effect. Of course, bad lubricator pads, discussed previously, can cause failures. Since wedges and brasses are merely setting on the journal, they can become cocked and sometimes popped out of the journal box altogether. Pads get stolen for barbecuing, children fill boxes with sand or stones, and even the weather claims its share of failures by condensing water into the box and freezing, thus forcing the oil out. Sometimes a car will be coupled on to a fast train after sitting idle for a few months; the high speed, before the lubrication film forms is fatal.

Tank and gondola cars suffer a disproportionately large number of hot boxes. Most tank cars operate in a hostile environment, especially those hauling liquid fertilizers and asphalt products. The corrosive fumes produce journal pitting which eventually prevents the lubricating film formation resulting in overheating and failure. Pitting is detected by an inspector who runs a hook lightly along the journal surface, much as a dentist probes for small cavities in a tooth. Gondola-cars are chronically overloaded since they are so easily accessed and are usually in general hauling service. If the load is great enough, the lubrication film fails, leading to bearing failure.

So there are many causes of bearing failures, the most ironic of which are the devices or procedures designed to prevent the failures. There are cases of burn-offs on the same day as repacking and also cases of stabilizing devices getting wrapped around the journal which causes rapid failure.

There are two general types of bearing failures, cold breaks and burn offs. A cold break may have been preceded by overheating, but usually it is simply a metal fracture due to a flaw or a minor accident. Since the bearing surface is not directly above the wheel/rail contact, the axle flexes slightly every revolution (the wheel and axle turn as a unit). Any flaw or accident-caused weakness can lead to a failure in the vicinity of the wheel seat. Burn offs are terminal hot box situations. Since the train cannot "turn" the journal, the excessive heat "extrudes" the journal to a noticeably smaller diameter. The brass also penetrates the journal to a depth such that it is often still present when the journal is turned to a standard undersize. This is another reason the railroads are trending away from stepped bearings.

5.4 Railroad Compliance Costs

The costs to rail carriers of implementing the FRA reporting and safety standards for cars equipped with friction bearings have been divided into two categories: initial compliance costs and ongoing compliance costs. Initial costs include all costs and expenses incurred by the railroads prior to the date the proposed standards take effect, and as an example, would encompass programs developed by the railroads for compliance with the new equipment standards.

In addition to the development of compliance programs, a specific requirement of the proposed equipment standards, railroads will be making expenditures for the expansion of existing facilities to facilitate compliance with the record keeping and periodic inspection requirements of the new standards. Such expenditures might include investments in record keeping or filing equipment, expansion of existing repair facilities, preparation of forms and related systems and costs of initially training personnel to conduct the inspections in accordance with the FRA standards. Most of the initial expenditures will result from the railroads anticipating and preparing for the increased frequency of car inspections. Failure to adequately make such preparation will increase the risk of incurring fines for cars found to be in violation of the standards.

Ongoing or continuing costs will be incurred by the railroads during the fifteen year period* after the standards take effect. During this period, railroads will be implementing their compliance programs and will be incurring ongoing expenses as a result of the periodic inspection requirements. These expenses include maintenance of inspection records and data for interline billing, the ongoing training of railroad personnel necessary to conduct FRA inspections, labor and material costs for the inspection and losses of car utilization while removed from service.

In order to estimate the costs railroads will incur in complying with the proposed safety standards addressing friction bearings, it was necessary to ascertain the most probable method of railroad compliance. This is a methodological step that will be required for any cost-effectiveness analysis of proposed railroad safety standards. For the purposes of this study, it was assumed that railroads would minimize their compliance costs whenever practical or feasible to do so. It was assumed that the FRA would approve sound economical programs of compliance that conform as closely as possible to the intent of the proposed standards without placing an overwhelming financial burden on the railroads. The standards proposed in September, 1972, which

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*As explained earlier, the time frame over which proposed rail standards would be analyzed was defined to be 15 years.

included inspection record keeping tasks, were amended in consideration of the extensive administrative burden they would impose upon the railroad industry.

There were also a number of issues that had to be resolved in order to calculate the costs of compliance with the proposed friction bearing standards. Briefly stated, they are:

1. How often the railroads will inspect a car and its components.

2. The actual work that will be undertaken, that is, the steps completed in performing the periodic inspection and maintenance of journal bearings on friction bearing cars.

Paragraph 215.23 states that every freight car must be given a visual inspection by a qualified inspector at the point the train is made up (or at the next location where an inspector is available). Paragraph 215.25 requires a periodic inspection of high utilization cars (automobile carriers, etc., and/or continuous service cars) every year and of non-high utilization cars every four years. The periodic inspection necessitates shopping a car.

Interviews with railroad officials, AAR personnel, and car leasing companies were conducted to obtain estimates of how many cars, equipped with plain friction bearings, fell into the high versus low utilization category. Based on their responses it was determined that the vast majority of high utilization cars are equipped with roller bearings and thus are considered outside the scope of the immediate analysis. Trailer-Train, for example, stated that their entire fleet of piggyback cars was equipped with roller bearings, while North American indicated that all but 10 of their piggyback fleet were similarly equipped.

In addition, some resolution of the FRA and AAR overlapping inspection requirements had to be made, for while there are basic similarities in the requirements, there are also basic differences. The essential question to be determined then were the specific inspection procedures that would be followed by the railroads.

5.4.1 Inspections and Repackings

The proposed equipment standards mandate that all cars be visually inspected at the reporting terminal. As this regulation is common to current railroad operating practices and AAR inspection practices, no additional costs will be incurred by the railroads in complying with the visual inspection requirements. On the other hand, the periodic inspection requirements will impose a major cost burden on the rail industry, as will subsequently be explained.

The AAR has for many years required that all freight cars be periodically inspected and the journal boxes repacked in accordance with their specifications. This recommended maintenance practice, while not mandatory, has nevertheless, been followed and adhered to reasonably closely by the railroads. However, there are instances where cars, by a unique set of circumstances, elude the watchful eyes of car inspectors and are not inspected and repacked within the recommended limits. Sometimes the lack of timely inspections and repacking results from shortages in maintenance personnel while in other cases it results from deliberate procrastination as a consequence of overloaded shops and limited capacity. Considering the number of friction bearing cars presently in the United States rail fleet, it is not surprising that at any given point in time there will be a good many cars in train service that will be "overdate," that is, running past the prescribed interval without the desired inspection and repacking having been accomplished. Since bearing wear is thought to partially correlate with age, the longer the car exceeds this periodic inspection interval, the more likely are the bearings and their components to be worn and potentially capable of failure.

Cognizant of these factors the FRA, in developing safety standards for journals and their components, has proposed mandatory inspection requirements, and imposing fines nominally of $750 per car for cars found to be overdate. In this fashion, it was assumed that a significantly higher percentage of cars would be inspected at the required interval, thus minimizing the numbers of overdate cars and chances for journal failure.

However, there are differences between the proposed FRA standards, e.g., timing of the inspection, and the AAR standards, which determine the probable costs of railroad compliance.

The AAR periodic inspection and repacking of journal boxes are required every 30 months for cars equipped with "stabilized boxes"* and every 24 months for all other cars. The FRA periodic inspections are required every 48 months for non-high utilization cars regardless of whether they are stabilized or not. The unstabilized cars can be inspected at repack time at no additional cost. Since the stabilized cars will almost automatically be inspected on a 30-month cycle to satisfy repack requirements, the 48-month inspection requirement is a superfluous standard except for the following consideration. A stabilized car which becomes 18 months overdate violates both the repack standard and the inspection standard and the operating road is liable to two civil penalties for each succeeding day of violation.

The major compliance costs will result, not from the inspections, but from the mandatory nature of the repack standards. Actually, the FRA standards tend to be less stringent than the AAR interchange rules.

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*A stabilized journal box is one that has been equipped with journal stops or the newer flat back bearings, improved rear seals and lid seals and clamps. The stops and flat back bearings are designed to eliminate bearing rotation resulting from high impacts. These improvements in the AAR's judgment merited a longer inspection period and consequently the 30 month interval was established.

For example, the FRA safety standards for lubricator pads, Section 215.85 (a) through (f), declares a bearing defective, if the pad is missing or has any of the following conditions: (a) an exposed core or metal part contacting the journal, (b) the pad is not contacting the journal, (c) a scorched or burned area, (d) glazing over half the pad surface, (e) deteriorated or decayed fabric, or (f) a tear along the top, front, back or side more than half the length of the pad.

On the other hand, the more stringent AAR Interchange Rules list all of the above as causes for renewal plus five other conditions that would require the lubricator pad to be replaced upon periodic inspection.

By inspecting the journal boxes in accordance with the more stringent AAR requirements, the railroads can simultaneously satisfy the FRA safety requirements and AAR's recommended maintenance priorities.

5.4.2 Additional Costs from Increased Repackings

The major railroad costs from the FRA safety standards appear to be a stricter compliance to the interchange repacking rules (now the FRA safety standards). In order to calculate this additional cost, several predictions about the characteristics of the present and changed freight car fleet must be made. This task corresponds to the box labeled "Average Industry Condition" in the flow chart of Figure 2.

The plain bearing car fleet is estimated at 875,330 cars at the end of 1973, with 61,000 cars retired each year and 2,000 converted to roller bearings, which produces the forecast of Table 14. The numbers fall between the AAR predictions and those of several bearing manufacturers. From AAR information, initial results of the FRA field inspections and interviews with individual carriers, it is estimated that 25 percent of the fleet is stabilized and 10 percent is overdate. The average overdateness of one carrier's cars is 4.7 months based on a 5000 car survey. Since this road is above average in maintenance, a value of 5 months overdateness appears realistic for an overall industry average.

The number of repackings per year under AAR interchange rules can now be estimated. If N is the total number of friction bearing cars in use in any given year, 25 percent are stabilized; 2.5 percent are overdate, and 22.5 percent are not overdate. The overdate cars are on a 35 month repack cycle while the non-overdate cars are on a 30 month cycle. Similarly, 67.5 percent of the fleet (unstabilized, non-overdate cars) is on a 24-month cycle and 7.5 percent is on a 29-month cycle. Expressed algebraically, the number of repackings per year under current practice is:

TABLE 14: Increased Repackings Under FRA Standards

Year	Plain Bearing Cars in Service at End of Year*	Additional Repackings Under FRA Standards
1973	875,330	0
1974	813,330	6,272
1975	749,330	5,779
1976	686,330	5,293
1977	623,330	4,807
1978	560,330	4,321
1979	497,330	3,835
1980	434,330	3,350
1981	371,330	2,864
1982	308,330	2,378
1983	245,330	1,892
1984	182,330	1,406
1985	119,330	920
1986	56,330	434
1987	--	--
1988	--	--

*Based upon 61,000 retirees/year, plus 2,000 conversions/year. Data from AAR and bearing suppliers.

$$\text{Repacks per year under AAR Interchange Rules} = \left[\frac{.225}{30/12} + \frac{.025}{35/12} + \frac{.675}{24/12} + \frac{.075}{29/12}\right] \times N = 0.467106 \times N$$

By similar reasoning, and with the assumption that under the mandatory standards, only one percent of the cars will be overdate,* and will average only one month in that condition, the expression is:

$$\text{Repacks per year Under FRA standards} = \left[\frac{.2475}{30/12} + \frac{.0025}{31/12} + \frac{.7425}{24/12} + \frac{.0075}{25/12}\right] \times N$$

$$= 0.474818 \times N$$

Additional repacks = 0.474818 x N - 0.467106 x N = 0.007712 x N. For 1974, this amounts to 6,272 additional repacks as shown in Table 14, along with the additional repacks for all the years until the plain bearing fleet is phased out.

In addition to the costs of these extra repackings, the overdate cars will also occasionally incur fines at $750 per day.*** Assume that 5 percent of the overdate cars are found in violation for one week of operation. Allowing for customary diminution of the fines and the foregiveness of hardship and "good character" cases, take 60 percent as the collectable amount of the fines.** Then the total industry cost is:

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*This is considered by the industry to be the practical minimum.
**The present collectable ratio on track standards.
***Since fines are transfer payments, they will also be entered as societal benefits.

(1 percent overdate) x (5 percent found) x (7 days*) x ($750/day)

x number of cars x 60 percent collectable

Fine cost = $1.575 x number of cars.

For example, for 1974, the total cost of fines is $1,281,000.

5.4.3 Initial Costs

In determining the cost-effectiveness of a subpart of an entire set of equipment standards, it is necessary to determine what part of the initial costs of implementing the entire set of standards should be allocated to each subpart. In the immediate case, the standards addressing friction bearings are a subpart of a set of standards that apply to all the components of a freight car.

As has been discussed, the total program development, record keeping, and training costs resulting from compliance with the entire set of equipment standards, must be allocated to the subparts of this entire set of equipment standards. In this analysis these costs were distributed evenly across the six equipment groups, since an adequate rationale (based on precise time and motion studies of each of the subparts of the equipment standards) was lacking and considered beyond the scope of this analysis.

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*One week was felt to be realistic because, although most "found" cars would be longer overdate, it would be difficult to prove that the offending road operated the car for longer than one week.

Subparts of Equipment Standards

- Wheels,
- Axles,
- Journal bearings,
- Other truck components,
- Couplers, and
- Draft systems.

Thus, one-sixth of the total costs of developing a program of compliance for friction bearing cars would be allocated to those standards or subparts that address the friction bearings of the car. The same method of proration would apply to any cost that cannot be readily attributable to actual compliance with the friction bearing standards but can only be interpreted as a cost of implementation of the entire set of safety standards.

In accordance with the new safety standards, railroads submitted a program to the FRA detailing how they intend to comply with the safety standards. Rather than having the 603 Class I and Class II line haul railroads and switching and terminal companies submit separate programs, the AAR, acting on behalf of all railroads, submitted a program developed by representatives of various member carriers to the FRA for approval. This program, which was accepted by the FRA, will be followed by each and every railroad in the country.

Based on interviews with the AAR and individual railroads, it was determined that a 10 man joint committee would take approximately five working days to discuss, formulate, draft, and submit a program of compliance for friction bearing cars. Assuming eight man-hours per day, the total man-hours expended during this conference would be 400 man hours. This figure does not include the research and development costs incurred prior to the meeting of the joint committee. These prior development costs would be a result of independent research done on the part of each member of the committee in preparation for the meeting. It was also assumed that 400 man-hours would be spent prior to the conference in research and drafting individual proposals and that total man hours would then amount to 800 man hours. Using $15.00 per hour for the average salary and overhead, total costs for the development of a program of compliance for friction bearing cars would be:

Development Costs = 800 man-hrs. x $15.00/man-hr. = $12000.00.

The $12000.00 represents the total expense of developing a program of compliance for friction bearing cars for the entire set of safety standards.* A portion of the expense must be allocated to the friction bearing standards individually. Using the procedure described earlier, the compliance program initial development costs allocated to the friction bearing standards would be:

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*Program development costs would naturally be higher if each and every carrier were to individually develop their own programs for compliance.

Compliance Program Development
Costs Allocated to Friction = $12000 x 1/6 = $2000
Bearing Standards

These numbers appear to be reasonable from the present vantage point of looking back at actual costs, as far as could be ascertained.

5.4.4 Other Costs

There are several other costs associated with the increased inspections and repackings. Some of the more significant of these are listed below.

5.4.4.1 Expansion of the AAR Billing Files

Only those friction bearing cars repacked by non-owning railroads will have an affect on the billing files. For each year, there was a certain number of cars repacked under FRA standards that would not have normally been repacked. Of this difference (Δcars), it was assumed that one-half would be repacked by non-owning railroads that must issue bills to the owners of the car and to the AAR. Distribution of the inter-line billing data would follow current practices specified in the AAR office manual.

For example, each month, railroads will produce a summary billing statement for every other railroad listing the foreign cars that were inspected and repacked in accordance with FRA requirements. There will obviously be an additional cost to keypunch and computer to prepare the bill from the railroads copy of the inspection report, however, since there is an established ongoing system for such interline billing, the exact incremental costs are difficult to estimate.

For calculation purposes, it was assumed that the railroads copy of the original inspection report would be used for billing purposes and that the keypunching of data from the inspection report would take approximately 5 minutes per report. At $10.00 per hour the keypunching of data would cost $.83 per form: $\frac{\$10.00}{12 \text{ reports}} = \$.83/\text{report}$, and the total billing costs would be:

$$\left(\frac{\text{\# of cars inspected}}{\text{\# of reports keypunched/per hour for billing purposes}}\right) \times \text{hourly rate} = \text{Total billing preparation cost}$$

No additional costs for computer processing, paper or postage were assumed, since the current AAR interline billing system would be employed even though the monthly repair settlements would be a little bit longer.

5.4.4.2 Training Costs, Inspection Costs, and Lost Car Utilization Costs

There are approximately 1000 repair tracks in the United States. For each track, it was assumed that there will be three inspectors, one for each of two shifts and one relief man. Based on interviews and railroad practice, it is assumed that each man will undergo on the average, 2 man-hours of training and/or retraining per year for the entire set of equipment standards. Using a \$10.00 per hour rate to cover labor and overhead, the yearly training costs will be:

$$\text{Training Costs Per Year} = \left\{ 1000 \text{ repair tracks} \times 3 \text{ inspectors per track} \times 2 \text{ man-hours per year per inspector} \right\} \times \left\{ \$10.00 \text{ per hour} \right\}$$

$$\text{Training Costs per year} = \$60,000 \text{ per year}$$

Allocating this training cost to the friction bearing standard:

$$\text{Training Costs Per Year Allocated to Friction Bearing Standards} = \text{Total Training Costs Per Year} \times \frac{1}{6} = \$10,200$$

For friction bearing standards, direct inspection costs, per diem losses and car utilization losses are all a function of the differences between the number of cars inspected under FRA standards and the number of cars that would have been repacked without the standards. The underlying assumptions are that in order to inspect a friction bearing in accordance with FRA standards, it would cost as much in labor, material, per diem loss and utilization loss as to repack the same bearing under AAR regulations. In order to perform the periodic inspection in accordance with FRA standards, a complete dismantling of the bearing is necessary. The lubricator pad must be removed and replaced if defective. All other components have to be gauged and inspected. Only after complete visual inspection could the bearing then be reassembled, following the identical steps completed in an AAR schedule repack.

The labor and material costs used to determine the cost of these additional inspections were based on AAR billing allowances, effective August 1, 1974, for repacking. For an average freight car, the costs were determined as follows:

Material Cost -	8 lubricator pads @ $3.20	=	$ 25.60
	4 brass @ $19.75	=	$ 63.00*
	2 wedges @ $6.56	=	$ 13.12
	miscellaneous oil & dust guards	=	$ 19.00
	Total Material		$120.72

Note that, on the average, for each repack, it was assumed that four defective brass are found. This estimate was based on a sample of approximately 3,500 cars provided by one of the major carriers cooperating with CONSAD in the development of this cost-effectiveness analysis.

Labor costs for one freight car would be as follows:

Labor costs -	4 brass @ $1.42	=	$ 5.68
	8 lubricator pads @ $1.42	=	$11.36
	general labor @ $15.61 per car	=	$15.61
	seals, etc. @ $11.36/car	=	$11.36
	Total Labor		$44.01

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*This is a net cost determined by taking the cost of a new brass and subtracting the salvage value of the old brass.

Total labor and material costs would thus amount to $164.73 for each car that is inspected and repacked in accordance with the FRA standards. Yearly, direct inspection costs for complying with the friction bearing standards can be determined as follows:

Inspection costs per year allocated to friction bearing standards = Δ cars inspected x $164.73 per car

where Δ cars inspected = {cars inspected with FRA standards in effect} - {car inspected without FRA standards in effect}

In determining the costs of compliance with the proposed standards addressing journal failures, the time lost in movement to and from inspection and repair tracks and the time required for the inspection must be considered. For the purposes of this analysis, it was assumed that on the average a car will lose a day in movement to the inspection and repair track, one day undergoing inspection and repair if any is necessary, and one day in returning to operation. It was also assumed that the entire periodic safety inspection would be undertaken and that any normal or special maintenance such as lubrication and air brake alteration would be completed. Thus, the costs for lost car utilization would be prorated, as have been illustrated previously, among the six major equipment categories, with one-sixth of the total costs applicable to journal standards. In order to calculate the total lost car utilization, an average per diem figure of $4.20 was employed in the following manner:

$$\begin{array}{l}\text{Annual car days}\\ \text{lost due to friction}\\ \text{bearing standard}\end{array} = \begin{array}{c}\Delta\text{cars}\\ \text{inspected}\end{array} \times \begin{array}{c}\text{3 days}\\ \text{per}\\ \text{car}\end{array} \times \$4.20 \times \frac{1}{6} = \$2.10 \times \Delta\text{cars}$$

An alternative means of calculating lost car utilization is to assume that the lost car days are replaced through the purchase of new equipment. However, these calculations would tend to overstate car utilization losses in the case of the declining friction bearing fleet. Calculating the cost of yearly car days lost utilizing a representative average per diem produces a more realistic estimate.

Finally, it was assumed for the purposes of this analysis that effective December 31, 1975, all railroads would be in nearly 100 percent compliance with the equipment standards. In this manner, the costs of compliance would be taken at their maximum potential level. In reality, however, there will be a slow tapering off in the numbers of overdate cars rather than an overnight elimination of all overdate cars.

5.4.5 Summary of Railroad Compliance Costs

All of the railroad costs developed above are summarized in Table 15. In addition, each cost, in constant dollars, is discounted at 10 percent, as recommended by the Office of Management and Budget.

TABLE 15: Summary of Railroad Compliance Costs

Year	Plain Bearing Cars in Service at End of Year	Additional Repackings Under FRA Standards	Discount Factor (10%)	Additional Repacking Costs @$164.73	Civil Penalties* @$1.575	Lost Car Utilization Costs @$2.10	Expansion of AAR Billing file @$0.415	Training of Additional Inspectors*
1973	875,330	0		0	0	0	0	0
1974	813,330	6,272	1.000	$1,033,000	$1,281,000	$13,200	$2,600	$10,200
1975	749,330	5,779	.909	865,300	1,072,800	11,000	2,200	8,500
1976	686,330	5,293	.826	720,200	892,900	9,200	1,800	7,100
1977	623,330	4,807	.751	594,700	737,300	7,600	1,500	5,900
1978	560,330	4,321	.683	486,200	602,800	6,200	1,200	4,800
1979	497,330	3,835	.621	392,300	486,400	5,000	1,000	3,900
1980	434,330	3,350	.564	311,200	385,800	4,000	800	3,100
1981	371,330	2,864	.513	242,000	300,000	3,100	600	2,400
1982	308,330	2,378	.467	182,900	226,800	2,300	500	1,800
1983	245,330	1,892	.424	132,100	163,800	1,700	300	1,300
1984	182,330	1,406	.386	89,400	110,800	1,100	200	900
1985	119,330	920	.350	53,000	65,800	700	100	500
1986	56,330	434	.319	28,300	28,300	300	100	200
1987	--							
1988	--							
Total Costs (Itemized present value)				$5,125,300	$6,354,500	$ 65,400	$12,900	$ 50,600
Total Present Value Cost	$11,608,700							

* Unit costs for civil penalties and inspector training are based on the total fleet. All other costs are based on additional repackings.

Total additional repacking costs are $5,125,300, civil penalties come to $6,354,500 and lost car utilization costs are $65,000. Yearly training costs for additional inspectors and costs for the expansion of the AAR billing files bring the total present value of the railroad industry's compliance cost to $11,608,700.

5.5 Societal Costs

The societal costs associated with the development and promulgation of these standards are primarily those costs incurred by the FRA as a result of the development, implementation, and maintenance of the proposed safety standards. Funds that have been budgeted and spent by the FRA have attractive alternative uses both within the federal government and without. Thus the use of these funds in developing and promulgating the safety standards represent a cost to society that must be considered in the overall cost/effectiveness analysis. As in the case of railroad compliance costs, societal costs are divided into initial and ongoing cost categories. Initial costs consist of the following:

1. Development Costs -- man-hours spent by FRA in developing the proposed standards.

2. FRA investment in record keeping equipment.

3. Initial training of FRA inspectors, by the FRA.

Ongoing societal costs are comprised of:

1. Salaries, fringe benefits, expenses of the FRA field inspectors and personnel involved in compliance monitoring.

2. Filing and record keeping costs associated with standards administration, adjudication, and compliance monitoring.

Discussion and calculations of these costs follow.

5.5.1 Development of the Standards

While efforts were made to obtain specific estimates from Bureau of Safety personnel as to the costs of developing rail safety standards, no estimates were actually provided. Instead it was suggested that by reviewing the official testimony before the House Committee on appropriations that this information could be developed. Accordingly, a careful perusal of the 1972 hearings on the 1973 budget was made and on the basis of data provided therein, estimates of the developmental costs were made.

As best as could be determined, the principal work of developing the standards was conducted by the Safety Programs Division of the Office of Safety while additional assistance was provided by the Office of Chief Counsel in developing the rules and regulations and participating in the overall promulgation of the new standards.

Approximately 30 percent of the total manpower in the Safety Program Division and Office of Chief Counsel was assumed to have been devoted to developing and promulgating the new equipment standards during 1972 and 1973. Consequently 1/6 of this amount was prorated as the developmental cost for standards addressing journal failures of which 50 percent was assumed to be allocated to friction bearing standards and 50 percent to roller bearing standards. The total cost for developing the equipment standards was roughly calculated to amount to $518, 118 with that attributable to standards addressing journal failures on friction bearing cars amounting to $43, 159. ($518, 118 x 1/6) x 1/2.

5.5.2 Investment in Record Keeping Equipment

In anticipation of a potential 800, 000 inspection reports that would be filed with the FRA by the railroads in 1975, the FRA was assumed to make an initial investment in filing cabinets or a computer-based record system to accommodate these inspection records. Assuming each report consists of two pages and a standard four drawer filing cabinet is capable of holding 19, 200 reports, the FRA would purchase the following number of cabinets:

$$\text{Cabinets purchased by FRA} = \frac{800,000 \text{ reports}}{19,200 \text{ reports per cabinet}} = 41.7 \text{ or } 42 \text{ cabinets}$$

At $100 per cabinet, the initial investment in filing cabinets would amount to $4200. Allocating this total expenditure to the friction bearing standards:

$$\text{FRA investment in filing cabinets allocated to friction bearing standards} = 4200 \times 1/6 = \$700$$

5.5.3 Initial Training of FRA Inspectors

It is assumed, from FRA budgeting requests, that 12 equipment or car inspectors would be hired to ensure compliance on the part of the railroads.* Assuming each inspector will undergo two weeks of training prior to entering the field, total man-hours of training accumulated would be 80 hours per man or 960 man-hours. Assuming a training cost of $20/man-hour to cover salary, travel, overhead, and other expenses, total training costs would amount to $19,200. Allocating this total expenditure to the friction bearing standards:

FRA training costs
Allocated to friction = $19,200 x 1/6 - $3,200
Bearing standard

While it is anticipated that state inspectors would also be employed to effect compliance with the safety standards, no estimates of the numbers of inspections and applicable expenses of their activities was available for this analysis.

5.5.4 Summary of Societal Costs

Filing and Record Keeping Expenses -- Assuming it takes five minutes for handling and filing of each inspection report, the annual FRA record keeping costs, based on a $10.00 per hour rate to cover overhead and labor, would be as follows:'

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*Source: Hearings before the House Committee on Appropriations, 92nd Congress.

Total FRA handling and filing costs per year = Total number of inspection reports Filed for X $.83 x 1/6 Bearing cars each year

Allocated to the friction bearing standards:

Yearly FRA handling and file costs allocated to friction bearing standards = Total FRA handling and filing x 1/6 costs per year

<u>Ongoing Costs of Inspection</u> -- Based on FRA estimates and proposed budgets, the yearly costs for 12 inspectors, including salaries, benefits, and travelling expenses would average $16,676 per man or $200,112 per year total.

These inspectors would spend approximately 50 percent of their time in the field and would make 100,000 car inspections.* By assuming that these inspections are distributed randomly among the total fleet, the percentage of friction bearing cars being inspected at any given time can be ascertained.** Thus the annual field inspections costs that should be allocated as a societal cost of compliance with the journal standards can be calculated as follows:

$$\text{Annual FRA field inspection costs allocated to friction bearing standards} = \text{Total field inspection costs} \times \frac{\text{No. of friction bearing cars in fleet} \times 1/6}{\text{Total cars in fleet}}$$

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*Hearings before the House Committee on Appropriations, 92nd Congress, p. 519.

**Considering the size of the sample, the assumption of a normal distribution of field observations is statistically valid.

Table 16 summarizes the total initial and ongoing societal costs in constant dollars. These costs are discounted at 10 percent, as recommended by the Office of Management and Budget, to yield a net present value of $275,600.

Table 16

Summary of Initial and Ongoing Societal Costs

Initial Costs	1972 + 1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Development of Journal Bearing Standards	$43,159																
Investment in Filing Equipment	700																
Initial Training FRA Field Inspectors	3,200																
Total Initial Costs	$47,059																
Ongoing Costs																	
Filing and Record Keeping Expenses			27,829	25,199	22,599	20,082	17,632	15,190	12,817	10,510	8,272	6,157	4,105	2,171	353	316	281
Field Inspection			15,608	14,167	12,727	11,326	9,965	8,604	7,264	5,963	4,702	3,501	2,321	1,220	200	180	160
Total			43,437	39,366	35,326	31,408	27,597	23,794	20,081	16,473	12,974	9,658	6,426	3,391	553	496	441
Discount Factor		1.000	.909	.826	.751	.683	.621	.564	.513	.467	.424	.386	.350	.319	.290	.263	.239
Present Value	$47,059	47,059	39,484	32,516	26,530	21,452	17,138	13,420	10,302	7,693	5,501	3,728	2,249	1,082	160	130	105
Total Present Value	$275,600																

5.6 Societal Benefits

Societal benefits are those benefits that society will experience as a result of a reduction in accidents due to friction bearing failures. Societal accident costs are difficult to quantify because of the serious lack of data in this area. In general, these costs include any damage to non-railroad or community property; any personal injury or death; any community services, such as fire and police assistance; or any loss of revenue due to evacuation, fire, explosions that resulted from a train accident and that was not paid for by the railroads. After investigating friction bearing accidents that have occurred over the past three years, it was determined that societal dollar costs resulting from these accidents, on the average, have been small. The primary reason for this is that railroads bear most of the expense for an accident and in the past have usually compensated private individuals and concerns for damages caused by train accidents.

In an effort to quantify and measure these societal accident costs, the following data sources were reviewed:

- T forms.
- NHTSB reports
- FRA Hazardous Material Accident Reports
- FRA reports for Class A accidents

From a review of these sources, it was determined that significant societal costs result in one type of accident -- hazardous materials are involved. These were the only significant societal accident costs that were found in the review of available data sources.

The methods used in determining what accidents involving hazardous materials were caused by failed journals was tedious and time consuming. Every time a railroad experiences an accident involving hazardous materials such as explosives, flammable liquids or gases and poisonous liquids or gases, the carrier must file a Hazardous Material Accident Form, independent of the T-form, to the FRA. This form is filed and information from it and from a subsequent investigation if found necessary, is condensed and logged in a summary book or bibliography of Hazardous Materials Accidents. Nowhere, in this summary of accidents is the cause of the accident listed. As a result, it was necessary to review the T-forms for friction bearing accidents, record the date, location and description of accident and corss-check this information with the Hazardous Accident

Summary in order to determine what accidents involving hazardous materials were caused by friction bearing failures. This work would have been enormously simplified with the addition of the accident cause code to the Hazardous Materials Summary and/or some cross-referencing to the applicable T-form. After locating these accidents in the summary, the corresponding hazardous material file was reviewed to determine if any societal costs had occurred because of the accidents. Finally, after the accidents with these potential societal costs were located, an investigation of the major accidents was made to determine the extent of the societal costs that resulted.

Following these steps, it was found that, of the 305 accidents due to friction bearing failures that were reported to the FRA in 1972, a total of three of those accidents involving hazardous materials resulted in societal costs resulting from the damage or destruction of cars carrying hazardous materials. These three accidents were investigated in more detail and the results are discussed below.

Accident #1 -- Approaching a small midwestern town, a train derailed due to a burned off journal on the 27th car at approximately 7:32 a.m. Twenty-three cars derailed with one tank on the ground and into an adjacent wheat field. Because of the nitric acid fumes, the sheriff ordered the town and other nearby areas evacuated as a safety measure, but returned the same day when the evacuation was lifted at 4:15 p.m. Since the accident occurred on a national holiday, there was no loss in business to the downtown area of the community or loss in wages to workers who may have been evacuated. Had there been, there would probably have been no compensation on the part of the railroad in the opinions of several local officials.* However, this is only speculation on their part. Those people that were evacuated, moved in with friends or relatives that lived close by. No compensation was made by the railroad as a result of this evacuation for the expense of quartering the evacuees or for minor costs incurred in their dis-location.

The sheriff's department reported 18 people taken to the hospital for treatment of chest pains, nausea and shortness of breath. In a phone call to the hospital administrator, it was reported that the bills for these treatments were paid by the carrier.

Because of the evacuation and extent of cleanup operation, the local sheriff, town deputies, five to six civil defense people, two or three volunteer fire departments and two state policemen were on hand

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*The difficulty in measuring lost business due to an accident is well recognized, and can only be approximately ascertained by sampling local businesses. Comparisons between normal or average daily sales can be made to roughly estimate the magnitude of these losses.

at one time or another to assist in the protection of the safety of the community. The entire cost of these community services went unpaid for by the carrier and were borne by the members of the surrounding areas. Estimates by the sheriff, fire chiefs, and other local officials placed the cost for these services at about $25000 in time, labor and materials. While these people were occupied at the scene of the accident, there were no other fires, crimes or accidents that took place in the rest of the community.

In an interview conducted with the owner of the wheat fields, it was reported that the railroad compensated the farmer in the amount of $7500 for damage to his crop. When asked if this was a fair price, he said yes but expressed doubts as to whether the field would yield as well as it did before. He claimed one acre was gone for good as a crop producer and that it couldn't be used for grazing cattle since the railroad would not replace the fence that was destroyed in the accident. The fence is owned by the railroad but the carrier will only replace it if the farmer assumes half the cost of the 800 foot fence. The farmer noted that since the expense was too much for him, he would leave the one acre fallow.

Finally, the state-owned road along the right-of-way was damaged by the wrecking equipment employed to clear the wreck.

From interviews with officials, it was assumed that the railroads would pay for the repairs of this road.

Accident #2 - On a Sunday at 9:15 a.m., a train of a major rail carrier suffered a derailment about 3 1/2 miles from a small mid-western city having a population of about 10,000 people. Five cars derailed with one of them being a box car carrying phosphorous penta-sulfide. This material is a persistent burner and can not be controlled by the usual methods since the addition of water creates hydrogen sulfide fumes, which are very toxic. An effective method of extinguishing is to use sand.

Immediately after the accident, the hazardous material began to smolder. FRA inspectors were called on Sunday and in turn the EPA was notified of the potential release of the toxic gas on Monday. During this time, since Sunday morning, local law enforcement groups, and volunteer fire departments headed by the county sheriff's office stood watch in preparation for any immediate danger. Twenty to thirty women, wives of the police and firemen, assisted in the watch. Throughout the entire course of events, about 200 people from the surrounding areas were involved in assisting the railroad.

On Tuesday morning, after the other cars were cleared, the boxcar with the smoldering phosphorous pentasulfide was righted, and the door opened and the contents immediately began to burn. Two families were evacuated near the wreck and the nearby city of 10,000 was ordered evacuated by a EPA trainee at the sight. The railroads appealed this as unnecessary and notified FRA and EPA officials. The evacuation was limited to the aged and infirm with the decision to evacuate anyone else being based on the future wind direction and left up to the judgment of the EPA man at the accident site. Approximately 1100 people were evacuated before the fire was extinguished on Wednesday morning. These people were evacuated to other local hospitals and homes until the area was declared safe. No mention was made by local officials of compensation on the part of the rail carrier for this evacuation.

In interviews conducted with the county sheriff who supervised the entire safety procedures and evacuations, it was indicated that at no time were the local agencies offered compensation for their services. The sheriff noted that a portable water tank was destroyed in the process and that the volunteer fire department who owned this tank was reimbursed by the carrier for the damage. He reported that this was the only instance he could recall where compensation was received by the local agencies servicing the wreck.

The sheriff and other local officials said they resented the high handed attitude taken by railroad officials during the clearing of the wreck. The railroad's prime concern in their opinion was for opening the line with little thought to the safety and consolation of community members.

In this particular accident there was no direct damage done to non-railroad property. However, leaves on trees along the right-of-way turned brown from the H_2S gas and fell earlier that year. Though there were no personal injuries suffered by non-railroad personnel, the county sheriff claims that both he and his deputy are suffering from sinus conditions brought on from inhaling the H_2S gas for two or three days. When asked if he reported this to the railroad he said he had not because of the difficulty he would have proving his case.

Estimates derived from information provided by the local agencies placed total societal costs of this accident between $5000 and $10,000.

In subsequent discussions it was learned that the action taken by the EPA representative was considered precipitous and unnecessary considering the circumstances and that the evacuation costs, rather than being attributable to the accident, were primarily the result of a hasty decision.

Accident #3 - In early Spring, approximately five miles from a small town in the northeastern section of the country, a major rail carrier experienced a derailment due to a burned off journal. The accident occurred in the late afternoon and 17 cars derailed, including a tank car carrying liquid chlorine. Upon inspection of the derailed tank car, a hissing noise was heard and the owners of the tank car, a chemical company, about 200 miles away, were notified as instructed on the waybill of the car. The chemical company dispatched several of its men to secure the leaking tank car.

Shortly after the derailment occurred, the surrounding area was evacuated by the local police chief and volunteer fire department, as a precautionary measure. Since the area was sparsely populated, only four families were involved in the evacuation. In an interview with the local fire chief, it was reported that he had railroad officials sign an agreement to pay for the hotel rooms and food for the four families through the duration of the evacuation. He said had he not done this, he or the families would have been stuck with the bill.

During the two to three days it took to secure the chlorine tank car and clear the wreck, members of the local fire and police departments were on hand to cordon off the area. The State police also assisted in manning barricades and rerouting traffic. Estimates by the fire chief fixed a dollar amount of approximately $3200 for the time and labor expended by local agencies. This was based on an average of 20 men working 8 hours a day for four days at $5.00 an hour.

When asked if he submitted a bill for his services, the chief said there was no way the railroad was going to pay his men. He claimed he had submitted bills involving similar services performed for the railroad but that these were ignored or sent back with the claim that the railroad considered itself a "free rider".

From investigations of these three hazardous accidents involving significant societal costs, it was found that:

a. For those friction bearing accidents involving hazardous materials, it was found that railroads do pay for property damage to private property but often times refrain from paying local emergency agencies for their services. This perhaps reflects the fact that the individual costs associated with an evacuation are frequently small and thus the individual has less motivation for seeking compensation. In other cases the provision of community services of police and firemen is thought to be a normal part of their workload and thus not an incremental cost for which compensation should be sought. Nevertheless, the concept of opportunity costs suggests that the costs of such services be considered in a complete cost/effectiveness analysis.

b. Only three of the hazardous materials accidents involving evacuation and significant societal costs were found in 1972, three in 1971 and three in 1970. Thus, the chances of having an accident of this type are very small and when the societal costs are averaged over the total number of accidents due to failed journals, the average societal cost per accident are relatively small. In addition, while other non-hazardous materials accidents can conceivably result in societal costs, little evidence of this happening can be found. Interviews with FRA Bureau of Safety personnel, AAR and individual officials confirmed this basic thesis.

c. In 1970, a serious accident involving hazardous materials occurred in a midwestern town (Crescent City) due to a failed friction bearing. The resulting damage to the town was estimated to be greater than one million dollars (1.7 million). On the following pages are photographs illustrating the nature of damages resulting from the accident. However, this is the only catastrophic accident in approximately the 1700 friction bearing accidents that occurred over those three years. Based on our limited field investigations it was found that the vast majority of property damage and personal injuries were paid for by the railroads. However, it was also found that the minor or incidental costs arising from such accidents were ofter ignored. Based on the limited research that was done on the extent of societal costs of journal bearing accidents the following calculations were made:

1. Accidents involving societal costs were investigated in 1972 and it was found that these accidents caused an average societal cost of about $5000 per each accident. Using this number for the average cost of similar accidents in 1971 (3) and 1972 (2), the total cost for these accidents was calculated to be:

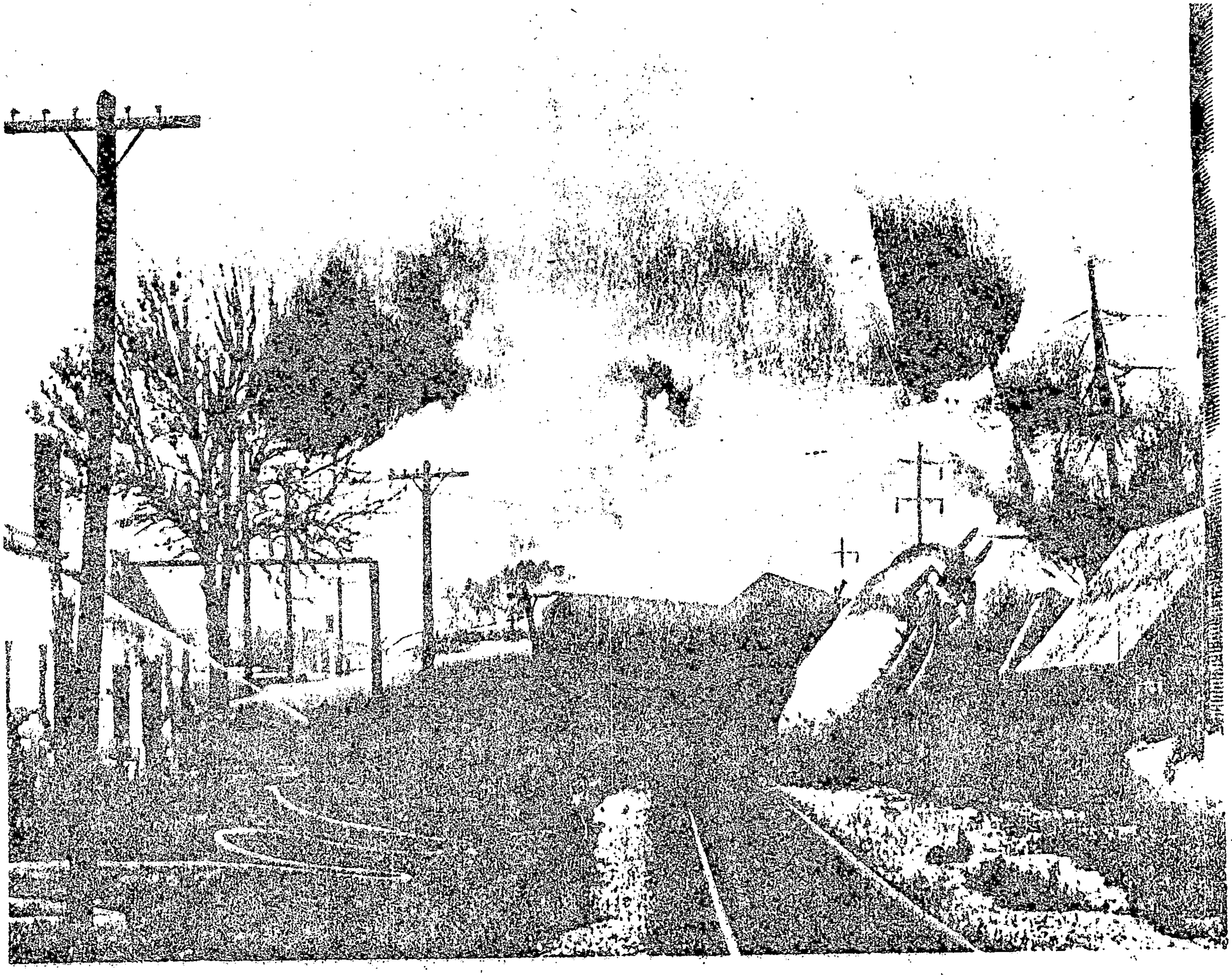

Figure 14. Location of tank car NATX 32025 on the East End of the General Derailment

Figure 15. A Fireball Emitted from Ruptured Tank Car NATX 32025 Extended Upwards about 1000 feet.

Figure 16. Part of the extensive damage to Crescent City

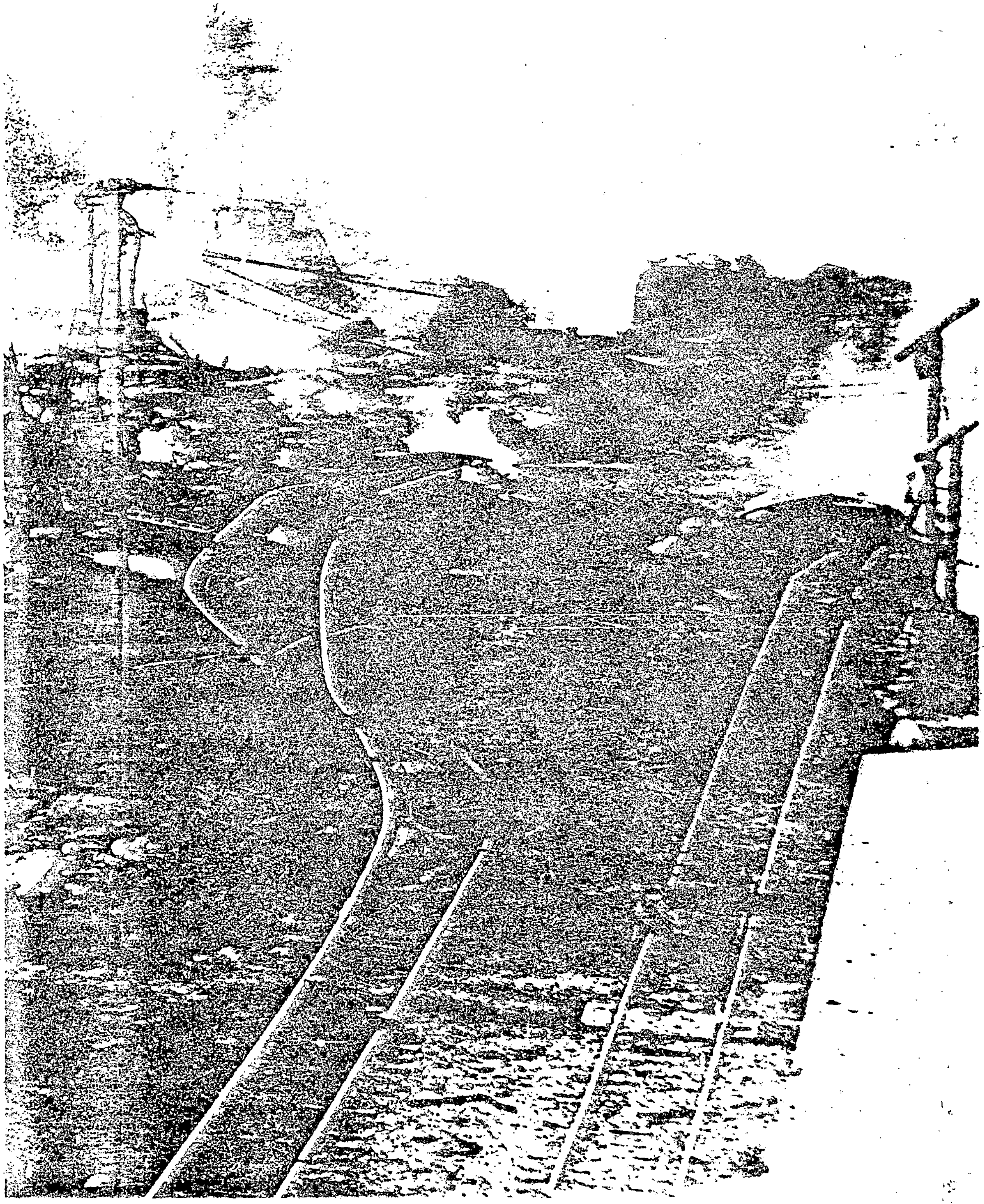

Figure 17. Area at East End of the General Derailment following the Rupture of NATX 32025

$5000 x (3 accidents in 1972 + 3 accidents in 1971 + 2 accidents in 1970) = $40,000.

2. The societal cost of the Crescent City disaster in 1970 was estimated to be approximately $356,000 in damages and losses that went uncompensated by the railroads. Losses for death were excluded in this tabulation since over this three year span there were no deaths involved. The 16 non-disabling injuries* associated with the approximately 1700 friction bearing accidents that occurred were estimated to cost $2100/per non disabling injury of which the railroads provided compensation for everything but the losses due to pain and suffering, the losses to others of security and losses of time spent in home and family duties. These losses amounted to an estimated $250 per non disability injury** or a total of $4,000 for the 16 injuries. Average societal cost per accident was thus:

$$\text{Average Societal Cost per Accident (1972 dollars)} = \frac{\$40,000 + \$356,000 + \$4,000}{1700 \text{ accidents}} = \$235 \text{ per accident}$$

This figure was used for subsequent benefit calculations. Even with a sizeable accident in 1970, societal costs appear to be considerably smaller when averaged over all the accidents that have occurred in a

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*FRA Accident Bulletin -- 1970, 1971, 1972, Table 126.

**Societal Costs of Motor Vehicle Accidents, U.S. Department of Transportation, April 1972, Table D. 2.

three year span than was originally anticipated at the outset of the study. However, because of time constraints and lack of data, the results of this particular study of journal bearing accidents should not be considered as representative of a "true measure or societal costs".

The one year intensive analysis of 1972 accident reports took approximately two-man weeks to accomplish with the current FRA accident data system. A more reliable extensive survey would have analyzed such accident reports for the last ten years during which time there was at least one death due to journal failures and in 1963, 29 injuries of which 17 involved individuals other than railroad employees and trespassers, or in other words, innocent bystanders. However, with the current lack of cross-referencing between the hazardous materials accidents reports and the T-forms, the lack of random T-report retrieval by accident types, and the lack of car and component identification, such a survey substantially exceeded the resources committed to this study.

Societal costs of railroad accidents are probably much less severe than was previously anticipated, at least by CONSAD. On the other hand, until a thorough analysis of rail accident costs is completed, we can only hazard a guess as to their true magnitude. Such a study should contemplate a large scale field investigation of individuals, property owners, injured parties, etc., involved in the accidents, for

for while railroads can provide inputs and data on the compensated losses, only those affected parties can provide a meaningful identification of the nature and value of their losses. As a further component of this research, an analysis of the damage producing events resulting from an accident should be undertaken to ascertain cause and effect relationships and possible remedial and preventive action that can be taken.

Summary of Accident Costs

It is felt that, while accident costs vary enormously over a sufficient number of accidents, a societal cost of $235 per accident is a realistic figure. This value, of course, when used in conjunction with reductions in number of accidents, is a societal benefit.

5.7 Railroad Benefits

The benefits accruing to railroads as a result of compliance with existing or proposed FRA safety standards addressing friction bearings would be the dollar savings resulting from the reduction in accidents caused by failed friction bearings and any improvements in overall service and business that would result from compliance activities. In order to determine the principal railroad benefits, the average cost of a friction bearing accident was calculated based on data supplied by the FRA, the AAR, the ICC and various individual railroads. This average accident cost will then be multiplied by the number of friction bearing accidents that would be reduced or prevented by the proposed standards to determine the yearly railroad benefits.

The costs to railroads of a friction bearing accident were divided into the following categories:

- Damage to railroad track and right of way
- Damage to railroad equipment
- Wreck clearing costs
- Damage to lading paid for by railroads
- Personal injury and fatalities
- Damage to non-railroad property
- Delays in service

In general, the above costs were determined based on data accumulated by various agencies and railroads for the year 1972. Where no actual data on records existed for certain costs (e.g., delays in service), estimates were made based on the responses made in carrier interviews during Phase I and II of this project. Table 17 summarizes the types of accident costs and the sources used for estimating these costs.

From the AAR Failed Axle Report data, it was estimated that of the 323 failed bearing accidents reported to the FRA in 1973, 293 involved friction bearing and 30 involved roller bearing equipped cars. These 293 accidents were reported to the FRA because damages to railroad track and equipment exceeded $750, the minimum requirement set by the FRA for reporting an accident.

From AAR data, it was found that a total of 336 friction bearing failures actually occurred in 1973 and that 43 accidents were consequently not serious enough in nature to warrant reporting to the FRA. Since we are interested in the total number of friction bearing accidents that occurred in 1973 and an average cost of an accident based on that total, the average cost for non-reported accidents as well as reported accidents had to be estimated. These estimates will be discussed in more detail in the following sections.

Table 17

Accident Costs and Sources

Costs	Sources
Damage to Track and Right of Way	FRA T-forms; estimates by rail carriers.
Damage to Railroad Equipment	FRA T-forms; estimates by rail carriers.
Wreck Clearing Costs	Estimates by carriers; ICC accounts.
Damage to Lading Paid by Railroads	Carrier records; carrier estimates; ICC accounts; AAR records.
Personal Injury and Fatalities	<u>FRA Accident Bulletin</u>; <u>Societal Costs of Motor Vehicle Accidents</u>, U.S. DOT; NTSB Reports.
Damage to Non-Railroad Property	Carrier records and estimates; NTSB Reports.
Losses Due to Delays in Service	Carrier records and estimates.

5.7.1 Damage to Railroad Equipment

For 1973, the average damage to equipment due to failed journal bearing accidents was $22,730 per accident for 323 broken journal accidents. This figure is based on damages estimated on the FRA T-forms. This cost was used as the average equipment damage per accident for the estimated 293 friction bearing accidents reported. For the 43 unreported friction bearing accidents an estimate of $300 per unreported accident was used for an average equipment damage cost. Thus, for 1973 the average equipment damage per friction bearing accident would be:

$$\text{Avg. Equipment Damage Cost per Friction Bearing Accident} = \frac{293 \text{ reported} \times \$22,730 \quad + \quad 43 \text{ unreported} \times \$300}{336 \text{ total friction bearing accidents}}$$

$$\text{Avg. Equipment Damage per Friction Bearing Accident} = \$19,858 \text{ per accident}$$

5.7.2 Damage to Railroad Track

For 1973, the average damage to track and right of way resulting from the 323 broken journal accidents reported to the FRA was $6,625. This figure was used to estimate average damage to track for the 293 reported friction bearing accidents. As in the case of equipment damage, track damage is also reported on the FRA T-forms. As noted before, these are the only two cost estimates reported to the FRA on the T-form. For the 43 unreported accidents, an estimate of $200 per unreported accident was used as an average track damage cost. This number added to the $300 estimated equipment damage yields a total of $500 for the total damage to equipment and track in an unreported broken journal accident. This total is below the $750 cut-off point established by the FRA as a minimum cost requirement for the reporting of a train accident.* For 1973, the average track damage per friction bearing accident would be:

$$\text{Avg. Track Damage per Friction Bearing Accident} = \frac{293 \text{ reported} \times \$6,625 + 43 \text{ unreported} \times \$200}{336}$$

$$\text{Avg. Track Damage per Friction Bearing Accident} = \$5803$$

5.7.3 Wreck Clearing Costs

These costs are reported by railroads to the ICC each year. However, the total as published by the ICC, does not indicate how many accidents the figure is based on nor is it broken down to type of accidents. Various railroads were contacted to obtain their estimates of wreck clearing costs and the consensus of opinion was that these costs

*As discussed in the Phase I report, the $750 cut-off substantially limits the reportable accidents and thus understates the total number of accidents.

were a direct function of how many cars were involved in the derailment. The average wreck clearing costs based on their more recent experience were estimated to be $1,500 per car derailed which includes material and labor expended by railroad personnel in clearing the wreck.

The average number of cars derailed per friction bearing accident was then determined and for the 293 journal failures reported in 1973, an average of six cars were assumed derailed per accident. For unreported accidents, it was assumed that since these accidents were not of a serious nature, only one car was estimated to derail in an unreported accident. Average wreck clearing costs were calculated as follows:

$$\text{Avg. Wreck Clearing Costs per Friction Bearing Accident} = \frac{293 \text{ reported} \times 6 \text{ cars derailed} \times \$1,500 \text{ per car} + 43 \text{ unreported} \times 1 \text{ car derailed} \times \$1,500 \text{ per car}}{336 \text{ total friction bearing accidents}}$$

Avg. Wreck Clearing Costs per Friction Bearing Accident = $8,040

5.7.4 Damage to Lading

This figure is also reported by the railroads to the ICC and to the AAR but is again not broken down by type of accidents. Damage records of several railroads were examined and officers of various railroads were contacted in an effort to obtain expert estimates of this cost. From these efforts, a figure of $30,000 per accident was calculated as the average damage to lading resulting from a friction bearing accident whether it is reported or unreported. This figure is used for both reported and unreported friction bearing accidents since considerable damage to lading can, and often does, result even in cases where the car itself is not damaged. Consequently, the $30,000 per accident will be used as estimated lading damage for all friction bearing accidents.

5.7.5 Personal Injury and Fatalities

Examination of the FRA Accident Bulletins for 1970, 1971, 1972 and 1973 showed no fatalities resulting from accidents caused by broken journals for these four years. Also, it was found that in 1970 there were 14 non-disabling injuries resulting from broken journal accidents, in 1971 there were none, in 1972 there were two and in 1973 there were five injured as a result of a broken journal accident. Further investigation of the 1972 injuries indicated that these were minor injuries and that neither man was disabled. Thus, for the purpose of this cost/effectiveness analysis, it is assumed that personal injury or fatality costs associated with accidents caused by broken journal bearings amount to $1000 per man disabling injury.* Assuming 2200 broken journal accidents (AAR estimates) over this four year period, the average injury damages paid by the railroads would amount to $10 per accident ($21,000 ÷ 2200).

5.7.6 Damage to Non-Railroad Property (Paid for by Railroads)

While this analysis did not include an extensive search of railroad claims files and court records, it was confirmed in interviews with individuals suffering losses as a result of accident and with railroad claims agents that railroads settle the great majority of claims filed against them for damages resulting from train accidents. Rough estimates place the average cost of damage to non-railroad property paid for by the railroads at $800 per accident. It should be understood that the vast majority of friction bearing accidents do not involve damage to non-railroad property and therefore the bulk of the $800 per accident represents a prorating of the non-railroad property damage costs associated with the Crescent City accident discussed in another section.

5.7.7 Delays and Disruptions in Service

Any time an accident or derailment occurs, there is a probability that a delay or disruption in service may occur, not only for the

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*Societal Costs of Motor Vehicle Accidents, U. S. Department of Transportation.

derailed train but also for subsequent trains travelling along the same track. These costs range from very severe to insignificant depending on the location and severity of the wreck. A derailment on the main line track of a railroad could delay numerous trains while a branch line derailment would cause little or no disruption of service. Actual losses resulting from such delays frequently depend on whether or not the carrier involved has a policy prohibiting rerouting by other carriers.

The following assumptions were used to estimate the average loss in revenue and customer goodwill that railroads experience when a friction bearing accident occurs:

- One percent of all carloads are delayed as a result of train accidents.*
- Friction bearing accidents comprise 5 percent of all reportable train accidents in 1973. $\left(\frac{293}{9375} = 3\%\right)$

Then, taking one percent of all carloads in 1973 (27,300,000 x 1% = 273,000 carloads) and multiplying by 3 percent, the resulting 8,190 carloads will be those carloads delayed one day** by a friction bearing accident. At $4.20 average diem cost, the per diem loss due to friction bearing accidents is:

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*A number of carriers provided specific accounting of the cars involved in accidents.

**Some cars are delayed for only a few hours while others are delayed for many days. This average has been roughly estimated on the basis of interview responses.

Per Diem Loss Due to Friction Bearing Accidents = Carloads delayed x $4.20 per day x 1 day delayed
= 8,190 x $4.20 = $34,410

The total per diem accident losses for 1973 amount to $\frac{\$34,410}{336}$ = $102/accident.

Loss of goodwill was based on the assumption that if each carload delayed represents one customer, then loss of customers would be equal to one-half of one percent* of the total cars delayed due to a friction bearing accident.

Loss of Customers = 1% x carloads delayed = customer loss

= 8,190 x .005 = 41 customers

Assuming the 41 customers ship an average 12 cars a year, the total annual carloads lost by the entire rail industry due to friction bearing accidents amounts to 492 carloads. At an annual revenue loss for 1973 of $500 per car, the net revenue loss would be $246,000. The average revenue loss, due to loss of good will, per friction bearing accident in 1973 would then be:

Revenue Loss Due to Loss of Goodwill per Friction Bearing Accident in 1973 = $\frac{\$246,000}{336}$ = $732 per accident

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*The interview responses indicated that most customers do not penalize the railroads when their cars are involved in an accident, which explains the diminutive response.

Total average railroad costs for a friction bearing accident in 1973 dollars would be $64,545. These costs are summarized in Table 18. When used in conjunction with the number of accidents prevented, this value represents a benefit to the rail industry.

Table 18

Summary Table
Railroad Benefits Per Accident
Reduced (Cost of Accident)

	Costs
Average Damage to Track and Right of Way per Friction Bearing Accident	$ 5,803
Average Damage to Railroad Equipment per Friction Bearing Accident	$19,858
Average Wreck Clearing Costs per Friction Bearing Accident	$ 8,040
Average Damage to Lading Paid by Railroads per Friction Bearing Accident	$30,000
Average Personal Injury Damages Paid by Railroads per Friction Bearing Accident	$ 10
Average Per Diem Loss Due to Friction Bearing Accidents	$ 102
Average Revenue Loss Due to Loss of Goodwill from Friction Bearing Accidents	$ 732
Total Average Railroad Cost of a Friction Bearing Accident	$64,545

5.8 Accident Reduction

The benefits railroads and society will experience for compliance with the FRA friction bearing standards will be principally the dollar savings resulting from a reduction in accidents due to journal failures. In the previous section, the average cost of a friction bearing accident, in 1973 dollars, was determined to be $64,545. In order to determine the benefits due to the reduction in friction bearing accidents, this average accident cost must be multiplied by the yearly reduction in accidents effected by the standards. This reduction in accidents is based on the difference between those accidents that would have occurred without the new standards in effect and those accidents that would have occurred with the proposed standards in effect. This is a measure of the accident reducing effectiveness of the proposed standards and will be used to calculate total railroad and societal benefits which, when compared with total compliance costs, will determine the net cost effectiveness of the proposed friction bearing standards.

In order to determine the accident reducing capabilities of the standards, it is necessary to forecast the number of friction bearing accidents that would occur with or without the proposed standards in effect. Preliminary regressions were computer run in an attempt to correlate frequency of friction bearing accidents with yearly equipment, maintenance expenditures (from ICC accounts and Moody's) and ton miles travelled (Moody's) by freight cars over the past ten years. Though some of these regressions indicated a correlation, this method of forecasting was not used for the following reasons:

a. There proved to be virtually no way of forecasting dollar expenditures for maintenance of equipment with any degree of confidence for the years 1975 through 1989.

b. Though a correlation was established, the variables were too general to provide meaningful sensitivity, for while equipment maintenance expenditures include the maintenance and repair of friction bearings, they also include all other equipment components, such as couplers, air brakes, etc. Moreover, it was practically impossible to determine from the data available, what specific dollar expenditures were made by railroads for the repair and maintenance of friction bearings.

c. Most important was the fact that accident data for the years 1961 through 1970 was obtained from the FRA data file. As has been discussed previously, this data understates the number of friction bearing accidents that occur annually due to the $750.00 reporting criteria. To estimate the total number of accidents caused by broken journals for those years would compound the potential for error in the regression analysis.

In light of these considerations, regression analysis was not employed in developing the accident forecast. However, a certain trend was indicated through the analysis of the data available: over the ten years from 1961 to 1970, the amount of money, in deflated dollars, spent for equipment maintenance, divided by the total ton miles travelled by all freight cars (a measure of work) was negatively correlated to the number of friction bearing accidents reported to the FRA for those years. In equation form:

$$\text{No. of friction bearing accidents per year} = A - B \left\{ \frac{\text{Yearly Equipment Maintenance}}{\text{Ton Miles per year}} \right\}$$

where A and B are constants.

The implications are that friction bearing accidents will be reduced by a decrease in ton miles travelled or a proportionately greater increase in maintenance expenditures which is no more than good common sense would expect.

An equally high correlation ($r^2 \approx .5$) was found when the number of friction bearing accidents were regressed with the number of friction bearing cars in service for the respective years. This indicated that more than one or two variables would need to be considered before a regression equation could be adequately specified, i.e., a multivariate analysis. However, due to the magnitude of the data gaps that exist, serious constraints are placed on an analysis of this type.

From AAR sources it was found that there were 566 friction bearing accidents that occurred in the U.S. in 1972 based on accident reports made to them by member railroads. A review of the 305 T-forms submitted for broken journal accidents (friction and roller) to the FRA in 1972 indicated that approximately 281 of the reported 305 broken journal accidents involved failed friction bearings with the remaining 24 involving roller bearing failures. This large difference in friction bearing accidents reported to the FRA and those reported to the AAR is primarily due to the FRA reporting requirements. As long as the actual number of accidents is known, independent of the severity of the accidents, the forecasting of future accidents is more readily accomplished. It was principally by means of the data supplied by individual railroads and the AAR that the forecast of friction bearing accidents was developed.

As discussed previously, the major effect of the new standards is mainly because of the civil penalty which will tend to increase the number of repackings per year and reduce the average age (with respect to repacking) of the entire friction bearing fleet. To estimate the accidents due to the changing makeup of the fleet the following analysis was performed. First, probabilities of failure versus age in repack were calculated from available data, then total failures were calculated for the fleet which will evolve under FRA safety standards.

5.8.1 Failure Probabilities

The probability distribution of friction bearing failures as a function of months after repack is difficult to calculate for two reasons. There is a lack of data on failures as a function of months after repack and also on the total number of cars in each month after repack. The fact that there is a decline of failures after the 24th month is largely due to the fact that a large portion of the United States fleet, namely, the unstabilized cars, is on a 24 month repacking cycle. Confusing the picture are the unknown number of overdate cars, some stabilized and some unstabilized. Cars being retired from service during the year further complicate the matter because their population varies throughout the year.

However, the behavior of many subpopulations has been investigated in detail and total numbers are known for the nation in general. Several assumptions were made about how the total figures were divided up among different groups of friction bearing cars. The allocations were based on data as far as possible and sensitivity analysis was performed on the allocation to determine how critical each assumption was. The allocation groups are of two types, status groups and age groups. The age groups depend upon the number of months since repack. The status groups are the stabilized and unstabilized cars in each of the following three categories:

- Those cars not overdate at the end of the year,
- Those cars overdate at the end of the year,
- Those cars retired during the year.

Because of the two repacking cycles, neither of which coincides with the calendar year and because of the three categories, calculating the number of cars in a certain month of use is quite involved. For example the number of cars in the 22nd month after repack includes 4/10 of the non-overdate stabilized cars, 1/2 of the non-overdate unstabilized cars, a small proportion of the cars which will become overdate before the end of the year and a larger proportion of the cars which will be retired during the year.

The general approach used to determine bearing failure probabilities is to form mathematical expressions for the number of bearing failures in each age group. Each expression is of the form:

Failures in Age Group X and Status Group Y = (Probability of failure) x (Population)

As will be seen later, the population in each age group depends on the age group itself. That is, the total population is not divided equally among all the age groups. For each age group, the failure expressions are added algebraically and set equal to the total failures derived from statistical data. The total population is then allocated among the status groups according to other statistical information. With this information, the probability of failures can then be solved for each age group.

The symbols used in the derivations are defined in Table 19. The easiest way to depict the distributions of the age groups is by a sketch of the time streams of the various cohorts* of population. Figure 18 is a representation of the stabilized-car population. If it is assumed that all cars are repacked on the first day of their repack month, then there are thirty different cohorts of stabilized cars, all of which are assumed to be of the same size. A vertical bar indicates the repacking date of each cohort, the numbers on the lines indicate the end of a month, while the numbers in the boxes indicate the month of age. Assume a year is picked at random, such as the one indicated by the long vertical bars in Figure 18. The repack ages of the 30 cohorts are given for each month of the selected year. The expression for the failures in January in the 9 month age group, for example, is $P_9 * \frac{S_n}{30}$. For the entire year, the number of failures is $P_9 * \frac{12S_n}{30}$. Since aggregation is desirable for reasons of data availability and ease of labor, six month age groups were chosen. For all the stabilized cars the total failure expression is:

$$F_{Sn} = S_n * \frac{12}{30} \left[P(1,6) + P(7,12) + P(13,18) + P(19,24) + P(25,30) \right]$$

where the symbols are as defined in Table 19.

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*A cohort, as used here, is a group of cars of the same repack age.

TABLE 19: Symbology Used in Failure Probability Calculations

S_n	=	Number of stabilized cars not overdate at the end of subject year
U_n	=	Number of unstabilized cars not overdate at the end of subject year
S_o	=	Number of stabilized cars overdate at the end of subject year
U_o	=	Number of unstabilized cars overdate at the end of subject year
S_r	=	Number of stabilized cars retired during subject year
U_r	=	Number of unstabilized cars retired during subject year
F	=	Number of failures during the subject year
P_n	=	Probability of failure during the nth month of repack
P(a, b)	=	Probability of failure during the ath through the bth month of repack. $P(a,b) = P_a + \ldots\ldots + P_b$

Stabilized-Car Population
Not overdate, Not retired

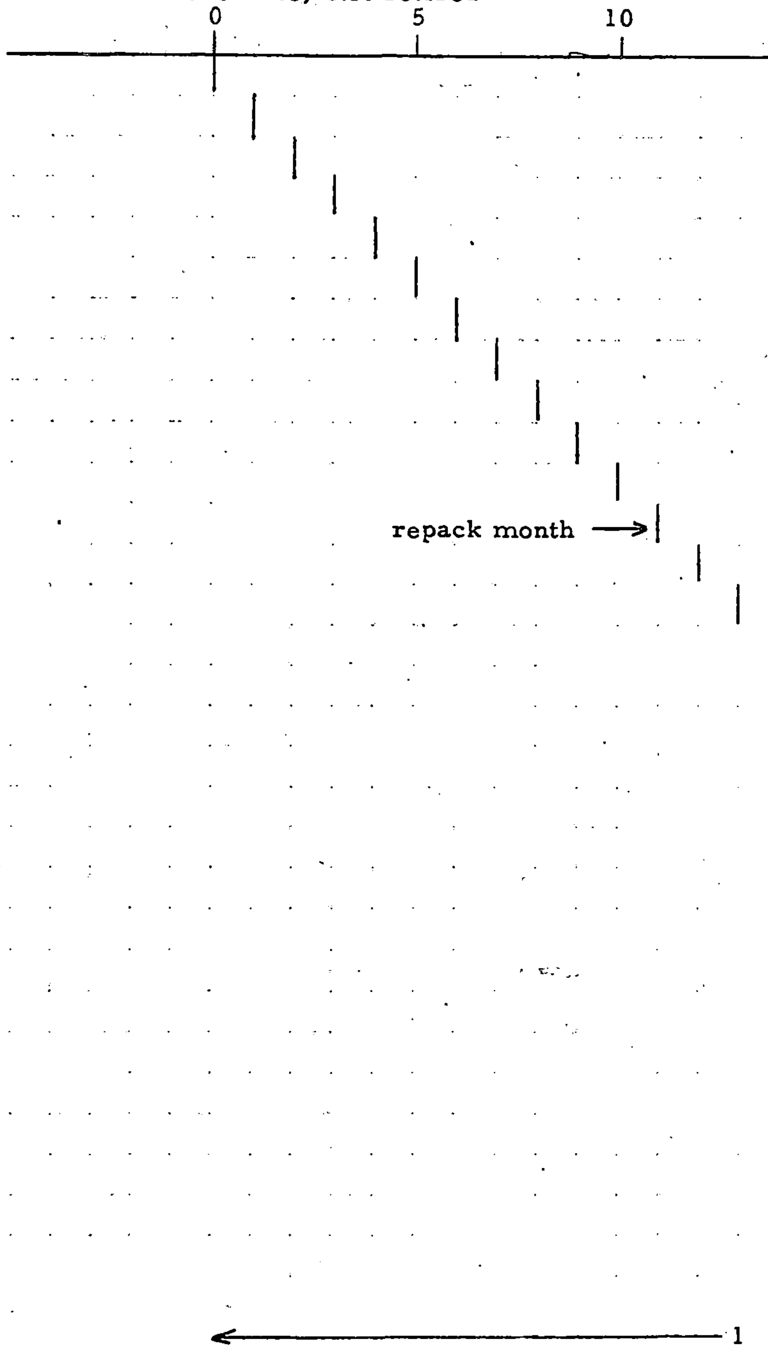
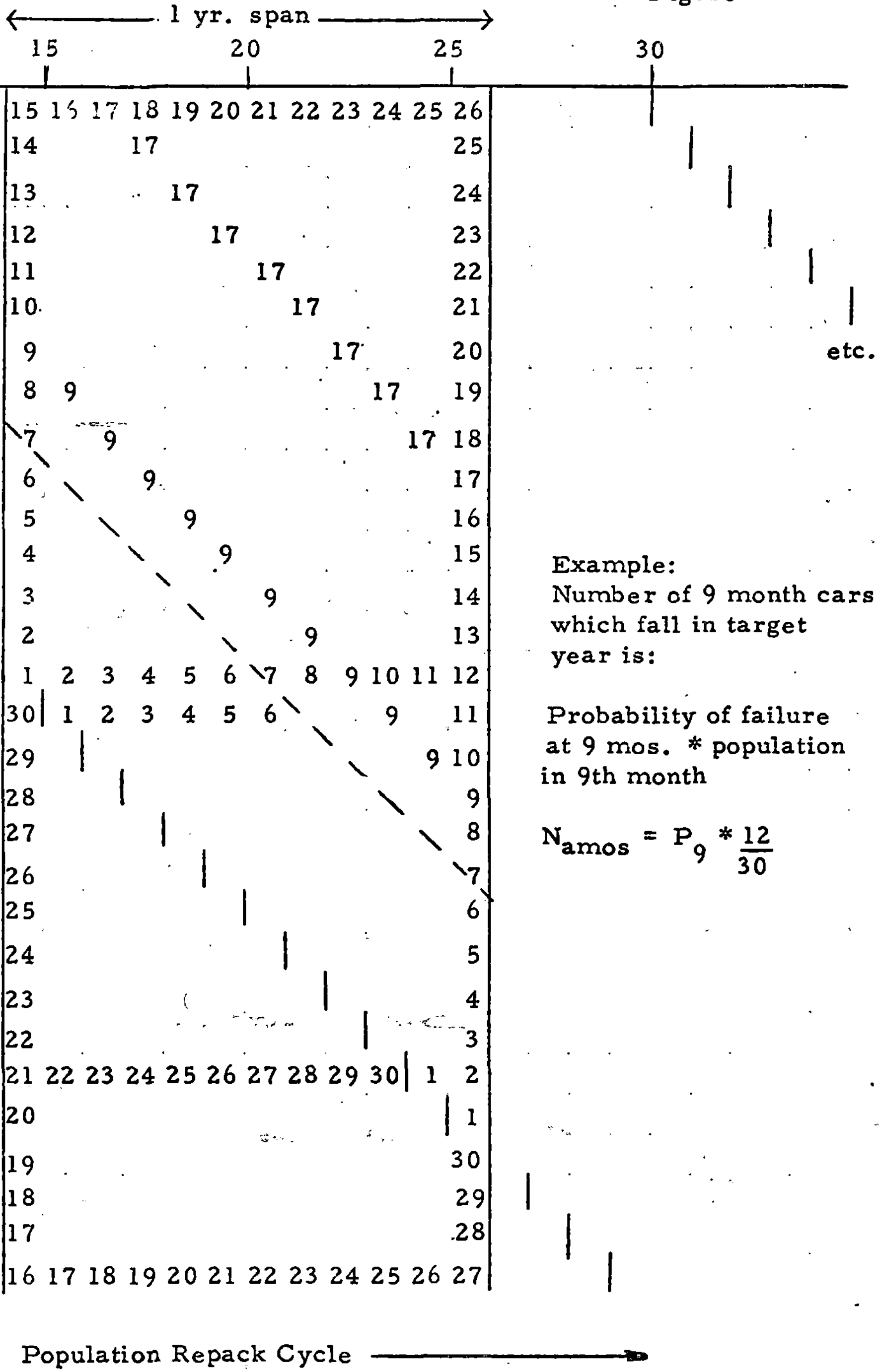


Figure 18



Example:
Number of 9 month cars which fall in target year is:

Probability of failure at 9 mos. * population in 9th month

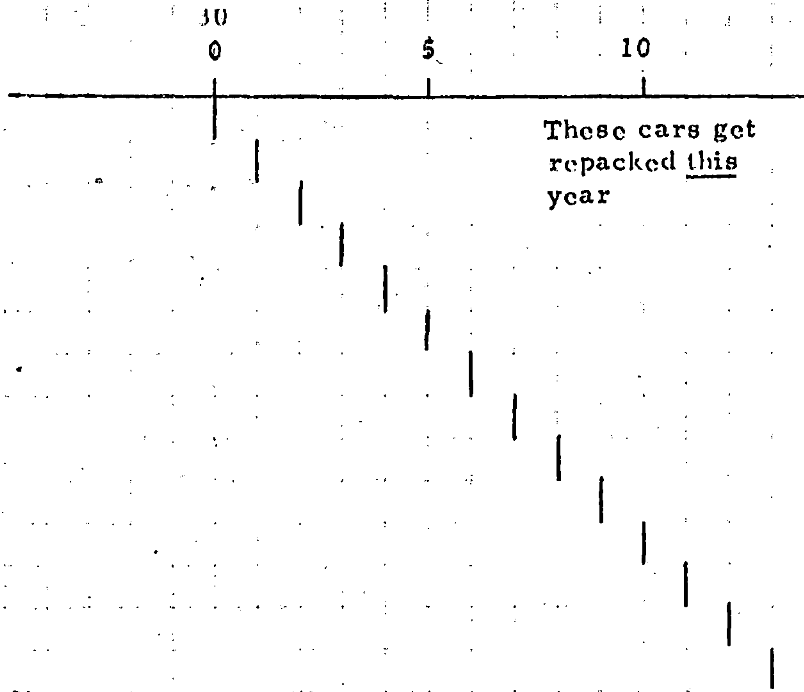
$$N_{amos} = P_9 * \frac{12}{30}$$

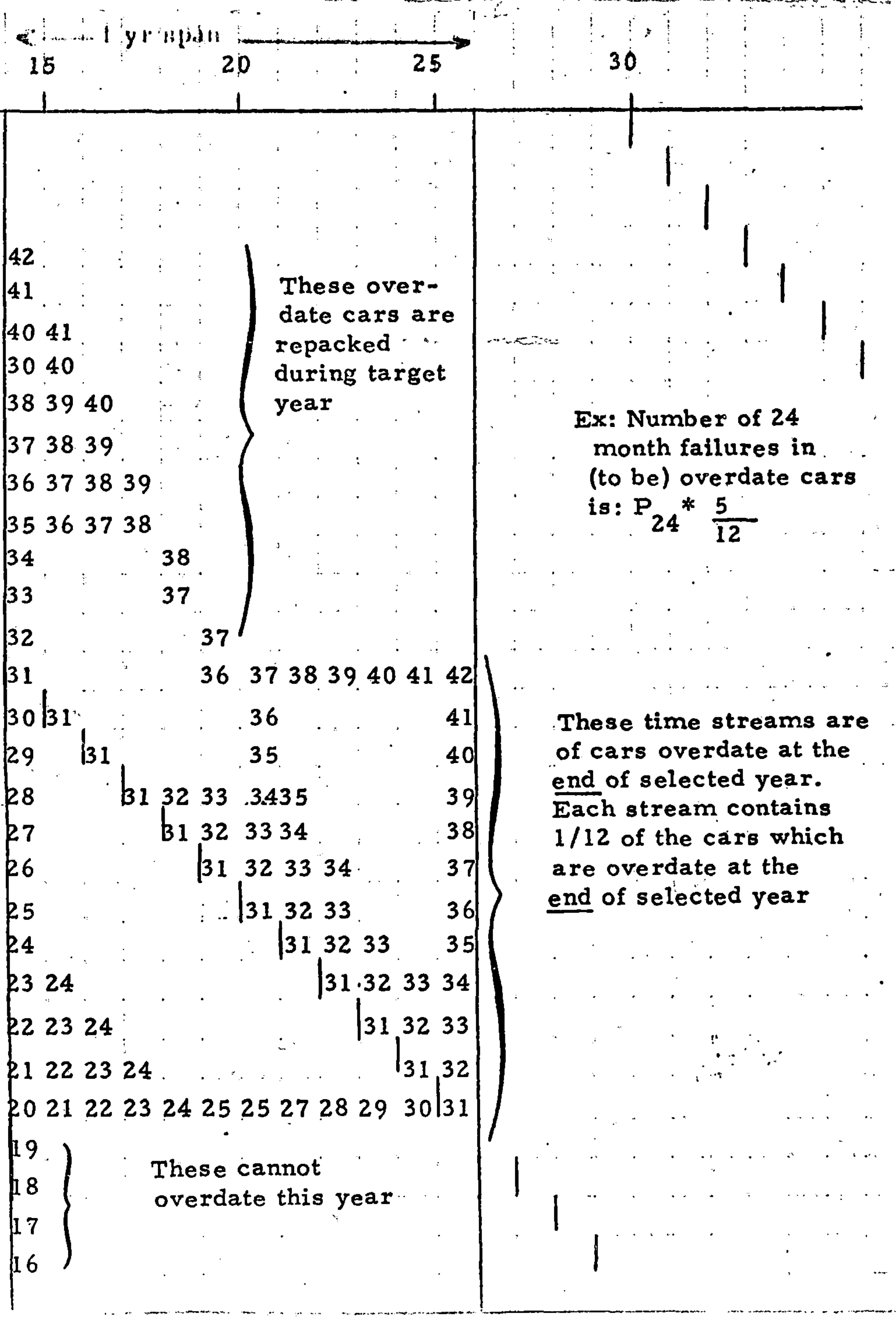
Similar reasoning can be used to derive the expression for the unstabilized cars, which are on a 24 month repack cycle.

$$F_{Un} = U_n * \frac{12}{24} \left[P(1,6) + P(7,12) + P(13,18) + P(19,24)\right]$$

The derivation of the expressions for the overdate cars requires another time stream diagram, Figure 19, with the same conventions as used in Figure 18, except that the short vertical bars indicate the missed repack dates. Some additional assumptions are needed about overdate cars. Assume the cars overdate uniformly and that no car goes overdate more than 12 months. Then, looking at their missed repack dates, the top three cohorts will get repacked the year previous to the subject year. The next eleven cohorts get repacked during the subject year and the last four cohorts cannot overdate during the year. This leaves twelve cohorts which become overdate by the end of the year.

The youngest of the cars which become overdate at the end of the year are the 20 month cars. These cars are 20 months old in January (actually at the end of January) and 31 months old in December. The number of failures, out of this group is $F_{So_{20}} = P_{20} * \frac{S_o}{12}$ for January and also for the entire year, since 20 month cars don't exist in any other month. If the assumption is made that $P_{20} = P_{21} = P_{22} = P_{23} = P_{24}$, then $F_{So_{19,24}} = S_o(\frac{5}{12}P_{20} + \frac{4}{12}P_{21} + \frac{3}{12}P_{22} + \frac{2}{12}P_{21} + \frac{1}{12}P_{20})$


0
5
10
These cars get repacked this year



15
20
25
30
These over-date cars are repacked during target year
Ex: Number of 24 month failures in (to be) overdate cars is: P24* 5/12
These time streams are of cars overdate at the end of selected year. Each stream contains 1/12 of the cars which are overdate at the end of selected year
These cannot overdate this year

$$F_{So19,24} = S_o * \frac{15}{12} * \frac{P(19,24)}{6} = \frac{15}{72} P(19,24) * S_o$$

$$= \frac{15}{72} P(19,24) * S_o$$

Proceed in this fashion to obtain the failures from the entire overdate stabilized cars:

$$F_{So} = S_o \,[.20833\ P(19,24) + .70833\ P(25,30) + .79167\ P(31,36) + .29167\ P(27,42)]$$

A similar procedure yields the following failure expression for overdate non-stabilized cars:

$$F_{Uo} = S_u \,[.20833\ P(13,18) + .70833\ P(19,24) + .79167\ P(25,30) + .29167\ P(31,36) + 0 * P(37,42)]$$

Failure calculations for the cars which retire during the year require some further assumption. Assume that the same number of cars are retired each month and that cars were repacked 12 months or more before retiring, but not overdate more than 12 months. Then their time stream could be sketched as in Figure 18 and 19 with the same conventions as before except that the population diminishes by 1/12 each month. The expression for failures among retirees is:

$$F_{Sr} = S_r \,[.07407P(1,6) + .19074P(7,12) + .21667P(15,18) + .21667P(19,24) + .21667P(25,30) + .09398P(31,36) + .02593P(37,42)]$$

Similarly the failures expression for non-stabilized cars which are retired during the subject year is:

$$F_{Ur} = U_r\ .09259P(1,6) + .23843P(7,12) + .27083P(13,18)$$

$$+ .27083P(19,24)\ .09722P(25,30) + .03241P(31,36)$$

$$+ 0 \cdot P(37,42)$$

Each age group can now be summed across all the status groups to get a total number of failures for each age group. Since these failure numbers were obtained in another way (as actual data), the equations can be used to solve for the probability of failure versus months after repacking. For example:

$$F(19,24) = P(19,24)\Big[.4S_n + .5U_n + .20833\,S_o + .70833\,S_u$$

$$+ .21667S_r + .27083U_r\Big]$$

Hence, the probability of failure in the 19 to 24 month age group is:

$$P(19,24) = F(19,24)/\text{Bracketed Terms}$$

The values of the probabilities depend upon two things, the status group populations and their distributions among the age groups. These distributions are listed in Table 20 in matrix form.

The populations of the status groups are derived by allocating the total car population. Since there is some uncertainty in the population numbers, a baseline case with its associated probabilities could be defined. A sensitivity analysis, described later, will show how sensitive the probabilities are to the assumptions. The baseline

TABLE 20: Car Population Distribution

Status Group	Population	Age Group Distribution 1 - 6	7 - 12	13 - 18	19 - 24	25 - 30	31+
S_n	196,949	.200000	.200000	.200000	.200000	.200000	-0-
U_n	590,848	.250000	.250000	.250000	.250000	-0-	-0-
S_o	21,883	-0-	-0-	-0-	.104167	.354167	.541667
U_o	65,650	-0-	-0-	.104167	.354167	.395833	.145833
S_r	15,750	.037500	.095833	.108333	.108333	.108333	.059722
U_r	47,250	.046296	.119213	.135417	.135417	.048611	.016204
All	938,330						

values are given in Table 21. The total plain bearing fleet size is as of the end of 1973. The number of cars retired during the year (which includes cars converted from plain to roller bearings) is derived from data furnished by the AAR and bearing manufacturers' market projections. The biggest discrepancy here is the conversion estimate. The AAR number is 6000 conversions per year while the bearing manufacturers' only see sales corresponding to about 1000 conversions per year. However, since conversions account for only about 10 percent of retirements, this discrepancy is not a major one. For the baseline case, the combined number of retirements and conversions was chosen as 63,000 cars per year.

AAR estimates that 30 percent of the plain bearing fleet is stabilized. This is a drastic downward revision of their 50 percent estimate last year. From interviews at railroads and also from preliminary results of the twenty-railroad survey being conducted by the AAR, 25 percent seems more realistic. This was the value chosen for the stabilized car percent. AAR estimates that 8 percent of the cars are overdate on repacking. The above mentioned sources plus results from FRA's field inspections would suggest that at least 10 percent and probably more is overdate. However, 10 percent was the value chosen for this parameter.

TABLE 21: Parameters for Failure Probability Calculations

Parameter	Value
Total plain bearing car fleet	875,330
Cars retired each year	63,000
Percent of fleet which is stabilized	25%
Percent of fleet which is overdate	10%
Number of failures (1973)	
Age Group 1-6*	70.9**
7-12	68.7
13-18	63.7
19-24	67.4
25-30	45.7
31+	19.4

Change in Parameters to Calculate Failures Under FRA Safety Standards

Parameter	Value
Percent of fleet which is overdate	1%

*Age n means in the nth month since repack
**These numbers were scaled up to distribute "unknown" ages.

The number of failures is from good data from the AAR Failed Axle Report for the year 1973. Of the 336 failures reported (note that all failures are supposedly reported; there is no monetary threshold as is the case in reporting to the FRA), 41 were of unknown age. These unknowns were distributed among all the ages proportionately to keep the correct total.

From the population distributions of Table 20, summed by age group, and the number of failures in each group, a probability of failure can be calculated for each age group. These probabilities are listed in Table 22.

To calculate the number of accidents prevented by the FRA safety standards, assumptions similar to those made in the section on railroad compliance costs will be made as to overdate cars. Assume that only 1 percent (as opposed to the present 10 percent) of the cars will be overdate in any one year. Then, with some reworking of the population distribution, the numbers of failures under FRA safety standards are as listed in Table 22. More failures will occur in the "younger" months (infant mortality) while fewer failures will occur in the "older" months for a net saving of fourteen prevented accidents the first year. If it is assumed that the ratio of accidents to total cars is constant (which is the basis of the failure probability derivations), then the number of prevented accidents over an entire 15 year span can be calculated.

TABLE 22: Failure Probabilities and Failures

Age Group	Failure Probability	Failures undr Under AAR Interchange Rules	Failures Under FRA Safety Standards	Prevented Accidents by FRA Safety Standards
1-6	.0003734	70.9	77.9	-7.0
7-12	.0003588	68.7	76.4	-7.7
13-18	.0003154	63.7	67.7	-4.0
19-24	.0003054	67.4	66.1	+1.3
25-30	.0005926	45.7	30.1	+15.6
31+	.0008369	19.4	3.2	+16.2
All Ages		335.8	321.4	+14.4

5.8.2 Benefits from Accident Reductions

From the fleet forecasts used previously (see Tables 14 and 15) and the prevented accidents arrived at in Table 22, the benefits from accident reduction can now be calculated. The 14.4 prevented accidents were based on a total fleet of 875,330 cars. If the prevented accidents are scaled down according to the projected fleet sizes listed in Table 23, the number of prevented accidents can be calculated for each succeeding year. Use of the OMB recommended discount factor of 10 percent and the per-accident cost of $64,545, which was determined in previous sections on railroad and societal benefits, produces the discounted dollar figures in the last column of Table 23. The sum of these numbers gives the current value of the benefits from prevented accidents, $4,279,900.

TABLE 23: Benefits From Prevented Accidents

Year	Plain bearing cars in Service at end of Year	Combined Inflation/Discount Rate @ 10%	Prevented Accidents @14.4/ 875,330	Discounted Benefits from Prevented Accidents @$64,545
1973	875,330	0	14.4	0
1974	812,330	1.000	13.4	$ 864,900
1975	749,330	.909	12.3	721,700
1976	686,330	.826	11.3	602,500
1977	623,330	.751	10.2	494,400
1978	560,330	.683	9.2	405,600
1979	497,330	.621	8.2	328,700
1980	434,330	.564	7.1	258,500
1981	371,330	.513	6.1	202,000
1982	308,330	.467	5.1	153,700
1983	245,330	.424	4.0	109,500
1984	182,330	.386	3.0	74,700
1985	119,330	.350	2.0	45,200
1986	56,330	.319	.9	18,500
1987	--			
1988	--			

Total (Societal and Railroad) Benefits from Prevented Accidents (Discounted) $4,279,900

5.9 Net Cost Effectiveness

The net cost effectiveness can now be computed by algebraically adding the benefits and costs which were determined in the previous sections. These are restated below in terms of present value of the fifteen year dollar amounts.

Railroad Costs	$11,608,700	
Societal Costs	$ 275,600	
Total Costs	$11,884,300	
Railroad and Societal Benefits		$4,279,900
Civil Penalties (transfer from railroads)		$6,354,500
Net Cost		$1,249,900

Civil penalties, the fines paid by the railroads for non-compliance with the standards, are part of railroad costs and, on the other side of the ledger, part of societal benefits. Since they represent a large incidence effect, a burden on the railroads which is practically impossible to back-distribute, these fines have been itemized in the accounting.

From these calculations, the strict enforcement of the repacking rules would not be cost effective unless some large imponderables, such as political considerations, for example, were thrown onto the benefit side of the scales. Indeed, the purpose of a cost-effectiveness study is to furnish the decision maker with detailed information on quantifiable items in his decision making process. When he adds his special unquantifiable and exogenous considerations, the equation is complete and the decision can be made.

5.10 Sensitivity Analysis

In the absence of firm data, a sensitivity analysis is very important. If it can be shown that the results of our analysis are insensitive to the magnitude of a particular parameter, then the uncertainty in the value of that parameter is not important.

The largest uncertainties in this present analysis were in the plain bearing fleet phase out, the percent of cars which were stabilized, the percent of cars overdate and the failure rates themselves. Each of these are discussed in turn below.

5.10.1 Sensitivity to Phase-Out Rate

In discussions with the AAR and bearing suppliers, discrepancies arose as to the phase-out rate of plain bearing cars (i.e., conversions per year to roller bearings plus retirements per year). Since costs and benefits both tend to be proportional to the number of cars in the fleet each year, it is felt that the actual phase out rate will not substantially change the net cost effectiveness.

Another effect however of varying retirement rate is in the failure probabilities calculated in Section 5.8. The computer program, used to calculate the probabilities, was exercised with changes in all parameters. The retirement rate produced less than 1/2 percent change in any of the probabilities, even in conjunction with other parameter changes. Thus, the retirement rate was judged to be an uncritical parameter.

5.10.2 Sensitivity to Percent Cars Overdate

Data on overdate cars are difficult to get because cars operating overdate are operating contrary to AAR interchange rules (and recently, contrary to FRA safety standards). Preliminary returns from FRA field inspections are not sufficient to comprise a valid sample. However, from this sample, and from initial results of the AAR twenty-railroad survey, 10 percent seemed like a realistic value. To test the effect of an 8 percent value for overdate cars, this change was run through the computer program. Both the probabilities and the subpopulations change, of course, and the number of prevented accidents changes from 14.4 per year to 15.0 per year for the first year. This scales up both societal and railroad benefits to $4,458,200, as shown in Table 24, to yield a total net cost of $1,071,600. The analysis is judged insensitive to the percent of cars overdate since the change in net cost is only 14 percent.

5.10.3 Sensitivity to Percent of Cars Stabilized

Indications are that a very small proportion of the plain bearing fleet is stabilized. The assumption made was 25 percent. To test the sensitivity of the analysis to this parameter, a value of 30 percent was used in the computer, which changed the failure probabilities and the

TABLE 24: Sensitivity Analysis: Overdate and Stabilized Cars

	Baseline Case*	8% Overdate	30% Stabilized
Railroad Compliance Costs	$11,608,700	$11,608,700	$11,454,200
Societal Costs	$ 275,600	275,600	275,600
Accident Reduction(first year)	14.4	15.0	14.9
Railroad Benefits (@ $64,545/accident) Societal Benefits (@$235/accident)	$ 4,279,900	$ 4,458,200	$ 4,428,500
Civil Penalties	$ 6,354,500	$ 6,354,500	$ 6,354,500
Net Costs	$ 1,249,900	$ 1,071,600	$ 946,800

*In the baseline case, it is assumed that 10% of the cars are overdate and 25% are stabilized.

subpopulations. The number of accident reductions come out to be 14.9 in the first year. This changed the societal and railroad benefits to $4,428,500 as shown in Table 24. It was necessary also to change the railroad compliance cost since part of this cost is due to repackings which also changed. The total net cost is $946,800, which, since it represents a 24 percent change, caused this parameter to be judged sensitive, although the analysis results would undergo only a quantitative change.

5.11 Implications of the Analysis

The immediate question that arises as a consequence of this test analysis is whether anything more can be done to lessen journal failures. The following discussion will review the kind of action that might be taken by FRA.

a. The distribution of journal failures as a function of the month since repacking reveals that a high percentage of failures occur in the first few months after repacking.* This infant mortality phenomenon is responsible for the small reduction in accidents which are predicted from the promulgation of the safety standards. As a consequence, several approaches to accident prevention are suggested.

*Of the 1973 failures, 8 1/2 percent occurred in the first two months; for 1972, the figure is 14 percent.

- Deal with the phenomenon of infant failure as is, designing standards that recognize the high probability of early failure.

- Attempt to eliminate the causes of early failure and thus produce a more normal wearing or distribution of failure.

Unfortunately before either approach can be selected, additional information must be developed on the real causes of this infant mortality syndrome.

It was suggested in the words of the mechanical department personnel interviewed, that "if a friction bearing fails to seat properly, it will show up as a hot box very soon after the repacking -- within the first few months." This being the case, a standard that would require an inspection perhaps 10 to 20 days after the repacking, to insure that the bearing is seating properly, might be in order. If the inspection could be readily accomplished in the field and could be done without dismantling the entire bearing, then the additional costs to the railroad could be minimized. In this eventuality, each car would have to be stenciled or marked in such a way as to call attention to the fact that a repacking and/or bearing replacement has occurred within the previous 10 to 20 days and that an immediate visual inspection is in order. However, it is questionable whether a suitable field inspection procedure can be economically developed and whether it is even possible to visually determine whether a bearing is seating properly or not. If a standard can be developed which is economically feasible and implementable from a pragmatic standpoint, then the existing infant mortality phenomenon can be dealt with directly.

b. Prevailing railroad practice is to avoid repacking a loaded car. One reason for this, of course, is to avoid delays to shippers. There is also the feeling that a bearing will seat more successfully if it is lightly loaded. Strict enforcement of the FRA repacking standards will considerably limit discretionary action in this area.

The big unknown is whether or not a heavily loaded bearing is less likely to seat properly than a lightly loaded one. A review of one carrier's data or 383 hot boxes in 1974 gave the following figures: 83 percent of all the hot boxes were on loaded cars while 87 percent of the first month hot boxes were on loaded cars. However, without knowledge of what percent of all these cars were repacked in the loaded condition, no conclusion can be reached. Again it is the population figures, rather than the failure figures, which are missing. If all railroads reported whether a car was repacked loaded or empty then at least some judgment could be formed on the effect of load on bearing seating. This would provide a basis for either retaining or changing the span (now one month) within which a bearing may be repacked.

c. Information on the numbers of cars in different repack age groups is generally sketchy; on the older groups, it is particularly vague. Individual carriers are understandably reluctant to advertise the number of cars they are operating in an illegal condition. This, along with the fact that relatively small numbers of cars are involved, make population on older cars both suspect and also variable.

By actually conducting a broad scale field test of longer repacking intervals, the real or natural distribution of failures can be ascertained for a wide variety of conditions, equipment types, and services; it may well be that journal failures would be minimized by establishing a longer interval for periodic repacking thus reducing the infant mortality effects. Since this real or natural distribution of failures is unknown at this time, the optimum interval is likewise unknown, and FRA as a consequence should encourage the development of standards or rules that would encourage experimentation in this area.

Evidence developed in this analysis suggests that dealing with the present failure distribution and the "infant mortality phenomenon" directly will be a difficult task at best. Accordingly, the second approach, that of trying to eliminate the root causes for infant failure, should also be considered.

Since very little tangible evidence exists pointing to failures in reassembly, versus component incompatibility-failure, mismatching, etc., a program of field experimentation could be established to diagnose hot boxes or incipient hot boxes and their contributing causes.

Many carriers have been tabulating causes in attempts to determine basic failure causes. Eight months data from one carrier provides the following breakdown of first and second month (infant) hot box causes:

- 33% improper assembly or procedures
- 22% failure to replace defective parts
- 11% infant mortality of parts
- 10% unknown
- 24% other (e.g. pad missing, water in box)

Another carrier, in analyzing data on hot boxes which occurred over a span of one and a half years, provided this distribution of infant hot boxes (in this case three month olds were also included):

- 24% improper assembly or procedures
- 12% failure to replace defective parts
- 21% infant mortality of parts
- 28% unknown
- 14% other

Although these breakdowns are incompatible because of different reporting procedures, standardization at the national level would produce large volumes of compatible data which would indicate the relative blames for example, of improper packing procedures and poor quality control on parts.

c. By accelerating the replacement of friction bearings with roller bearings, the numbers of accidents due to journal failures would be cut drastically. Roller bearings account for roughly half the U.S. fleet, but only 9 percent of the failures. This number is even more impressive in view of the higher utilization rates of roller bearing cars.

The available evidence to date indicates that existing roller bearings are much more effective in reducing hot boxes than are plain friction bearings. Moreover, Timken has developed a new permanently sealed roller bearing which does not require any lubrication unless mainten-nace, repair or replacement of related parts such as wheels causes it. The quality of the seals, both front and rear on these new bearings has been vastly improved as have the lubricants for a target duration of 600, 000 miles. Four hundred car sets are in service and will reach two years service next year. Preliminary examinations of bearings involved in accidents (due to other causes) indicate wear characteristics as predicted.

FRA should examine the alternatives that can be taken in concert with the AAR and the bearing manufacturers to step up the present replacement of friction bearings either by promulgating appropriate standards or other similar action oriented measures.

d. A program of field research designed to identify all causes of hot boxes and journal failures could be fostered and promoted. This program would examine the alleged causes of hot boxes as well as potentially unknown factors and would provide a sound analytical base for FRA accident countermeasures. Within the scope of this program some of the following factors could be considered for evaluation.

- The role of lubrication or the lack of it in causing hot boxes.

- The functional causes for lubrication losses and the probability of various types of lubrication losses occurring.

- The loss of lubrication and/or effects due to non-movement. It is believed that lubrication and saturation of the pad is a function of the rotational movements of the journal and consequently, it is not known how long a car can remain motionless without causing any loss and resulting friction and wear.

- The effects of high impacts on stabilized and unstabilized boxes. Impacts could be simulated in field testing for a variety of lubricationg conditions.

- The effects of high dynamic loads on bearing wear and bearing lubrication. Under what operating conditions does the lubrication film break down or dissipate.

e. Previous suggestions have focused on diagnosing the real causes of hot boxes in order that countermeasures can be developed for their prevention. An alternate but equally valid strategy is to improve hot box detection thereby preventing journal burn offs and resultant accidents.

FRA could consider developing a safety standard that would require the installation of additional hot box detectors in accordance with formulas developed to determine the optimum location for such detectors. While most railroads readily acknowledge the efficiency of installing additional detectors in accordance with standard formulas that have been developed for this purpose, a few carriers credit the scientific analysis of optimum location and installation of such detectors as one of the major reasons for their success in reducing journal failures.

One carrier's success is due to the precise installation of hot box detectors on tracks where traffic density and past hot box occurrences indicates a high probability of prevention or detection effectiveness, and to an ongoing program designed to train and upgrade inspectors to detect incipient failures. While the total cost of this program has not been ascertained, the comments made concerning its effectiveness seemed to indicate that it is paying off; consequently, CONSAD feels that it should be investigated as a potential model for other railroads and as a prototype to be considered by FRA in designing hot box standards.

Another valid alternative to consider in a FRA preventative program is the development of a low cost hot box detector.

Current hot box detection equipment costs in the neighborhood of $20,000 per installation and generally must be located where:

- There is tangent track,
- There has not just been a brake application,
- They are accessible for maintenance,
- A tie to existing communications is feasible,
- There is a power supply,
- The roadbed is stable,
- Sunlight is not a problem,

- Trains can be stopped without interference,
- There are existing tracks that can be used for set offs,
- The set offs are accessible for car repairs.

The initial costs and location limitations have greatly reduced the ability of railroads to install detectors at optimum locations in terms of their effectiveness in preventing accidents. What is needed are low cost detectors, perhaps battery powered, that can be installed between existing detectors. Ideally such detectors would be installed at intervals which would permit the detection of rapid heat buildup that occurs with roller bearing failures, thus providing a measure of economic insurance* for these failures as well as for similar but slower buildups in friction bearing cars.

Considering the financial position of the rail industry, the development of such devices could be the responsibility of the Federal Railroad Administration.

A program of research and development of low cost hot box detectors could be undertaken by the Office of Research Development, FRA or alternatively by the Transportation Systems Center.

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*Since friction bearing cars are being slowly phased out of the fleet, the installation of hot box detectors soley for detection of hot boxes in these cars would not be economically justified for many carriers. However, since such detectors properly spaced can detect hot boxes on roller bearing cars, the investment makes greater sense.

Another area needing research in hot box detection is in eliminating false alarms which presently run as high as 60%. This appears to be a problem more of signal processing than of procedures used by personnel. It appears that experience and procedures have gone about as far as they can, leaving an expensive and time consuming high false alarm rate.

Summary Implications for Prevention of Accidents

Most of the previous suggestions have been offered in an effort to provide FRA with some alternative considerations for preventing the serious, costly accidents that result from journal failures. These are but a few of the many possible countermeasures which can be evaluated in establishing an effective accident prevention program. Considering the substantial gaps in the state of the art and the inadequate knowledge and understanding of the root causes for journal failures, CONSAD recommends that initial FRA work be directed at developing a basic understanding of such factors as a foundation for subsequent action programs.

APPENDIX A

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APPENDIX B

INTERVIEWS WITH RAILROAD RESPONDENTS

RAILROAD INTERVIEWS

Interviews were scheduled with a representative cross-section of railroads in order to provide direct input from the industry on the design of the cost/benefit methodology.

Most of the questions asked during the interviews were directed toward determining whether or not the carriers had completed a cost/benefit analysis of the safety standards or had measured the impacts in some other fashion, and the specific approaches or methods followed in their analysis. These questions helped clarify the type of data required for measuring the costs of compliance and produced a number of excellent procedural suggestions which have been incoporated in the recommended design. The personnel contacted on each road varied but generally included the Chief Operating Officer, Chief Engineer, Chief Mechanical Officer, Transportation Superintendent, Vice President of Marketing, Vice President of Finance, Director of Safety, Director of Operation Planning, and Chief Claims Agent.

A total of eight Class I carriers were contacted and one Class I switching and terminal company. Of this total, only one carrier declined to participate, while another carrier facing its imminent dissolution felt their contribution would be of doubtful value considering their position. The carriers ranged in size and financial strength from very large to very small, from very strong to very weak (bankrupt), and covered all geographical sections of the country, providing a well-distributed sample.

In the course of the interviews, a number of suggestions were made which did not relate directly to our principal concerns, namely, the design of a methodology for cost/benefit analysis of safety standards. However, we have included the more pertinent comments where it was felt to be appropriate.

In general, the railroads contacted were extremely helpful, candid in their responses, and provided generously of their time in the conduct of these interviews. We have categorized their principle comments and our own observations, under the headings: general comments, costs, and benefits.

A. General Comments

Only two of the carriers interviewed had done any specific costing of the safety standard impacts on their railroads, although two other carriers as a result of our interviews did provide ballpark estimates of the cost of compliance on their roads. While most of the carriers felt that the standards would reduce accidents, a few were uncertain of the effects, while one suggested that accidents might actually increase over the long run. The latter comment was based on a belief that implementing the FRA track standards would seriously affect planned maintenance activities and thus the railroad would suffer a loss in net efficiency over a longer period of time. None of the carriers made any effort to quantify the benefits stemming from compliance with the standard, relying on the aggregate figures assembled by the AAR committee to represent their common viewpoint.

As to the overall financial impacts of the standards, the responses were equally divided between those that said the standards would have little or no impact, and those who felt the standards would have a major impact. Those carriers who felt the safety standards would have little impact offered these explanations for their views:

- Their particular railroad track and equipment is in relatively good shape and thus incremental maintenance expenditures required to comply with the standard were felt to be minimal.

- Their financial planning dictates the funds that can be spent on upgrading track and equipment and hence generally limits the extent of compliance. What they are planning to allot for compliance activities must be consistent with their overall financial plans.

- FRA would be unable to provide effective field inspection forces due to manning deficits and thus the carriers were planning to slowly integrate compliance activities over a longer period rather than meet the compliance dates established by FRA.

Overall, the reactions to the establishment of the standards and the action being taken by FRA in developing these standards was extremely favorable. Comments were made to the effect that "This should have been done a long time ago," "The industry will benefit from accident reductions in the long run," "We haven't had a good set of standard practices prescribing minimum maintenance levels in the past, now we have one and they will provide an excellent guideline for future planning," "The standards will force improvement in marginal carriers perhaps improving the quality of interline movements through improved equipment utilization and reduced delays due to accidents." Negative points mainly addressed specific features of the standards which were found objectionable.

B. Costs

In order to determine the degree of compliance required, or number of defective components requiring replacement, more than half of the railroads favored some type of sampling approach. Most mentioned inspecting shop records as a potential data source, and others suggested the AAR's interline billing records as a reasonable sample reflecting overall conditions.

With regard to the abandonment of tracks as a consequence of stringent track standards, no carriers indicated that they had plans to abandon more tracks than that which had already been put up for abandonment. A few carriers have downgraded the allowable speed on some sections of tracks as a result of the track standards. While the potential for service reduction exists, as a result of this downgrading, no evidence was presented of any significant deterioration in service quality. Two carriers indicated that their slow orders have increased as a consequence of the standards, and one indicated that they would use the costs of complying with track standards as an additional argument strengthening their petitions for abandonments already filed with the ICC or planned for future filing.

A number of railroads voiced strong concern about the effects the new track standards would have on planned maintenance activities, expressing the view that compliance efforts would reduce the overall efficiency of track maintenance.

To determine the cost of compliance with track standards, the majority of carriers would rely on the estimates of local roadmasters and superintendents as to the number of of miles requiring improvement.

Track inspection standards as they are now written are inefficient in that they prohibit back-to-back inspections. In addition, the alignment standards could never be followed due to a lack of equipment which can measure alignment on a 62' cord. Most carriers felt that manual inspection of alignment would be much too expensive.

The common interpretation of the periodic equipment inspection standard by most of the carriers interviewed, was that inspections would be necessary at an arbitrary point in place and time. Following this line of reasoning, carriers anticipated that once a defect was discovered, cars would have to be cut out of a train and moved to shop areas, which would consume approximately 6 days including time for repairs. Furthermore, they interpreted the standard to require a complete dismantling of equipment, a process which would be unnecessarily expensive and dangerous, as compared to visual inspection, which they considered to be entirely adequate when conducted in a shop or at a repair track facility.

Two railroads were of the opinion that the periodic complete inspection and dismantling of components required by the standard as it is now written is unjustified. As they see it, the complete inspections could be done at any time prior to the 2-year period. They would simply inspect the car completely whenever it hit a repair track three to four months before the periodic inspection date, and would stencil the newly completed inspection date on the side of the car. In this event, the only additional costs incurred to comply with the standard would be the incremental costs of the FRA inspection. One carrier pointed out that the material costs for replacement parts would be insignificant because they would simply be replacing all defective components at one time, whereas now they are effecting item-by-item repairs as the need arises over a longer period. Thus, the anticipated costs of equipment inspection were dependent on each carrier's interpretation of the standard as it is now written.

Estimates for conducting the complete FRA periodic inspection ranged from 12 to 30 hours.

Due to the general shortage of certain types of equipment, any decrease in equipment availability would hurt the railroads traffic-wise. Therefore, in determining the costs of complying with the new equipment standards, the losses resulting from decreased equipment availability should be considered.

C. Benefits (Avoidance of Accident Costs, Etc.)

The cost of service disruptions and delays due to accidents were felt to be considerable by some carriers and minimal by others. One carrier records every car that is delayed or destroyed as a result of accidents, and based on his figures estimates that one percent of all carloads transported are affected by accidents. If this sample is typical, it would mean that an average of 250,000 carloads a year are delayed or involved in accidents. Variations in the cost of accident delays were attributable to rerouting policy, (Does the carrier use connecting carrier routes when his are blocked?) and the existence of alternative routes (Many western lines are really held up by accidents due to a lack of alternative routings.).

A number of carriers expressed interest in the CONSAD routine for predicting accidents based on past maintenance expenditures and work measurements. Questions were asked as to its ability to predict accidents on an individual railroad (this is currently being studied).

Claim costs and compensation awarded by the courts to those injured in railroad accidents is rising rapidly on most railroads. Even in cases where there is absolutely no railroad negligence, the courts have been increasingly ruling against them.

Loss and damage to lading resulting from accidents has declined in recent years. It was generally felt that most shippers do not penalize the railroads as a consequence of losing their shipments in a rial accident as long as they are quickly notified of the loss, and claims are settled in an expeditious and acceptable manner. However, all of the carriers could point to instances where traffic was permanently lost as a result of accidents.

Carriers internal safety reporting systems varied from crude to highly sophisticated. Most systems generated a report of accident costs for management purposes, however, the report frequently covered only the direct costs and understated the total losses attributable to the accidents.

Depending on the circumstances of the accident, some carriers are billed for community services such as Red Cross assistance, and do provide compensation for these accident induced costs.

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A Methodology for Evaluating the Economic
Impacts of Applying Railroad Safety Standards, US
DOT, FRA, RG Kennedy,III, FH Lloyd, R Lowrey,
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