Report No. Rp-41
Volume 2

DOT-FR-20047

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

OCTOBER 1974

FINAL REPORT

Document if available to the public through the
National Technical Information Service
Springfield, Virginia 22151

Prepared for

U. S. DEPARTMENT OF TRANSPORTATION
Federal Railroad Administration
Washington, D. C. 20590

TECHNICAL REPORT STANDARD TITLE PAGE

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
RP-41		PB 244 267

4. Title and Subtitle	5. Report Date
A METHODOLOGY FOR EVALUATING THE ECONOMIC IMPACTS OF APPLYING RAOLROAD SAFETY STANDARDS - VOLUME II	
	6. Performing Organization Code
7. Author(s)	8. Performing Organization Report No.
Frank H. Lloyd	
9. Performing Organization Name and Address	10. Work Unit No.
CONSAD Research Corporation 121 North Highland Avenue Pittsburgh, Pennsylvania 15206	11. Contract or Grant No. DOT-FR-20047
	13. Type of Report and Period Covered
12. Sponsoring Agency Name and Address	Final Report 12/72 - 10/74
UNITED STATES DEPARTMENT OF TRANSPORTATION Federal Railroad Administration Washington, D. C. 20590	14. Sponsoring Agency Code

15. Supplementary Notes

Volume 2 of 2 volumes.

FRA Project Officer:
Richard J. Crisafulli
Office of Federal Assistance (RFA-20)

16. Abstract

This manual is intended as a working document for Federal Railroad Administration personnel, and provides step-by-step procedures which are intended for use in determining the economic impact of proposed railroad safety standards. It is a companion piece to Volume I, the Final Report.

The procedural framework described herein is broad enough to encompass safety standards in 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 developing this manual, high priority was placed on presenting workable procedures that can be used immediately for economic impact evaluation. Special attention is given to accidents and accident prediction, discounting, quantification problems and the role of sensitivity analysis. A completely worked example is presented in the appendix.

Volume I of this report is the Final Report which describes the methodology in general terms.

PRICES SUBJECT TO CHANGE

17. Key Words	18. Distribution Statement
Economic Impact Railroad Safety Standards Accident Costs Cost-Effectiveness	Availability is unlimited. Document may be released to the National Technical Information Service, 5285 Port Royal Road, Springfield, Virginia 22151, for sale to the public.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
UNCLASSIFIED	UNCLASSIFIED	169	

Form DOT F 1700.7 (8-69)

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EXECUTIVE SUMMARY

This manual is intended as a working document for Federal Railroad Administration personnel in determining the economic impact of proposed safety standards. As such, it is a companion piece to the final report* which describes the methodology in general terms. The procedural framework described herein is broad enough to encompass safety standards in equipment, track and other categories. 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 developing this manual, a high priority was placed on presenting workable procedures that can be used immediately for economic impact evaluation. Any less detail would neglect important impacts, while greater detail would be unjustified. The procedures are oriented around data availability which is a key consideration. 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

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* A Methodology for Evaluating the Economic Impacts of Applying Railroad Safety Standards, Contract DOT-FR-20047.

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. Procedures for treating data-associated problems are discussed.

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.

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. 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. Special appreciation is due Mr. Richard Crisafulli of the FRA Office of Policy and Plans for his guidance. We are also grateful for the 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.

1.0 INTRODUCTION

This manual is intended as a working document for Federal Railroad Administration personnel in determining the economic impact of proposed safety standards. As such, it is a companion piece to the final report* which describes the methodology in general terms. The procedural framework described herein is broad enough to encompass all types of safety standards in the categories of equipment, track and other categories. 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 developing this manual, 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.

In the above context, it is important to avoid the extremes of overcomplexity and triviality in economic impact analysis. Although the analysis should include all major direct costs and benefits, an

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*A Methodology for Evaluating the Economic Impacts of Applying Railroad Safety Standards, Contract DOT-FR-20047.

accounting of all direct and indirect effects upon each member of society is both impractical and undesirable.

It is felt that the methodology described in the final report and presented in this manual is practical and effective. Any less detail would neglect important impacts, while greater detail would be unjustified. The procedures are oriented around data availability which is a key consideration. 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.

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 this manual 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.

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.

The first three sections of this manual are concerned with general discussion of the economic impact analysis. The methodology is presented in Section 4 as a sequence of steps with text and illustrative examples interspersed. This sequence is followed in detail in the worked example of the application of the methodology.

2.0 OVERVIEW OF THE METHODOLOGY

This section presents an overview of the recommended methodology for assessing the economic impact of railroad safety standards. The overview summary is presented in Figure 1. Both the steps and the subsections referenced are treated in detail in Section 4.0. A worked example is presented in Appendix A.

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 railroad 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

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

Preliminary Steps (Section 4.1)

Step 1: Identify the Safety Standard to be Evaluated

Step 2: Identify the Unit or Component Which Will be Affected by the Safety Standard

Step 3: Forecast an Inventory of the Affected Component Over the Analysis Period

Railroad Costs (Section 4.2)

Step 4: Develop Program Development Cost

Step 5: Develop Inspector Training Cost

Step 6: Develop Inspection Cost

Step 7: Develop Maintenance/Replacement Cost

Step 8: Develop Lost Utilization Cost

Step 9: Develop Record Keeping and Billing Cost

Step 10: Develop Non-Compliance Cost (Civil Penalties)

Step 11: Aggregation of Costs into Time Streams

Societal Costs (Section 4.3)

Step 12: Develop the Cost of the Development of the Standards

Step 13: Develop Record-Keeping Equipment Costs

Step 14: Develop Inspector Training Costs

Step 15: Develop Ongoing Unit Inspection Cost

Step 16: Develop Ongoing Unit Record-Keeping Cost

Step 17: Aggregation of Costs into Time Streams

Accident Reduction (Section 4.4)

Step 18: Obtain the Number of Accidents Caused by the Affected Component

Step 19: Calculate the Accident Probability

Step 20: Predict the Component-Caused Accidents Over the Analysis Period

Step 21: Predict the Accidents Prevented by the Proposed Safety Standard

Railroad Benefits (Section 4.5)

Step 22: Assess Track and Right-of-Way Damage

Step 23: Assess Equipment and Structures Damage

Step 24: Assess Wreck Clearing Costs

Step 25: Assess Damage to Lading

Step 26: Assess Damage to Non-Railroad Property

Step 27: Assess Personal Injury and Fatality Damages

Step 28: Estimate Costs of Delays in Service

Step 29: Formation of Railroad Benefit Time Streams

Societal Benefits (Section 4.6)

Step 30: Assess Societal Costs For Property Damage

Step 31: Assess Community Services Cost

Step 32: Assess Costs of Injuries and Fatalities

Step 33: Formation of Societal Benefit Time Streams

Net Cost Effectiveness (Section 4.7)

Step 34: Perform the Final Merging of the Time Streams

Step 35: Select Appropriate Inflation and Discount Rates

Step 36: Telescope the Time Streams

Step 37: Calculate Net Cost

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.

The major railroad 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. Such costs include 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. 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.

The steps for calculating benefits accruing to the railroad industry and to society at large is shown in Step 22 through Step 33. 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.

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.

An important aspect of analyses involving safety standards is the treatment of civil penalties. Strictly speaking, a civil penalty is a transfer payment rather than a bona fide cost, and, as a distribution problem, can be ignored in an economic impact analysis.

The FRA collected nearly $1 million from railroads in fiscal 1974 for safety violations. These monies go into the miscellaneous receipts of the U.S. Treasury into an undedicated status. Thus, they benefit society at large by reducing taxes nationwide. But any redistribution of these funds back to the railroads would jeopardize the essential objective of the penalties. A back distribution which effectively "returns" the penalty money destroys the effectiveness of the penalty. A back distribution which is not directly based on penalties paid, encourages game playing to minimize net costs rather than to maximize compliance.

It is felt that the proper treatment of civil penalties is to include them both on the (railroad) cost side of the ledger, and on the (societal) benefit side of the ledger. Along with the final accounting of the total net costs the railroads' net costs are presented separately. This treatment is illustrated in the Appendix.

3.0 PRELIMINARY CONSIDERATIONS

An important part of the decision making process regarding alternative public projects is an accounting of the costs and benefits, quantified as much as possible and projected as far into the future as possible. Since public funds, manpower and resources are finite, it is important to make efficient use of them. A good measure of efficiency is the net cost of a project -- all of the associated costs minus all of the associated benefits -- expressed as a single quantity, the present value of all of the cost and benefit time streams.

However, 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, unquantifiable 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 <u>incidence</u> effects 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, or it may be expensive to do (e.g., the Aid to Families with Dependent Children program). Sometimes, as in the example in the Appendix, it cannot be done without destroying the objective of the mechanism which caused the redistribution in the first place.

In the light of the above considerations, economic analysis is seen to have limitations. It is entirely proper that certain ingredients be omitted from a cost effectiveness analysis. As stated by Dr. James R. Schlesinger:

> "There exist certain fundamental issues of choice, which even complete modernization of the governmental structure cannot resolve. Analysis cannot bridge the gap between irreconcilable objectives. At its best, analysis can shed some light on the costs of accepting one objective at the expense of others. But there is a danger that analysis may help to disguise fundamental choice problems as efficiency problems."*

Cost-effectiveness is a powerful and indispensable tool for decision making on public projects. It is neither more nor less than that.

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*"Systems Analysis and the Political Process," RAND P-3464, June, 1967, pp. 25.

3.1 Basic Concepts of Benefits and Costs

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, the methodology presented in this manual is that which is felt to be most applicable to the assessment of railroad safety standards. In this case, there are four assessments to be made: the costs and benefits to the railroad industry and also to society at large.

Any discussion of methodologies 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".

Cost-benefit analysis and benefit-cost analysis are interchangeble terms. Both terms refer to a systematic examination and comparison of alternative courses for the achievement of a specified objective over some future span of time. 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.

A major difficulty in a pure cost benefit analysis, especially in the sphere of safety, is in quantification of such things as human life, peace of mind, and goodwill. Even if all the non-quantifiable, intangible, and secondary effects are dealt with satisfactorily in some way,* there are still problems with some quantifiable factors as will be pointed out later.

In a cost-benefit evaluation of the quantifiable effects of safety standards, the net benefit of each safety standard is computed and then that alternative with the highest net benefit is selected. The net benefit is obtained by subtracting the cost of implementing the safety standard from the gross benefit obtained from the safety standard. (All the costs and benefits over the years are transformed to determine their present worth.)

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

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

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.

Cost-effectiveness is a term which often is assigned the same meaning as cost benefit. Usually, 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.

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 all of the beneifts to society from 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 all direct and indirect effects of a particular public policy upon each 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 example included in the Appendix which dealt with 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.

The cost-effectiveness approach is recommended for the assessment of the economic impacts of safety standards. After a single dollar value (or at least a probable range of values) is calculated, a decision is not automatic. As discussed in the previous section, the unquantifiables, the exogenous considerations, the constraints and timing must all be placed on the decision scales, both on the "benefit" side and on the "cost" side, as essential ingredients to the decision maker's final decision.

3.2 Selection of the Time Period of 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 are addressed 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.

3.3 Interest and Discount Rates and Inflation

In any economic impact study extending over more than a year, the problem arises of comparing dollar values in different years. Since dollars at different points of time are not comparable, they must be transformed to equivalent values, all at the same point in time. The point chosen in this study is the present; thus, all the costs and benefits expressed in dollar units are transformed into present values.

There are many components of the change in a dollar over time and different costs and benefits change at different rates. The common adjustment for time is the discount factor which tacitly compares the time streams of costs and benefits to the time streams that would have occurred if the funds had been used in another manner or had been invested in an interest producing fashion. This is the basis of "discount rate" calculations in public investment decision making.

The present value of a cost to a railroad five years from now depends upon (or, at least, can be equated to) how much money need be invested now to appreciate to that amount in five years. Moreover, the lost opportunity (of investing the money) cost for railroads is different than the lost opportunity cost for society and both are different than for individuals. Thus, several discount rates may be needed in any one analysis.

Another component of change in dollars over time is inflation. This phenomenon, in relation to project evaluation, has received surprisingly little attention in the literature, probably because until recently inflation in countries which have been producing the literature has been mild. However, a simple example can illustrate the effect of inflation on a time stream of costs or benefits.

As of August 1, 1974, the AAR billing charge for a journal bearing lubricator pad is $3.20 (materials charge only). One year from now at 10 percent inflation the price of a pad would be $3.52. If the appropriate investment interest rate is 13 percent, $3.12 would have to be invested now to buy one lubricator pad one year from now. In other words, the discounting should be applied to the inflated cost rather than the current cost. Alternatively, it can be assumed that all price movements are at the same rate; then, all calculations can be carried out by using constant dollars.

The Office of Management and Budget has recommended (DOT 5000.1, 6-30-72) that a discount rate of 10% be applied (before taxes) on all future dollar values in constant dollars. This rule applies to analyses by all DOT Secretarial Offices with certain exceptions. This discount rate, applied to constant dollar time streams represents an estimate of the average rate of return on private investment, before taxes, and after inflation. Occasionally the price level of one particular time stream of costs (or benefits) is expected to change at a different rate relative to all the other price levels. If, for example, the rate is 3% below the general inflation rate, this effect can be represented by applying a discount rate of 13% to the more slowly inflating costs.

3.4 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 the Appendix. 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 the Appendix), 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.

However, quite a bit of caution is needed in doing sensitivity calculations because indiscriminate variations in all possible parameters will result in a meaningless set of final net costs. This is why it is necessary to perform sensitivity calculations as the study proceeds. A parameter which is non-sensitive, that is, whose variation has little effect on costs or benefits, needs no more investigation. If a parameter is very sensitive, on the other hand, it may be necessary to do quite a bit more investigation to attempt to narrow its range of uncertainty. The earlier in the analysis this is done, the better.

One of the biggest uncertainties in any analysis extending over a period of time is the change in monetary quantities. Inflation and discounting, which are discussed in the previous section, are highly variable both within the economy and over time. They are also unpredictable. For this reason it is preferable to aggregate all the monetary values for any one year into as few groups as possible. The last step in the analysis, then, is to perform sensitivity calculations using several discount rates and inflation rates.

4.0 SYSTEMATIC PROCEDURES FOR ECONOMIC IMPACT ANALYSIS

The major factors which are pertinent to railroad safety standards are costs and benefits, both to railroads and also to society. In Section 2.0, an overview of the economic impact methodology for railroad safety was presented, 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 Section 3.0, general principles were discussed along with special problems and preliminary procedures such as the selection of the analysis time period and the choice of discount and inflation rates. In this section, step-by-step procedures will be given for systematically carrying out an economic impact analysis. Although sample calculations will occasionally be given to illustrate a step, the emphasis in this section is on presenting the overall procedure. Further details for obtaining information are presented in the final report on economic impact methodology.* A complete example of the process is given in Appendix A, in which the impact of plain journal bearing standards is assessed.

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*A Methodology for Evaluating the Economic Impacts of Applying Railroad Safety Standards, Contract DOT-FR-20047.

4.1 Preliminary Steps

The safety standard to be considered must be defined in enough detail to do the analysis. The affected unit or component must be identified and an inventory of the components must be projected over the analysis period.

Step 1: Identify the Safety Standard to be Evaluated

From existing or proposed safety standards, select the standard or set of standards to be evaluated. Standards may be in any category under the FRA's jurisdiction -- track, equipment, structures or other factors. Describe the standard or set of standards as Item 1.

Item 1 ____________________

____

____

____

(standard to be evaluated)

Step 2: Identify the Unit or Component Which Will be Affected by the Safety Standard

Impacts of safety standards vary widely. Compliance with some, such as those involving inspections, may be highly labor intensive. Other standards, requiring equipment upgrading, for example, may necessitate high materials costs. The costs themselves may be mainly ongoing costs as would be the case with an increase in the rate of inspections. On the other hand, much of the cost may be in the first few years, to upgrade system-wide track to new standards. High administrative costs would be incurred by extensive record-keeping requirements. High managerial costs would follow from standards which required expansion of shop facilities, for example. It is important to identify which units or components will be affected. Often, both a group and subgroups are affected, in other words, a total population and subgroups of defective members. For example, the safety standards addressed to plain journal bearings affect the entire population of plain bearing cars with respect to inspections. The incremental number of journal repackings make up a subgroup of this population. Other subgroups consist of failed bearings and cars which are in violation in a given year.

Enter each unit or component which will be affected by the safety standard as Item 2.

Item 2 ________________

____

____

(affected components)

Step 3: Forecast an Inventory of the Affected Component Over the Analysis Period

In order to fully develop costs and benefits it is necessary to estimate yearly inventories of the affected group and subgroups over the analysis period. If it is expected that the proposed standard will change the population figures of the groups and/or subgroups, then separate inventories should be forecast. Enter these data as Item 3.

		with proposed standard	without proposed standard
Item 3	1975	____________	____________
	1976	____________	____________
	. . . . .	. . . . .	. . . . .
	1989	____________	____________

Note: As part of Step 3, it is desirable to also collect an inventory of the past five years in order to calculate the accident probability in Step 19.

4.2 Railroad Costs

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. Some standards, such as those involving inspections, may be highly labor intensive. Other standards, requiring equipment upgrading, for example, may necessitate high materials costs. The costs themselves may be mainly ongoing costs as would be the case with an increase in the rate of inspections. On the other hand, much of the cost may be in the first few years, to upgrade system-wide track to new standards. High administrative costs would be incurred by extensive record-keeping requirements. High managerial costs would follow from standards which required expansion of shop facilities, for example.

It is important that only incremental costs be attributed to the proposed standard. In other words, two worlds are postulated: a world which would exist if the standard were not promulgated, and a world which would exist if the standard were promulgated. The difference in costs to the rail industry existing in each of these worlds is the (incremental) cost of the proposed standard. Several problems arise in attempting to calculate these incremental costs. Since additional inspections, maintenance, and administrative work are integrated into present operations, allocations must be made to estimate the proportion of each cost which can be attributed to the proposed standard.

In addition, actual costs depend upon four factors: the present industry-wide condition of the affected item, the rail industry's extent of eventual compliance, and both their manner and their phasing of compliance action. In the case of track standards, for example, average industry condition is bad. Railroads' compliance has been marginal which has resulted in staggering civil penalties -- about one million dollars in the first three quarters of 1974. This is obviously a very different cost picture than would have occurred had the railroads attempted full compliance, with large initial costs, relatively small ongoing costs, and low incurrence of civil penalties.

Step 4: Develop Program Development Cost

The programs followed by railroads in complying with a new safety standard may simply be a quantitative scaling up of existing procedures. An increase in the inspection frequency of a particular component, for example, may necessitate only more inspectors and possibly, more inspection. On the other hand, some standards may require the development of a compliance program as part of the safety standard or simply for managements' own needs. A compliance program may be developed by the railroads individually or by a joint committee under the responsibility of the AAR.

The program development cost is arrived at by estimating the man-days needed to discuss, formulate, draft, and submit the program. In addition, an estimate should be made of man-days needed prior to the committee meeting for research and general preparation. The total man-days multiplied by an average salary and overhead rate (and prorated, if necessary) gives the program development cost to be entered as Item 4.

Item 4 ________________
(Program Development Cost)

Step 5: Develop Inspector Training Cost

In the simplest case, inspector training costs will be incremental, in which case, a simple scaling-up can be done (10% increase in inspection frequency implies a 10% increase in inspector training costs). Otherwise, for a new type of inspection for example, the cost estimation is more laborious. In both cases it may be necessary to prorate to properly allocate training costs to the proposed safety standard. It is also advisable to express the cost on a unit basis (miles of track, number of tank cars, etc.) so that adjustments can be made to reflect the changing quantity of components to be inspected over the years.

Enter inspector training (unit) cost as Item 5.

Item 5 ____________________
(Inspector Training (Unit) Cost)

Step 6: Develop Inspection Cost

Estimates of inspection times and the use of approximate manpower rates will provide inspection costs which should be put on a unit basis and should be prorated if necessary. In some cases, inspection requirements under a proposed safety standard will be the same as those under a current AAR regulation. Even so, this inspection activity may be stepped up by the railroads in order to avoid civil penalties attached to the safety standard.

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

The hourly AAR billing rate for general labor charges can be used to determine a unit inspection rate, which, in conjunction with the required inspection frequency, gives the unit inspection cost per year.

Enter inspection cost as Item 6.

Item 6 ________________
(Inspection (Unit) Cost)

Step 7: Develop Maintenance/Replacement Cost

Unit costs on increased maintenance and/or replacement of the affected component under the proposed safety standard can be developed fairly easily. For freight cars, for example, good sources of labor and material costs are 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.

Enter as Item 7.

Item 7 ________________
(Maintenance/Replacement Unit Cost)

Step 8: Develop Lost Utilization Cost

Compliance with a proposed safety standard often results in lost utilization time of equipment and, to a lesser extent of track. In the case of freight car components, for example, the time lost in movement to and from inspection and repair tracks and the time required for the inspection must be considered. In a major inspection a freight car may 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. If each of six major equipment categories are inspected, a proration of one-sixth must be made for the cost applicable to any one category. Under these assumptions and with a per diem cost of $4.20, the unit inspection cost for one equipment category is:

(3 days) X ($4.20 per day) X (1/6 proration) = $2.10

Enter the lost utilization unit cost as Item 8.

Item 8 ________________
(Lost Utilization Unit Cost)

Step 9: Develop Record Keeping and Billing Cost

When a new safety standard increases inspection/maintenance/replacement activity, only work done by non-owning railroads will have an effect on the AAR billing files. Thus, some proration, perhaps one-half, of the increased activity will result in increased billings.

Distribution of the interline 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 serviced in accordance with FRA requirements. There will obviously be an additional cost to keypunch and computer-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. However, it can be assumed that the railroads' copy of the original inspection report will be used for billing purposes and that the keypunching of data from the inspection report will take approximately five minutes per report. At $10.00 per hour the keypunching of data would cost $.83 per form $\left(\frac{\$10.00/\text{hour}}{12\ \text{reports/hour}}\right)$

The per-form cost multiplied by the foreign car ratio gives the unit billing cost.

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

In addition to billing costs, additional costs may be incurred in expanding a railroad's own records. This can also be put on a per-form basis.

Enter the combined per-form cost as Item 9.

Item 9 ________________
(Unit Record Keeping/Billing Cost)

Step 10: Develop Non-Compliance Cost (Civil Penalties)

In fiscal 1974, nearly $1 million was collected from the railroads for "safety violations." Although these civil penalties are, in a cost/benefit sense, transfer payments from one segment of society to another, it is useful to keep this large railroad cost separate in the bookkeeping.

Less than 100 percent compliance with a safety regulation will reduce compliance costs and incur penalties. In addition to civil penalties, flagrant non-compliance may result in disqualification of one or more inspectors and even their supervisor. Disqualifications can result in extra labor costs to a carrier because of relocation and retraining expenses involving the disqualified personnel.

The magnitude of expected civil penalties associated with the promulgation of a proposed safety standard can be estimated in two different ways. If the proposed standard is similar in effect to an existing standard, a comparison can be made with penalties actually paid out under the existing standard. Alternatively, a stepwise process can be performed in the following manner: estimate the number of components existing in violation in any given year (either in absolute terms or as a percent of the total population); estimate what percent of the violators will be found in violation by FRA inspectors, and the average number of days each violator will be charged with; estimate the amount of a typical fine from the schedule of civil penalties (Appendix D of Part 215) and the percent collectable, allowing for customary diminution and forgiveness of hardship and "good character" cases. The per unit civil penalty is: (percent of total population in violation) X (percent found) X (days in violation) X (penalty per day) X (percent collectable).

Enter this cost as Item 10.

Item 10 ____________________
(Non-Compliance Cost)

Step 11: Aggregation of Costs into Time Streams

Aggregate all unit costs which satisfy these two criteria: the unit costs apply to the same group or subgroup and the unit costs will be subject to the same inflation rate over the analysis period. For example, lost utilization costs and maintenance/replacement costs can likely be aggregated. Inspector training costs and lost utilization costs will likely apply to different groups (probably a group and a subgroup) and should be kept separate. Civil penalties and training costs will likely apply to the same group but may be subject to different inflation rates and should be kept separate.

The aggregation rule on inflation rates applies to at-large costs also. However, these costs tend to occur in the first few years of the analysis period which diminishes the effect of disparate rates.

The aggregation process is illustrated in Table 1. In Table 1.a, the costs (in constant dollars) are identified for each year of the analysis. Each cost is specified as an at-large cost or a unit cost applicable to the population group or the population subgroup. In Table 1.b, all costs are put on an at-large basis by multiplying each unit cost by the appropriate group or subgroup population. For example, the 1974 Training Cost of $9,288 is the product of the unit cost of $0.01142 and the group population of 813,330 freight cars. Some merging has also been done in Table 1.b. In Table 1.c, the final merging has been done. Two time streams of costs were maintained in this example because it was felt that civil penalties would not inflate at as fast a rate as would all of the other costs.

The time streams, expressed in constant dollars, constitute Item 11.

Item 11 ______________________
(Railroad Cost Time Streams)

ı: Cost Aggregation Example -- Identification

Year	Population Group: Freight Car Plain Bearing Fleet	Population Subgroup: Additional Bearing Repackings Required	Program Develop-ment (At-large cost)	Inspector Training (Group unit cost)	Inspection	Mainte-nance/Re-placement (Subgroup unit cost)	Lost Utilization (Subgroup unit cost)	Billing (Subgroup unit cost)	Non-Compliance (Group unit cost)
1973	875,330	0	$2,000	$0.001142	$0	$164.73	$2.10	$0.415	$1.575
1974	813,330	6,272	-0-						
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	3,349							
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	--	0							
1988	--	0							
1989	--	0	-0-	$0.01142	$0	$164.73	$2.10	$0.415	$1.575

Group Unit Costs, Subgroup Unit Costs, and At-large Costs

Table 1.b: Cost Aggregation Example -- Merging and Totalizing

	Program Development	Training Costs	Maintenance, Lost Utilization, Billing	Non-Compliance
1973	$2,000	$ 10,000	$ 0	0
1974	-0-	9,288	1,048,960	1,280,995
1975	-0-	8,557	966,509	1,180,194
1976	-0-	7,838	885,228	1,080,970
1977	-0-	7,118	803,947	981,745
1978	-0-	6,399	722,666	882,520
1979	-0-	5,680	641,385	783,295
1980	-0-	4,960	560,104	684,070
1981	-0-	4,241	478,990	584,845
1982	-0-	3,521	397,709	485,620
1983	-0-	2,802	316,428	386,395
1984	-0-	2,082	235,146	287,170
1985	-0-	1,363	153,865	187,945
1986	-0-	643	72,584	88,720
1987	-0-	0	0	0
1988	-0-	0	0	0
1989	-0-	0	0	0

Table 1.c: Cost Aggregation Example -- Constant Dollar Time Streams

Year	Time Stream with: Average Inflation Rate, Average Discount Factor; Components: Repacking, Lost Car Utilization, Billing File Expansion, Program Development, Training Costs	Time Stream with: Low Inflation Rate, Average Discount Factor; Component: Civil Penalties
1973	12,000	0
1974	1,058,000	1,281,000
1975	975,000	1,180,000
1976	893,000	1,081,000
1977	811,000	982,000
1978	729,000	883,000
1979	647,000	783,000
1980	565,000	684,000
1981	483,000	585,000
1982	401,000	486,000
1983	319,000	386,000
1984	237,000	287,000
1985	155,000	188,000
1986	73,000	89,000
1987	0	0
1988	0	0
1989	0	0

4.3 Societal Costs

The societal costs associated with the development and promulgation of safety standards are primarily those costs incurred 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 safety standards represents a cost to society that must be considered in the overall cost/effectiveness analysis. Societal costs can be 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.

As noted previously, the costs which should be allocated to a particular safety standard may be inextricably aggregated with the costs associated with a group of standards. For example, standards addressed to freight car couplers, may be part of a group of standards addressed to all railroad equipment. If so, the coupler standards may share development costs, record-keeping costs, inspector training costs, etc., with those for the entire group of equipment standards. Then it is necessary to prorate the group costs to arrive at an estimate of the costs which should be allocated to the safety standard under consideration.

Sometimes multiple proratings are necessary. For example, a safety standard addressed to plain bearings will impose inspection costs on the FRA. If total inspection costs are known, 98 percent of these can be allocated to freight cars, 51 percent of the freight car allocation can be allocated to plain bearing freight cars and one-sixth of the plain bearing allocation can be allocated to the bearing category out of the six equipment categories.

Step 12: Develop the Cost of the Development of the Standards

If the Office of Safety cannot provide estimates of the cost of the development of a particular safety standard, it will be necessary to use other means for these estimates. One source of information is careful review of budget hearings before the House Committee on Appropriations.

From this review, an estimate can be made of the percent of the total Office of Safety manpower which was used to develop the group standards, and the time span of the effort. Manpower estimates are also needed for the Office of Chief Counsel which is usually involved in the development of new safety standards. If this analysis applies to a proposed standard which has not yet been developed, the method is the same. The above method is used to estimate costs for a previously developed standard which is similar to the one being proposed.

The manpower estimates are used to prorate the total FRA budget to estimate the group cost of safety standard development. This cost is then prorated to estimate the development cost of the proposed standard as a member of the group.

Enter this amount as Item 12.

Item 12 ________________
(Standards Development Cost)

Step 13: Develop Record-Keeping Equipment Costs

In anticipation of the inspection reports that would be filed with the FRA by the railroads, an initial investment must be made 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:

$$\text{Cabinets purchased by FRA} = \frac{\text{total number of reports}}{\text{19,200 reports per cabinet}} = \text{number of file cabinets needed}$$

At $100 per cabinet, the initial investment in filing cabinets can be calculated. This dollar amount must be prorated to allocate the correct amount to the proposed standard.

Enter this amount as Item 13.

Item 13 ________________
(Record Keeping Equipment Costs)

Step 14: Develop Inspector Training Costs

Determine the number of inspectors who will be employed, their training period required prior to entering the field and the training cost per man-hour. Prorate the total training cost by the proper amount to estimate the proper allocation of training costs to the proposed safety standard. Care is needed to allocate, not only among subparts of equipment standards but also among groups of equipment. For example, standards which apply to tank car couplers incur inspection costs which should not be spread over all freight cars or over all equipment which includes locomotives and passenger cars.

Enter training costs as Item 14.

Item 14 ____________________
(Inspector Training Cost)

Step 15: Develop Ongoing Unit Inspection Cost

The ongoing inspection costs consist primarily of the inspectors' salaries, benefits, and expenses allocated to the proposed safety standard. The ongoing cost must be divided by the number of units to be inspected to obtain a unit inspection cost. As the number of inspected units varies over the years, adjustments can be made to the total yearly inspection cost. (If the overall inspection intensity varies over the years, a corresponding adjustment must be made).

Enter the ongoing unit inspection cost as Item 15.

Item 15 ____________________
(Ongoing Unit Inspection Cost)

Step 16: Develop Ongoing Unit Record-Keeping Cost

Estimates must be made of handling and filing time for each inspection report. The FRA labor and overhead rate can then be used to convert this time to a cost figure. Proper proration allocates this cost to the proposed standard. For example, a five minute handling time at a \$10.00 per-hour labor rate and a one-sixth proration, would give a unit record-keeping cost of:

$$\text{Unit Cost} = \left[5/60 \text{ hr.}\right] \times \left[\$10.00/\text{hour}\right] \times \left[1/6 \text{ allocation}\right]$$
$$= \$0.13889/\text{record}$$

Enter the estimated unit cost as Item 16.

Item 16 ____________________
(Ongoing Unit Record-Keeping Cost)

<u>Step 17</u>: Aggregation of Costs into Time Streams

As was done with railroad costs in the previous section, all of the societal costs should be aggregated and totalized and formed into as many time streams as is felt necessary.

These time streams constitute Item 17.

Item 17 ____________________
(Societal Cost Time Streams)

4.4 Accident Reduction

The principal tangible benefits which railroads and society experience from promulgation of cost-effective safety standards are dollar savings from a reduction in accidents. Of course, 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 can result from exposure to an unsafe environment. However, since the major impact of most safety standards is on accidents, accident data will be the principal measure of economic impact. These data form the basis for calculating the principal benefit component, namely, the reduction in total accident costs.

Although obtaining data on accidents can be very difficult and the calculations for predicting future accidents can be very complicated, the basic idea behind accident reduction is simple. Two future worlds are postulated; one in which the proposed safety standard does not exist, and the other world in which it does exist. The standard, if it is effective at all, will change the number of accidents. The number of prevented accidents (the number of accidents without the safety standard minus the number with the standard) represents the principal benefit of the safety standard.

A simple example is presented in Table 2 for a hypothetical standard addressing Brand X freight car wheels. Suppose 27 accidents in 1974 were caused by fractures of Brand X wheels and suppose there were 245,000 of these wheels in service. Then the probability of an accident being caused by Brand X wheels can be calculated to be 27/245000 = 0.000110. If this brand of wheels is being phased out as predicted on the left side of Table 2, the expected accidents each year will be predicted as shown on the left side of Table 2. However, if the promulgation of a safety standard results in a faster phase-out rate, shown on the right side of Table 2, the reduced number of expected accidents will be as shown on the right side of Table 2. The right-most column of the table lists the prevented accidents which represent the principal benefit from the promulgation of the safety standard.

Step 18: Obtain the Number of Accidents Caused by the Affected Component

This step is one of the most crucial in the entire analysis. It is often one of the most difficult. Much information is non-existent and, furthermore, there is often a reluctance on the part of railroads to release the little data they have if non-compliance with other standards or with AAR regulations is thus revealed.

Accident data should cover at least five years to average out random fluctuations.

Table 2: Accident Reduction Example

	Without Proposed Safety Standard		With Proposed Safety Standard		
Year	Number of Brand X Wheels	Expected Accidents	Number of Brand X Wheels	Expected Accidents	Prevented Accidents
1974	245,000	27*	245,000	27	0
1975	225,000	25	205,000	23	2
1976	205,000	23	165,000	18	5
1977	185,000	20	125,000	14	6
1978	165,000	18	85,000	9	9
1979	145,000	16	45,000	5	11
1980	125,000	14	5,000	1	13
1981	105,000	12	0	0	12
1982	85,000	9	0	0	9
1983	65,000	7	0	0	7
1984	45,000	5	0	0	5
1985	25,000	3	0	0	3
1986	5,000	1	0	0	1
1987	0	0	0	0	0

* In this simple example, 27 is the exact number of accidents which occured in 1974. This information, along with the number of wheels of this type in service, gives a yearly accident probability of 27/245,000 = 0.000110. Thus, the accident prediction for 1975 is 0.000110 X 225000 = 25.

Enter these data as Item 18.

Item 18 1975 ______________

1976 ______________

1977 ______________

1978 ______________

1979 ______________
(Accident Data)

Step 19: Calculate the Accident Probability

Use the five year accident data and the five year population data collected in Step 3 to calculate accident probabilities for each of the years. To do this, divide the number of accidents by the population for each year. Average the resulting five probabilities to obtain the mean accident probability for the affected component. Enter this probability as Item 19.

Item 19 ______________
(Accident Probability)

Step 20: Predict the Component-Caused Accidents Over the Analysis Period

Multiply the accident probability (Item 19) by each years' predicted population (Item 3) to forecast the expected number of accidents caused by the component if the proposed standard is not in force.

Enter these data as Item 20.

Item 20 1975 ________________

1976 ________________

. . . .

1989 ________________

(Predicted Accidents)

Step 21: Predict the Accidents Prevented by the Proposed Safety Standard

Using the inventory forecast in Step 3 for populations with the safety standard in force, calculate the predicted accidents in this case. Subtract these, year by year, from those calculated in Step 20.

Enter these differences as prevented accidents, Item 21.

Item 21 1975 ________________

1976 ________________

. . . .

1989 ________________

(Prevented Accidents)

These data will be used later to calculate the benefits expected from the promulgation of the proposed safety standard.

4.5 Railroad Benefits

Most of the benefits to the rail industry from safety standards will come from reduced costs because of a reduction in the number of accidents. Principal direct costs to railroads are damage to track and right of way, damage to equipment and structures, and wreck clearing costs. Railroads also make partial or total payments for damage to lading, damage to non-railroad property, and personal injuries and fatalities. Indirect costs are from delays in service.

Step 22: Assess Track and Right-of-Way Damage

Most of these data are available from FRA T-Forms or, more recently, accident/incident reports. An estimate must be made for damages incurred in unreported accidents. Divide total damages by the number of accidents to calculate the cost per accident and enter as Item 22.

Item 22 ______________________
(Track Damage Per Accident)

Step 23: Assess Equipment and Structures Damage

These damages are also reported to FRA. Estimate non-reported damage and calculate the cost per accident as Item 23.

Item 23 ______________________
(Equipment Damage)

Step 24: Assess Wreck Clearing Costs

Since wreck clearing costs are a large component of railroad accident expenses, it is important that these costs be realistic. ICC accounts provide total costs with partial breakdowns and individual carriers provide fairly detailed data.

Enter the average cost per accident as Item 24.

Item 24 ________________
(Wreck Clearing Cost)

Step 25: Assess Damage to Lading

Settlements for lading damage is currently developed by all carriers and is reported on a regular basis to the AAR and the ICC. There is often a significant delay, however, between the time of an accident and the settlement of all claims. Therefore, it may be necessary to use fairly old data and compensate with inflators. In addition, since the data are not broken down by type of accident, allocation is necessary to assign costs properly to the component under analysis. The cost picture should be completed by making allowances for unreported accidents, especially since lading damage may be quite high even though the freight car is practically undamaged.

Put lading cost on a per-accident basis and enter as Item 25.

Item 25 ________________
(Lading Damage)

Step 26: Assess 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 police assistance, Red Cross, and National Guard assistance can be substantial in the case of major rail accidents. On the other hand, most accidents do not involve damage to non-railroad property. The costs due to the relatively few spectacular accidents are thus distributed over a large number of cases.

Enter the per-accident cost as Item 26.

Item 26 ____________________
(Damage to Non-Railroad Property)

Step 27: Assess Personal Injury and Fatality Damages

These costs are difficult to develop because 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. 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.

It is necessary to review Federal count records and selectively interview individual carriers to develop injury and fatality costs for the particular category affected by the proposed safety standard.

Enter the per-accident cost as Item 27.

Item 27 ________________
(Injury and Fatality Damages)

Step 28: Estimate Costs of Delays in Service

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

Assumptions must be made (corroborated by interviews with selected carriers) to estimate the percent of accidents attributable to the component affected by the safety standard. An estimate must also be made of the number of cars delayed per accident. Multiply the average number of cars delayed per accident by an estimated number days delay and by a per-diem cost to obtain a per-accident delay cost.

Loss of goodwill is based on the assumption that is each carload delayed represents one customer, then loss of customers would be equal to a small percent of the total cars delayed due to an accident. The general feeling among railroads seems to be that most customers do not penalize the railroads when their cars are involved in an accide and that the lost customers will probably be less than 1 percent of the cars delayed. Multiply the lost customers by the average number of car shipments per year and by an average revenue per carload. Divid by the total number of relevant accidents per year to obtain the cost of goodwill lost per accident.

Examples of delay and goodwill cost calculations are presented below.

$$\text{Per-Accident Delay Cost} = \begin{bmatrix}\text{total carloads}\\ \text{per year}\end{bmatrix} \times \begin{bmatrix}\text{\% of carloads}\\ \text{delayed}\end{bmatrix} \times \begin{bmatrix}\text{\% of accidents}\\ \text{due to affected}\\ \text{component}\end{bmatrix} \times \begin{bmatrix}\text{average}\\ \text{days delay}\end{bmatrix} \times \begin{bmatrix}\text{per-diem}\\ \text{cost}\end{bmatrix} \div \begin{bmatrix}\text{number of accidents}\\ \text{caused by affected component}\end{bmatrix}$$

$$= [27,300,000] \times [.01] \times [.03] \times [1] \times [\$4.20] \div [336]$$

$$= \$102.38$$

$$\text{Per-Accident Goodwill Loss} = \begin{bmatrix}\text{total carloads}\\ \text{per year}\end{bmatrix} \times \begin{bmatrix}\text{\% of carloads}\\ \text{delayed}\end{bmatrix} \times \begin{bmatrix}\text{\% of accidents}\\ \text{due to affected}\\ \text{component}\end{bmatrix} \times \begin{bmatrix}\text{\% customers}\\ \text{lost}\end{bmatrix} \times \begin{bmatrix}\text{average cars per}\\ \text{year shipped per}\\ \text{customer}\end{bmatrix} \times \begin{bmatrix}\text{average revenue}\\ \text{per car}\end{bmatrix} \div \begin{bmatrix}\text{number of accidents}\\ \text{caused by affected}\\ \text{components}\end{bmatrix}$$

$$= [27,300,000] \times [.01] \times [.03] \times [.005] \times [12] \times [\$500] \div [336]$$

$$= \$731.25$$

Enter the combined delay and goodwill cost as Item 28.

Item 28 ________________
(Delay Plus Goodwill Cost)

Step 29: Formation of Railroad Benefit Time Streams

All of the costs arrived at in this section, multiplied by the prevented accidents estimated in Section 4.4, represent benefits to the railroads. If all of the costs (Items 22 thru 28) will inflate at the same rate over the analysis period, they can be lumped into one sum. Otherwise more than one aggregate cost will be needed to correspond to relative price level changes. For each aggregate cost, form a railroad benefit time stream by multiplying the cost, year by year, by the prevented accidents listed as Item 21.

Enter results in Item 29.

Item 29 1975 ________________

1976 ________________

. . . .

1989 ________________

(Railroad Benefits)

4.6 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 and explosions that result from a train accident and that is not paid for by the railroads. In the past, societal dollar costs resulting from accidents, on the average, have been small because railroads bear most of the expense for an accident and have usually compensated private individuals and concerns for damages caused by train accidents. The following data sources are useful for measuring societal accident costs:

- T forms and accident/incident reports
- NHTSB reports
- FRA Hazardous Material Accident Reports
- FRA reports for Class A accidents

from a review of these sources, it was determined that outstanding societal costs result from one type of accident -- where hazardous materials are involved. If the proposed safety standard would change the number of accidents involving hazardous materials, then investigation of a few of these accidents will yield extensive data on most of societal costs of railroad accidents. (It must be remembered that the costs under discussion are those not reimbursed by the railroads).

Step 30: Assess Societal Costs For Property Damage

Divide the total property damages from the large accidents investigated, plus estimates for all other accidents, by the total number of accidents to calculate the per-accident cost.

Enter as Item 30.

Item 30 ______________________
(Societal Cost for Property Damage)

Step 31: Assess Community Services Cost

Large railroad accidents frequently require assistance from local police, fire, and other groups like the Red Cross and/or National Guard. Although some of these costs are paid by the railroad, more frequently they are absorbed by the local community.

Community costs, including evacuation costs, costs for fire fighting equipment and police officers, and National Guard costs, can best be assessed at the local level. Extensive interviews at the sites of a few major accidents should enable reasonable estimates to be made of these costs.

Enter the aggregate cost as Item 31.

Item 31 ______________________
(Community Services Cost)

Step 32: Assess Costs of Injuries and Fatalities

Included in this step are some of the most intractable assessments in impact analysis. The problems of putting a dollar figure on a human life or on pain and suffering are well known. Some values such as court case awards, or present value of lost wages can be used. Insurance claims, funeral costs, and incidental costs, such as housekeeper pay, can all aid in attaching a value to this item.

When a fatality occurs, the present value of the person's lost wages can be used as a measure of this cost. The railroad retirement board gives the mean age of all railroad workers as 45 years; there will thus be 20 years of wages lost in the average fatality. The average railroad worker wage in 1975 is estimated to be about $13,800. Assume a 3 percent productivity and seniority increase in wages per year and use the OMB recommended discount rate of 10 percent. The present value of the lost wages can be approximated by using the factor of 10.5940 which, from annuity tables, corresponds to a "net" discount rate of 7 percent. The present value of the lost wages, under these assumptions, is $146,200.

The exact rates are really not too crucial in most analyses of railroad safety standards because fatalities tend to be spread out over many accidents. (Again, we are talking only about fatalities not compensated for by the railroads).

Personal injury costs estimated for automobile accidents in the NHTSA study, "The Societal Costs of Motor Vehicle Accidents" can be used as a guide for these costs which are listed in Table 3.

The total average cost per accident should be entered as Item 32.

Item 32 ______________________
(Cost of Injuries and Fatalities)

Step 33: Formation of Societal Benefit Time Streams

All of the costs arrived at in this section, multiplied by the prevented accidents estimated in Section 4.4, represent benefits to society. If all of the costs (Items 30 thru 32) will inflate at the same rate over the analysis period, they can be lumped into one sum. Otherwise more than one aggregate cost will be needed to correspond to relative price level changes. For each aggregate cost, form a societal benefit time stream by multiplying the cost, year by year, by the prevented accidents listed as Item 21.

Table 3
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.

Enter results as Item 33."

Item 33	1975 ______
	1976 ______
	. . . .
	1989 ______
	(Societal Benefits)

4.7 Net Cost Effectiveness

The monetary time streams of railroad costs and benefits and societal costs and benefits will now be telescoped to their present values and aggregated to produce the net cost effectiveness of the plain bearing safety standards. As explained earlier, all costs and benefits which have been quantified in monetary units can be summed directly within any given year. To compare monetary quantities of different years, however, requires adjustment for inflation and investment opportunity. Although different costs (wholesale and retail prices, labor fuel, etc.) inflate at different rates, and different sectors of society (rail industry, government, household, etc.) have access to different investment rates for their money, a single inflation rate and a single investment rate can often be used for all, or nearly all, of the time streams

There are several advantages to keeping the different classes of costs and benefits disaggregated until near the end of the analysis. One advantage is that incidence effects remain identified. For example, since civil penalties are transfer payments from railroads to society at large, they have no affect on net cost effectiveness. However, they do represent a considerable burden on the railroads. Another advantage of disaggregation is that it is easier to modify inflation rates and discount rates if these calculations are performed at the end of the analysis.

There may be quite a few time streams of costs and benefits which have been generated in the course of an economic impact analysis of a proposed railroad safety standard. In the simplest case there will be four -- railroad costs, societal costs, railroad benefits, and societal benefits. If it is felt that one inflation rate and one discount rate is appropriate for all the amounts, the four time streams can be merged into one (for each year, subtract the benefits from the costs). The inflation rate and discount rate (or, with no significant loss of accuracy, the "net" discount rate) can then be applied to each years' monetary value to discount it to a present value. The sum of all the present values equals the net cost effectiveness of the safety standard.

In most analyses, more than one time stream will need to be discounted. The previous rules in merging still hold: keep separate the time streams with different inflation rates or with different discount rates. In addition, it is useful to keep separate accounting of railroad's costs and benefits and society's costs and benefits.

Step 34: Perform the Final Merging of the Time Streams

Subject to the rules stated above, merge as many of the time streams, year by year, as possible. Thus, "Time Stream 1" may include railroad costs subject to one inflation rate, "Time Stream 3" may include the algebraic sum of societal costs and benefits, etc.

List the final time streams as Item 34.

Item 34 Time Stream 1.......Time Stream N

1973 ______

1974 ______

. . . .

1989 ______

(Merged Time Streams)

Step 35: Select Appropriate Inflation and Discount Rates

In Section 3.3 a discussion was given of adjustments to be made on costs and benefits to compare their values in different years. The major effects to consider are inflation, which has received little attention in the literature, and the return on alternative investments. The latter effect, which involves the discount rate, has been addressed extensively in the literature with little unanimity resulting.

The Office of Management and Budget has recommended (DOT 5000.1, 6-30-72) that a discount rate of 10 percent be applied (before taxes) on all future dollar values in constant dollars. This rule applies to analyses on all DOT Secretarial Offices with certain exceptions. This discount rate, applied to constant dollars time streams represents an estimate of the average rate of returns on private investment, before taxes, and after inflation. Occasionally the price level of one particular time stream of costs (or benefits) is expected to change at a different rate relative to all the other price levels. If, for example, a rate is 3 percent below the general inflation rate, this effect can be represented by applying a discount rate of 13 percent to the more slowly inflating costs.

Item 35 ______________
(Inflation and Discount Rates)

Step 36: Telescope the Time Streams

Each separate time stream should now be telescoped to a single value by applying an appropriate inflation rate and discount rate. Although this arithmetic can be done by hand, it is highly recommended that a simple computer program be used to do the calculations. With this approach, several combinations of rates can be used to determine sensitivity to discount rates. A fifty or sixty statement program (including data statements) will perform an inflation and discount rate sensitivity analysis, and also combine the costs into a net cost with an accounting breakdown. Such a program can also handle three cases (nominal, best case, worst case) which provide a range of values for the impact analysis, rather than a single value.

Enter all the time stream present values as Item 36.

Item 36 Time Stream 1 ______________
. . . .
Time Stream N ______________
(Present Values)

Step 37: Calculate Net Cost

The net cost of the proposed safety standard is the algebraic sum of the present values of the costs and benefits. However, a thorough analysis will usually involve a range of values corresponding to data uncertainties, and also several scenarios of inflation and discount rates. The final accounting should also break out railroad net cost as well as presenting the total net cost. An example of a final accounting is given in Table 4.

Enter the accounting as Item 37.

Item 37 ______________
(Net Cost)

This step completes the calculations for the economic impact of the proposed railroad safety standard.

Table 4 Example of Net Cost Presentation

Scenario			Net Cost ($000,000)					
			Rail Industry			Total		
Description	Prevailing	For Penalties	Nominal	High	Low	Nominal	High	Low
Normal Case	10%	13%	5.09	13.95	.35	.44	3.60	-1.57
Inflating Penalties	10%	10%	5.68	15.19	.62	.44	3.60	-1.57
Lower Discount Rate	8%	11%	5.54	15.07	.44	.54	3.94	-1.63
Inflating Penalties	8%	8%	6.21	16.47	.75	.54	3.94	-1.63

APPENDIX A: EXAMPLE OF THE COST-EFFECTIVENESS PROCEDURE

This appendix consists of a step-by-step exercise of the procedure described in the body of this manual. Both the section headings and the steps are numbered the same as in the text.

A.1 Preliminary Steps

Step 1: Identify the Safety Standard to be Evaluated

The set of safety standards chosen for evaluation is addressed to plain journal bearings on freight cars. It consists of sections 215.21 through 215.27 under subpart B-Inspection and sections 215.81 through 215.91 under subpart E-Journal Bearings. These sections, which are contained in Part 215-Railroad Freight Car Safety Standards, were published in the November 21, 1973 issue of the Federal Register with amendments stated in the July 11, 1974 issue of that publication.

Step 2: Identify the Unit or Component which will be Affected by the Safety Standard

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 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.

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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.

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

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.

Step 3: Forecast a Fifteen Year Inventory of the Component

The major railroad costs from the FRA safety standards appear to derive from 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.

The plan bearing car fleet is estimated at 875, 330 cars of the end of 1973, with 61, 000 cars retired each year and 2, 000 converted to roller bearings, which produces the fleet forecast of Table A. 1. The numbers fall between the AAR predictions and those of several bearing manufacturers.

Item 3 Table A. 1
(Fifteen Year Inventory

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.

TABLE A.1: Increased Repackings Under FRA Standards (Item 3)

Year	Plain Bearing Cars in Service at End of Year*	Additional Repackings Under FRA Standards Nominal**	High**	Low**
1973	875,330	0	0	0
1974	813,330	6,272	9,962	4,103
1975	749,330	5,779	9,179	3,780
1976	686,330	5,293	8,407	3,463
1977	623,330	4,807	7,635	3,145
1978	560,330	4,321	6,863	2,827
1979	497,330	3,835	6,091	2,509
1980	434,330	3,349	5,320	2,191
1981	371,330	2,864	4,548	1,873
1982	308,330	2,378	3,777	1,556
1983	245,330	1,892	3,005	1,238
1984	182,330	1,406	2,233	920
1985	119,330	920	1,462	602
1986	56,330	434	690	284
1987	--	0	0	0
1988	--	0	0	0
1989	--	0	0	0

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

**The nominal case is based on 10% of the cars overdate for an average of 5 months under AAR rules. The "high" case is based on 12% of the cars overdate for an average of 7 months under AAR rules, the "low" case is based on 8% overdates for 4 months. All three cases use the same figures for the percent of the fleet which is stabilized and the parameters under FRA safety regulations, as explained in the text.

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:

$$\text{Repacks per year under AAR Interchange Rules} = \left[\frac{.225}{(30/12)} + \frac{.025}{(35/12)} + \frac{.675}{(24/12)} + \frac{.075}{(29/12)}\right] \times N = .46710591 \times N$$

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:

$$\text{Repacks per year Under FRA Standards} = \left[\frac{.2475}{(30/12)} + \frac{.0025}{(31/12)} + \frac{.7425}{(24/12)} + \frac{.0075}{(25/12)}\right] \times N = .47481774 \times N$$

---

*This is considered by the industry to be the practical minimum.

Additional repacks $= [.47481774 - .46710591] \times N = .007711831 \times N$

For 1974, this amounts to 6272 additional repacks as shown in Table A. 1, along with the additional repacks for all the years until the plain bearing fleet is phased out. (Part of Item 3, Table A. 1)

There are five parameters in the above calculations whose values are uncertain. To obtain repacking time stream variations for the sensitivity analysis, a small computer program (30 statements) was used to vary the parameters in the following ranges:

Parameter	Normal	High	Low
Percent of cars stabilized	25%	30%	20%
Percent overdate under AAR rules	10%	12%	8%
Percent overdate under FRA laws	1.0%	1.5%	0.8%
Average months overdate under AAR	5	7	4
Average months overdate under FRA	1.0	1.5	0.5

In all, 243 cases were calculated (a portion of which are shown in Table A.2) along with the percent change in the repack coefficent in each case. It was found that, within the parameter range of the percent of cars stabilized, less than 2 percent change in the repack coefficent occurred. Also, variations in both the percent and average months overdate under the FRA safety regulations, caused less than 1 1/2 percent change in the coefficient. Therefore, the repack coefficient was judged to be sensitive only to the percent overdate and

TABLE A.2: Repacking Coefficient Sensitivity

SEL	Percent Stabilized PS	AAR Percent Overdate PDA	AAR Mos. Overdate EMA	FRA Percent Overdate PDF	FRA Mos. Overdate EMF	Repack Coeff AAR RA	Repack Coeff FRA RF	Δ Repack Coeff DELR	Percent Change CH	
11111	.25	.100	5.0	.010	1.0	.467106	.474818	.007712	0.00	Nominal
11112	.25	.100	5.0	.010	0.5	.467106	.474907	.007801	-1.16	
11113	.25	.100	5.0	.010	1.5	.467106	.474732	.007626	1.11	
11121	.25	.100	4.0	.010	1.0	.468466	.474818	.006351	17.64	
11122	.25	.100	4.0	.010	0.5	.468466	.474907	.006441	16.48	
11123	.25	.100	4.0	.010	1.5	.468466	.474732	.006265	18.76	
11131	.25	.100	7.0	.010	1.0	.464640	.474818	.010177	[illegible]	
11132	.25	.100	7.0	.010	0.5	.464640	.4749[illegible]	[illegible]	2.36	
11133	.25	.100	7.0	.010	1.5	[illegible]	[illegible]4814	.007708	0.05	
11211	.25	.100	5.0	[illegible]	[illegible]	.467106	.474464	.007358	4.59	
11212	.25	[illegible]	[illegible]	.020	1.0	.468466	.474635	.006169	20.00	
[illegible]	[illegible]	.100	4.0	.020	0.5	.468466	.474814	.006348	17.69	
[illegible]323	.25	.100	4.0	.020	1.5	.468466	.474464	.005997	22.23	
11331	.25	.100	7.0	.020	1.0	.464640	.474635	.009995	-29.61	
11332	.25	.100	7.0	.020	0.5	.464640	.474814	.010174	-31.92	
11333	.25	.100	7.0	.020	1.5	.464640	.474464	.009823	-27.38	
12111	.25	.080	5.0	.010	1.0	.468685	.474818	.006133	20.47	
12112	.25	.080	5.0	.010	0.5	.468685	.474907	.006222	19.31	
12113	.25	.080	5.0	.010	1.5	.468685	.474732	.006047	21.59	
12121	.25	.080	4.0	.010	1.0	.469773	.474818	.005045	34.59	Low
12122	.25	.080	4.0	.010	0.5	.469773	.474907	.005134	33.43	
12123	.25	.080	4.0	.010	1.5	.469773	.474732	.004959	35.70	
12131	.25	.080	7.0	.010	1.0	.466712	.474818	.008105	-5.10	
12132	.25	.080	7.0	.010	0.5	.466712	.474907	.008195	-6.26	
12133	.25	.080	7.0	.010	1.5	.466712	.474732	.008019	-3.[illegible]	
12211	.25	.080	5.0	.008	1.0	.468685	.474854	[illegible]	-4.69	
12212	.25	.080	5.0	.008	0.5	.468685	[illegible]	.005951	22.84	
12213	.25	.080	5.0	.008	1.5	[illegible]	.474814	.006129	20.52	
12221	.25	.080	4.[illegible]	[illegible]	[illegible]	.468685	.474464	.005779	25.07	
12222	.25	[illegible]	[illegible]	.020	1.0	.469773	.474635	.004862	36.95	
[illegible]	[illegible]	.080	4.0	.020	0.5	.469773	.474814	.005041	34.63	
12323	.25	.080	4.0	.020	1.5	.469773	.474464	.004690	39.18	
12331	.25	.080	7.0	.020	1.0	.466712	.474635	.007923	-2.74	
12332	.25	.080	7.0	.020	0.5	.466712	.474814	.008102	-5.06	
12333	.25	.080	7.0	.020	1.5	.466712	.474464	.007751	-0.51	
13111	.25	.120	5.0	.010	1.0	.465527	.474818	.009291	-20.47	
13112	.25	.120	5.0	.010	0.5	.465527	.474907	.009380	-21.63	
13113	.25	.120	5.0	.010	1.5	.465527	.474732	.009205	-19.36	
13121	.25	.120	4.0	.010	1.0	.467160	.474818	.007658	0.70	
13122	.25	.120	4.0	.010	0.5	.467160	.474907	.007747	-0.46	
13123	.25	.120	4.0	.010	1.5	.467160	.474732	.007572	1.81	
13131	.25	.120	7.0	.010	1.0	.462568	.474818	.012249	-58.84	High
[illegible]3132	.25	.120	7.0	.010	0.5	.462568	.474907	.01[illegible]		
[illegible]	[illegible]25	.120	7.0	.010	1.5	.462568	.4747[illegible]			
[illegible]	[illegible]	[illegible]	5.0	.008	1.0	.465527	.4[illegible]			
[illegible]	[illegible]	[illegible]	[illegible]	.008	0.5	.4655[illegible]				

average number of months overdate under AAR rules. The "high" and "low" coefficients from variations in these two parameters are identified in Table A.2. These coefficients produced the high and low repack time streams in Table A.1, which are the last parts of Item 3.

A.2 Railroad 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 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.

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.

<u>Subparts of Equipment Standards</u>

- 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.

Step 4: Program Development Cost

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. = $12,000.00.

This $12,000.00 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 standars is one-sixth of the total which is entered as Item 4. These numbers appear to be reasonable from the present vantage point of looking back at actual costs, as far as could be ascertained.

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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.

Item 4 $2000
(Program Development Cost)

Step 5: Inspector Training Costs

There are approximately 1,000 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:

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

Training costs per year = $60,000 per year

Allocate this training cost to the friction bearing standard:

$$\text{Training costs per year allocated to friction bearing standards} = \text{Total training costs per year} \times \frac{1}{6} = \$10,000.$$

This yearly training cost will diminish in proportion to the number of plain bearing cars extant.

Item 5 $10,000

Step 6: Inspection Cost

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. The periodic inspection requirements, also will impose no additional cost burden on the railroads for the inspection function itself.

Item 6 $-0-
(Inspection Cost)

Step 7: Develop Maintenance/Replacement Cost (Repacking Costs)

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} - {cars inspected without FRA standards in effect}

Item 7 — $164.73 (Maintenance/Replacement Cost)

Step 8: Develop Lost Utilization Cost

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 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:

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

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.

Item 8 $2.10 (Lost Utilization Cost)

<u>Step 9:</u> Develop Record Keeping and Billing Cost

Only those friction bearing cars repacked by non-owning railroads will have an effect 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 (Δ cars), 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 interline 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 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 $\left(\frac{\$10.00/\text{hour}}{12 \text{ reports/hour}}\right)$, and the total billing costs would be:

Total costs = \$0.83 x additional number of repackings x 1/2,

where the factor of 1/2 reflects the fact that about 1/2 of the repackings done by the owner road, are not billed.

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 take a little bit longer.

Item 9 $\underline{\qquad \$0.415 \qquad}$
(Record Keeping Costs)

Step 10: **Develop Non-Compliance Cost**

In addition to the costs of these extra repackings, the overdate cars will 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 forgiveness of hardship and "good character" cases, take 60 percent as the collectable amount of the fines.* Then the total industry cost is: (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.

Some sensitivity analysis is needed on this item because these costs are large and the parameters are uncertain. The two parameters most uncertain are the percent of cars which are overdate and the percent of cars which are found. If high and low values of 1.5 percent and 0.8 percent are used for percent overdate and 7 percent and 3 percent for percent found, the high and low civil penalties values are:

High $3.3075 x number of cars
Low $0.7560 x number of cars

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*The present collectable ratio on track standards.

**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.

Item 10		
	Nominal	$1.5750
	High	$3.3075
	Low	$0.7560
	(Non-Compliance Cost)	

Step 11: Aggregation of Rail Costs into Time Streams

The most expedient way to aggregate rail industry costs for use later is to form time streams in which each year's expense is expressed in constant dollars. Each time stream will have a set of nominal, high and low values associated with it. If applicable inflation rates and discount rates are equal for all the time streams, they can be aggregated into one stream (with an associated set of three values).

In the present case, two time streams are judged to be sufficient. One stream is subject to an "average" materals and labor inflation rate and will be discounted at an "average" discount rate. The second time stream, consisting of the civil penalties which are historically subject to less inflation, will have a different inflation rate associated with it. The discount rate, being that of the rail industry at large, can be assumed to be identical for all time streams.

As a preliminary step, all of the information generated up to this point is collected in Table A.3. All of the monetary values are expressed in constant dollars, that is, neither discounting nor inflation adjustments have been made. The first three unit costs apply to the increased number of repackings. The program development cost is an initial cost only. Civil penalties apply to the entire plain bearing freight car fleet and training costs are proportional to the entire fleet.

The cost aggregation process proceeds step by step through Tables A.4, A.5 and A.6. In Table A.4 the unit costs are aggregated by similar unit costs and similar inflation characteristics. In Table A.5, the unit costs are transformed into total costs with some aggregation left to be done. The final aggregation appears in Table A.6 which consists of two time streams with nominal, high and low cost values expressed in constant dollars for each year. The reason for having two separate time streams, as explained earlier, is that the civil penalties are expected to inflate more slowly than other market costs. Hence the right hand time stream will be subject to a different inflation rate during the process of converting the constant dollars to current dollars and the subsequent telescoping of the time streams to lump-sum present values. The two time streams of Table A.6 will be merged with other cost and benefit time streams which are developed later.

Item 11 <u>Table A.6</u>

TABLE A.3: Rail Industry Cost Aggregation: Preliminary Step 1 (Constant Dollars)

Year	Plain Bearing Fleet	Additional Repackings			Unit Repacking Costs Δ Repack	Unit Lost Car Utilization Costs per Δ Repack	Expansion of AAR Billing Files per Δ Repack	Program Development	Unit Civil Penalties Per Cars in Fleet			Training Costs per Cars in Fleet
		Nominal	High	Low					Nominal	High	Low	
1973	875,330	0	0	0	164.73	$2.10	$0.415	$2,000	$1.575	3.3075	0.7560	$0.01142
1974	813,330	6,272	9,962	4,103	164.73	2.10	$0.415	-0-				
1975	749,330	5,779	9,179	3,780								
1976	686,330	5,293	8,407	3,463								
1977	623,330	4,807	7,635	3,145								
1978	560,330	4,321	6,863	2,827								
1979	497,330	3,835	6,091	2,509								
1980	434,330	3,349	5,320	2,191								
1981	371,330	2,864	4,548	1,873								
1982	308,330	2,378	3,777	1,556								
1983	245,330	1,892	3,005	1,238								
1984	182,330	1,406	2,233	920								
1985	119,330	920	1,462	602								
1986	56,330	434	690	284								
1987	-	0	0	0								
1988	-	0	0	0								
1989	-	0	0	0	164.73	2.10	$0.415	-0-	1.575	3.3075	0.7560	$0.01142

TABLE A.4: Industry Cost Aggregation: Preliminary Step 2, Item 11
(Constant Dollars)

Year	Bearing Fleet	Additional Repackings			Unit Costs per Δ Repack; Repacking Lost Car Utilization, Billing File Expansion	Unit Cost per Cars in Fleet: Civil Penalties			Unit Costs Per Cars in Fleet: Training Costs	At Large Costs; Program Development
		Nominal	High	Low		Nominal	High	Low		
1973	875,330	0	0	0	$167.245	1.575	3.30750	0.7560	$0.01142	$2,000
1974	813,330	6,272	9,962	4,103						-0-
1975	749,330	5,779	9,179	3,780						
1976	686,330	5,293	8,407	3,463						
1977	623,330	4,807	7,635	3,145						
1978	560,330	4,321	6,863	2,827						
1979	497,330	3,835	6,091	2,509						
1980	434,330	3,349	5,320	2,191						
1981	371,330	2,864	4,548	1,873						
1982	308,330	2,378	3,777	1,556						
1983	245,330	1,892	3,005	1,238						
1984	182,330	1,406	2,233	920						
1985	119,330	920	1,462	602						
1986	56,330	434	690	284						
1987	--	0	0	0						
1988	--	0	0	0						
1989	--	0	0	0	$167.245	1.58642	3.31892	.76742	$0.01142	-0-
--										

TABLE A.5: Rail Industry Cost Aggregation: Preliminary Step 3, Item 11 (Constant Dollars)

Year	Repacking, Lost Car Utilization and Billing File Expansion Costs			Civil Penalties			Training Costs	Program Development
	Nominal	High	Low	Nominal	High	Low		
1973	0	0	0	0	0	0	10,000	$2,000
1974	$1,048,960	$1,666,095	$686,206	1,280,995	2,690,089	614,877	9,288	-0-
1975	966,509	1,535,142	632,186	1,180,194	2,478,409	566,493	8,557	
1976	885,228	1,406,029	579,169	1,080,970	2,270,036	518,865	7,838	
1977	803,947	1,276,916	525,986	981,745	2,061,664	471,237	7,118	
1978	722,666	1,147,802	472,802	882,520	1,853,291	423,609	6,399	
1979	641,385	1,018,689	419,618	783,295	1,644,919	375,981	5,680	
1980	560,104	889,743	366,434	684,070	1,436,546	328,353	4,960	
1981	478,990	760,630	313,250	584,845	1,228,174	280,725	4,241	
1982	397,709	631,684	260,233	485,620	1,019,801	233,097	3,521	
1983	316,428	502,571	207,049	386,395	811,429	185,469	2,802	
1984	235,146	373,458	153,865	287,170	603,056	137,841	2,082	
1985	153,865	244,512	100,681	187,945	394,684	90,213	1,363	
1986	72,584	115,389	47,498	88,720	186,311	42,585	643	
1987	0	0	0	0	0	0	0	
1988	0	0	0	0	0	0	0	
1989	0	0	0	0	0	0	0	-0-

TABLE A.6: Rail Industry Cost Aggregation: Final Step, Item 11
Time Streams in Constant Dollars

	Items 4 through Item 9 — Time Stream with: Average Inflation Rate, Average Discount Factor; Components: Repacking, Lost Car Utilization, Billing File Expansion, Program Development, Training Costs			Item 10 — Time Stream with: Low Inflation Rate, Average Discount Factor; Component: Civil Penalties		
Year	Nominal	High	Low	Nominal	High	Low
1973	12,000	12,000	12,000	0	0	0
1974	1,058,000	1,675,000	695,000	1,281,000	2,690,000	615,000
1975	975,000	1,544,000	641,000	1,180,000	2,478,000	566,000
1976	893,000	1,414,000	587,000	1,081,000	2,270,000	519,000
1977	811,000	1,284,000	533,000	982,000	2,062,000	471,000
1978	729,000	1,154,000	479,000	883,000	1,853,000	424,000
1979	647,000	1,024,000	425,000	783,000	1,645,000	376,000
1980	565,000	895,000	371,000	684,000	1,437,000	328,000
1981	483,000	765,000	317,000	585,000	1,228,000	201,000
1982	401,000	635,000	263,000	486,000	1,020,000	233,000
1983	319,000	505,000	210,000	386,000	811,000	185,000
1984	237,000	376,000	156,000	287,000	603,000	138,000
1985	155,000	246,000	102,000	188,000	395,000	90,000
1986	73,000	116,000	48,000	89,000	186,000	43,000
1987	0	0	0	0	0	0
1988	0	0	0	0	0	0
1989	0	0	0	0	0	0

A.3 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 represents a cost to society that must be considered in the overall cost/effectiveness analysis. Societal costs can be 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.

Step 12: 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

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*Again based on the assumption of equal cost distribution among six equipment groups. See the section on rail industry costs.

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 $43,176. ($518,118 x 1/6) x 1/2.

Item 12 $43,176
(Standards Development)

Step 13: Record Keeping Equipment Cost

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:

$$\text{Cabinets purchased by FRA} = \frac{800,000 \text{ reports}}{19,200 \text{ reports per cabinet}} = 41.67 \text{ cabinets}$$

At $100 per cabinet, the initial investment in filing cabinets would amount to $4,167. Allocate one-sixth of this total expenditure to the friction bearing standards.

Item 13 $694
(Record Keeping Equipment Cost)

Step 14: **Inspector Training Cost**

Approximately 50 equipment inspectors are employed for freight cars, passenger train cars and locomotives. If two weeks of training prior to entering the field is assumed, total man-hours of training is 80 hours per man or 4000 man-hours. Assuming a training cost of $20/man-hour to cover salary, travel, overhead, and other expenses, total training costs would amount to $80,000. Allocate this cost to freight cars (98 percent of the equipment), and plain bearing freight cars (51 percent of the freight cars) and journal bearings (1/6 of the equipment categories):

Allocated initial training costs = $80,000 x 0.98 x 0.51 x 1/6
= $6,664

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.

Item 14 $6,664
(Inspector Training Cost)

Step 15: Unit Inspection Cost

The yearly cost for each inspector is $16,676 which includes salary, benefits and expenses. The total cost must again be allocated to plain journal bearings:

Yearly inspection cost = 50 inspectors x \$16,676/inspector x 0.98 (freight cars) x 0.51 (plain bearing cars) x 1/6 (bearings)

= \$69,456

The unit inspection cost is:

Unit inspection cost = \$69,456/875,330

= \$0.079348

Item 15 — \$0.079348 Unit Inspection Cost

Step 16: Record Keeping Expenses

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

$$\text{Unit Record Keeping Cost} = \left[\$10/\text{hour}\right] \times \left[5/60\ \text{hour/report}\right] \times \left[\frac{1}{6}\ \text{(allocation to journal bearings)}\right]$$

$$= \$0.13889/\text{report}$$

In 1973, 406,336 pieces of equipment were inspected. The same allocation process as above gives:

Reports on plain bearing cars = 406,336 x 0.98 x 0.51

= 203,087

The yearly cost is for 1973 then is:

1973 record keeping cost for plain bearing cars = 203,087 reports x \$0.13889/report

= \$28,207

This produces a unit cost (based on 875,330 plain bearing cars) of \$0.032224. As the plain bearing fleet diminishes (see Table A.1) the yearly cost will diminish accordingly. The tacit assumption is that the overall inspection intensity will remain the same over the years. (In 1972 nearly twice as many pieces of equipment were inspected as in 1973.)

Item 16 \$0.032224
(Record Keeping Cost)

Item 17: Aggregation of Societal Costs into Time Streams all of the societal costs derived above are collected into a single time stream in Table A.7. This time stream tacity assumes that the inflation for all the societal costs will be at an "average" rate which is the same as that for most of the other costs and benefits. This time stream will be merged with all of the similar streams in a later step.

Item 17 Table A.7
(Aggregate Societal Costs

TABLE A.7: Societal Cost Time Stream, Item 17

		Items 12, 13, 14	Item 15	Item 16	
Year	Plain Bearing Cars in Service at End of Year	Initial Costs: Development of Standards, Record Keeping Equipment, Inspector Training	Unit Record Keeping Expense	Unit Inspection Cost	Time Stream of Societal Costs
1973	875,330	$50,534	$0.032224	$0.079348	$148,196
1974	813,330	-0-			90,745
1975	749,330				83,604
1976	686,330				76,575
1977	623,330				69,546
1978	560,330				62,517
1979	497,330				55,488
1980	434,330				48,459
1981	371,330				41,430
1982	308,330				34,401
1983	245,330				27,372
1984	182,330				20,343
1985	119,330				13,314
1986	56,330				6,285
1987	--				0
1988	--	-0-			0
1989	--	0	$0.032224	$0.079348	0

A.4 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 $51,156. 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.

Step 18: Obtain the Number of Accidents

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.

A.4.1 Failure Probabilities (Steps 19 and 20)

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.

Step 19: Calculate the Accident Probability

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 A.8. 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 A.9 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 30 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 Table A.9. 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, 6-month age groups are chosen. For all the stabilized cars the total failure expression is:

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

where the symbols are as defined in Table A.8.

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

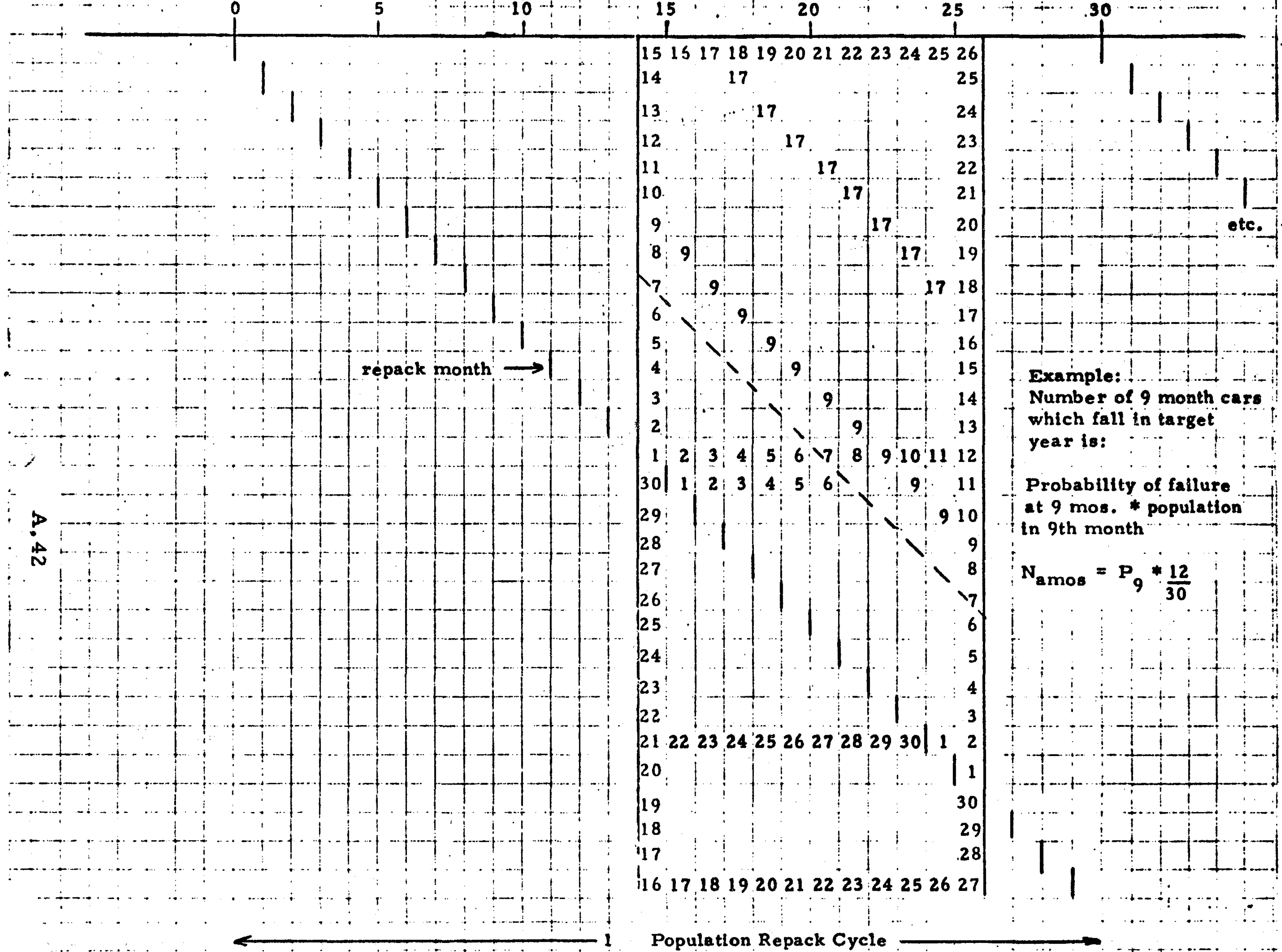
TABLE A.8: Symbology Used in Failure Probability Calculations

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. $P(a,b) = P_a + \ldots\ldots + P_b$

TABLE A.9

Stabilized-Car Population
Not overdate, Not retired

Figure 18



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, Table A.10, with the same conventions as used in Table A.9, 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 $F_{So_{19,24}} = S_o(\frac{5}{12}P_{20} + \frac{4}{12}P_{21} + \frac{3}{12}P_{22} + \frac{2}{12}P_{21} + \frac{1}{12}P_{20})$

TABLE A.10
Overdate Stabilized Cars
Not Retired

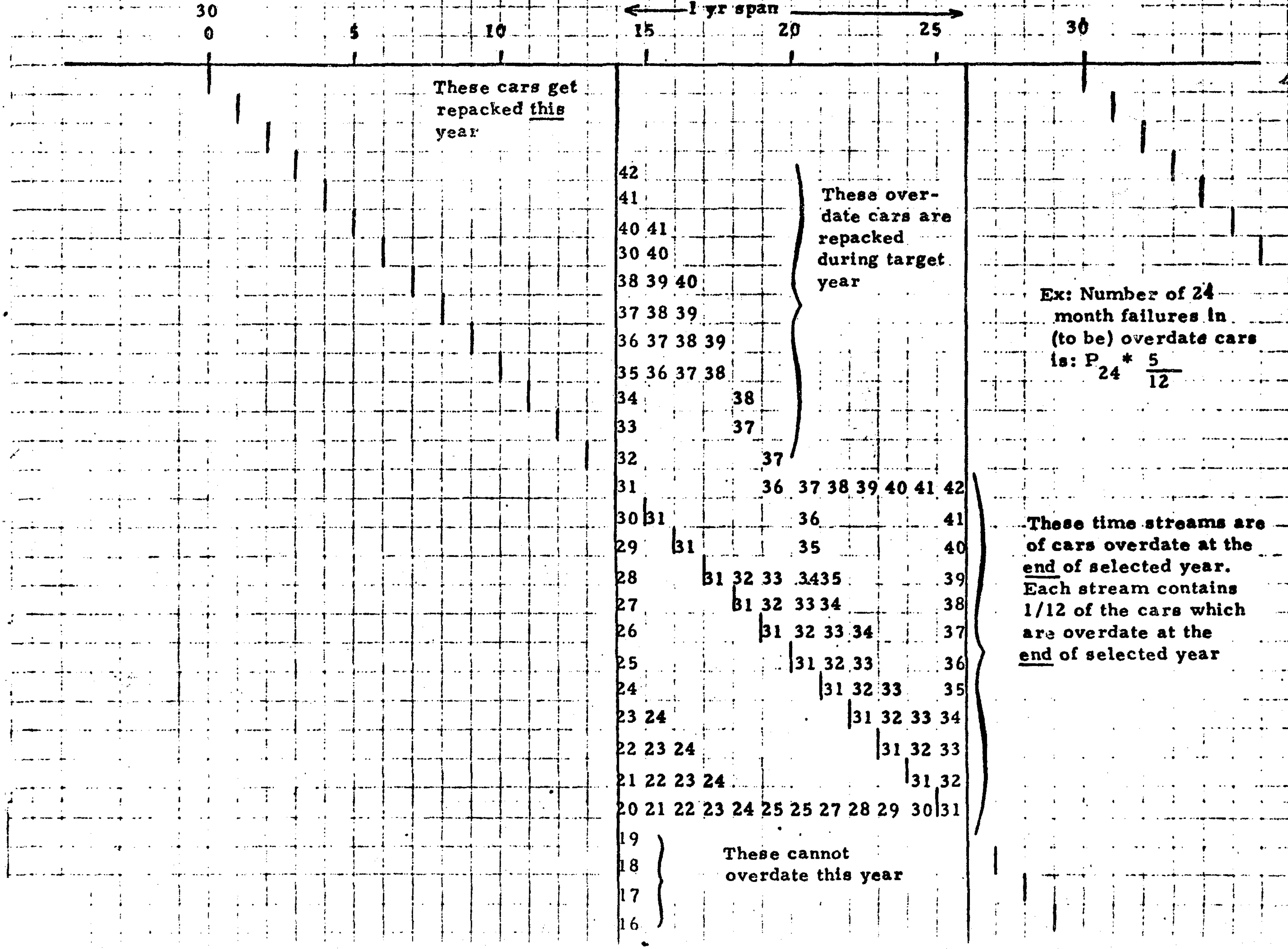


Figure 19

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

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

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

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

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

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

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 retirning, but not overdate more than 12 months. Then their time stream could be sketched as in Tables A.9 and A.10 with the same conventions as before except that the population diminishes by 1/12 each month. The expression for failures among retirees is:

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

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:

$$F(19,24) = P(19,24)\left[.4S_n + .5U_n + .20833\,S_o + .70833\,S_u + .21667S_r + .27083U_r\right]$$

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 A.11 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 A.11: 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 A.12. 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 A.12: 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 A.11, summed by age group, and the number of failures in each group, a probability of failure can be calculated for each age group.

Item 19 — Table A.13 (Accident Probabilities)

A.4.2 Prevented Accidents

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 A.13. More failures will occur in the "younger" months (infant mortality) while fewer failures will occur in the "older" months for a net saving of 14.4 prevented accidents the first year. If it is assumed that the ratio of accidents of 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 A.13: Failure Probabilities and Failures

Age Group	Failure Probability	Failures undr Under AAR Inter-change 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

A. 4. 3 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.

A. 4. 3. 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 previously. 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.

A. 4. 3. 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. Correspondingly, a 12 percent overdate value changes the number of prevented accidents to 15.6 per year for the first year and reduces societal and railroad benefits.

A. 4. 3. 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 subpopulations. Accident reduction in the first year is 14.9.

Step 21: Time Stream of Prevented Accidents

A time stream with nominal, high, and low values for prevented accidents can now be constructed. The "high" refers to a large number of preventions, and occurs when the overdate percent is decreased to 8 percent and the percent stabilized is increased to 30 percent. The number of preventions is 15.5 as shown in Table A.14. The "low" value is 13.3 accidents prevented in the first year.

The time stream is presented in Table A.15 by diminishing the accident preventions in proportion to the size of the plain bearing fleet. This time stream will eventually be merged with the others.

Item 21 Table A.15 (Prevented Accidents)

TABLE A. 14: Sensitivity Analysis on Accident Reductions

	Prevented Accidents		
	Nominal	High	Low
Percent of Fleet Overdate	10%	8%	12%
Percent of Cars Stabilized	25%	30%	20%
Prevented Accidents (first year)	14.4	15.5	13.3

TABLE A.15: Prevented Accidents (Item 21)

Date	Plain Bearing Cars in Service at End of Year	Nominal	High	Low
		10% Overdate	8% Overdate	12% Overdate
		25% Stabilized	30% Stabilized	20% Stabilized
1973	875,330	14.4	15.5	13.3
1974	812,330	13.4	14.4	12.3
1975	749,330	12.3	13.3	11.4
1976	686,330	11.3	12.2	10.4
1977	623,330	10.2	11.0	9.5
1978	560,330	9.2	9.9	8.5
1979	497,330	8.2	8.8	7.6
1980	434,330	7.1	7.7	6.6
1981	371,330	6.1	6.6	5.6
1982	308,330	5.1	5.5	4.7
1983	245,330	4.0	4.3	3.7
1984	182,330	3.0	3.2	2.8
1985	119,330	2.0	2.1	1.8
1986	56,330	0.9	1.0	0.9
1987	--	0.0	0.0	0.0
1988	--	0.0	0.0	0.0
1989	--	0.0	0.0	0.0

A. 5 Rail Industry 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 or records existed for certain costs (e.g., delays in service), estimates were made based on the responses made in carrier interviews.

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.

Step 22: Calculate 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:

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

Avg. Equipment Damage per Friction Bearing Accident = $19,858 per accident

Item 22 = $19,858
(Railroad Equipment Damage)

Step 23: Calculate 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:

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

Item 23: $5803
(Track Damage)

Step 24: Calculate 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

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*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:

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

Item 24: $8,040
(Wreck Clearing Cost)

Step 25: Calculate 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.

Item 25 = $30,000 (Lading Damage)

Step 26: Calculate Injury and Fatality Costs

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).

Item 26 = $10 (Personal Injuries and Fatalities)

Step 27: Calculate 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 the methodology report.

Item 27 = $800 (Non-Railroad Property Damages)

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

Step 28: Calculate 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 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 3 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

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

carloads will be those carloads delayed on day* by a friction bearing accident. At $4.20 average diem cost, the per diem loss due to friction bearing accidents is:

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

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*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.

**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.

average revenue loss, due to loss of good will, per friction bearing accident in 1973 would then be:

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

Item 28 = $732
(Service Delay Cost)

Step 29: Form The Railroad Benefit Time Stream

Total average railroad costs for a friction bearing accident in 1973 dollars would be $65,345. These costs are summarized in Table A.16. When used in conjunction with the number of accidents prevented, this value represents a benefit to the rail industry.

Item 29 = Table A. 19
(Railroad Benefit Time Stream)

TABLE A.16: Summary Table, Railroad Benefits Per Accident Reduced (Cost of Accident)

	Costs
Average Damage to Railroad Equipment Per Friction Bearing Accident	$19,858
Average Damage to Track and Right-of-Way Per Friction Bearing Accident	$ 5,803
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 Damage to Non-Railroad Property	$ 800
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	$65,345

A.6 Societal Benefits (Steps 30, 31, 32, 33)

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 -- where 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 summarary 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 cross-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 it was found that the average societal cost was about $5,000 per 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:

$5,000 x (3 accidents in 1972 + 3 accidents in 1971 +
2 accidents in 1970) = $40,000.

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 3-year span there were no deaths involved. The 16 non-disabling injuries* associated with the approximately 1,700 friction bearing accidents that occurred were estimated

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

to cost $2,100/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 3-year span than was originally anticipated at the outset of the study.

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.

$$\text{Item 33} = \frac{\text{Table A.20}}{\text{(Societal Cost Time Stream)}}$$

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

A.7 Net Cost Effectiveness

The monetary time streams of railroad costs and benefits and societal costs and benefits will now be telescoped to their present values and aggregated to produce the net cost effectiveness of the plain bearing safety standards. As explained earlier, all costs and benefits which have been quantified in monetary units can be summed directly within any given year. To compare monetary quanitities of different years, however, requires adjustment for inflation and lost opportunity. Although different costs (wholesale and retail prices, labor, fuel, etc.) inflate at different rates, and different sectors of society (rail industry, government, household, etc.) have access to different investment rates in their money, a single inflation rate and a single discount rate can often be used for all, or nearly all, of the time streams.

In the present example, however, the time streams are all kept separate up to the point at which their present values are combined. This was done to demonstrate the relative impact of the component costs and benefits, especially when the inflation and discount rates are varied. A single discount rate was used for all of the time streams and also a single inflation rate for all except civil penalties which were predicted to inflate more slowly than the general economy.*

*Because of past and current criticism, the FRA may keep the monetary value of their fines more "in line" with national price trends.

efits and Costs

Six time streams have been kept disaggregated to this point: rail industry compliance costs, civil penalties, societal costs, rail industry benefits, and societal benefits with the civil penalties occurring again as a separate societal benefit.

Step 34: Perform Final Merging of the Time Streams

The two rail industry cost time streams are presented in Table A.17 and the societal costs time stream is presented in Table A.18. Rail industry benefits, Table A.19, were developed by multiplying the number of prevented accidents (Table A.15) by the $65,345 cost per accident (Table A.16). A similar calculation produced the societal benefits (Table A.20) and the civil penalties were repeated in Time Stream 6, a societal benefit.

Item 34 Tables A.17, A.18, A.19, A.20 (Time Stream Merging)

As explained previously, although civil penalties are transfer payments, strictly speaking, they have two important aspects in this case. They represent a major cost to the rail industry and also, unlike most transfer payments, they cannot be redistributed back to the railroads without losing their compliance effectiveness.

Each of the time streams can now be telescoped to its present value and combined to give a net cost effectiveness. One precaution is necessary when combining high and low values of the various time streams. A parameter which produced a high dollar value in one time stream may produce a low dollar value in another stream. For

TABLE A.17: Time Streams 1 and 2: Railroad Costs (Item 11, Item 34)

	Time Stream 1: Repacking Costs, Training Costs, Lost Car Utilization, Program Development Billing File Expansion (Table A.6)				Time Stream 2: Civil Penalties (Table A.6)		
Parameter*	Nominal	High	Low	Parameter*	Nominal	High	Low
% Overdate	10%	12%	8%	% Overdate	1%	1.5%	0.8%
Mos. O'date	5	7	4	% Found	5%	7%	3%

Year	TS1 Nominal	TS1 High	TS1 Low	TS2 Nominal	TS2 High	TS2 Low
1973	$ 12,000	$ 12,000	$ 12,000	$0	$0	$0
1974	1,058,000	1,675,000	695,000	1,281,000	2,690,000	615,000
1975	975,000	1,544,000	641,000	1,180,000	2,478,000	566,000
1976	893,000	1,414,000	587,000	1,081,000	2,270,000	519,000
1977	811,000	1,284,000	533,000	982,000	2,062,000	471,000
1978	729,000	1,154,000	479,000	883,000	1,853,000	424,000
1979	647,000	1,024,000	425,000	783,000	1,645,000	376,000
1980	565,000	895,000	371,000	684,000	1,437,000	328,000
1981	483,000	765,000	317,000	585,000	1,228,000	201,000
1982	401,000	635,000	263,000	486,000	1,020,000	233,000
1983	319,000	505,000	210,000	386,000	811,000	185,000
1984	237,000	376,000	156,000	287,000	603,000	138,000
1985	155,000	246,000	102,000	188,000	395,000	90,000
1986	73,000	116,000	48,000	89,000	186,000	43,000
1987	0	0	0	0	0	0
1988	0	0	0	0	0	0
1989	0	0	0	0	0	0

*These are the parameters associated with the nominal, high and low values of the time streams. All the other parameters were judged insensitve or firm. The left table parameters are in relation to practice under AAR rules, the right table's relate to operation under FRA safety regulations.

TABLE A.18: Time Stream 3: Societal Costs (Item 17, Item 34)

Year	Time Stream 3 Development of Standards Inspector Training Record Keeping Inspection Costs (Table A.7) Nominal = High = Low
1973	$148,196
1974	90,745
1975	83,604
1976	76,575
1977	69,546
1978	62,517
1979	55,488
1980	48,459
1981	41,430
1982	34,401
1983	27,372
1984	20,343
1985	13,314
1986	6,285
1987	0
1988	0
1989	0

TABLE A.19: Time Stream 4: Rail Industry Benefits (Item 29, Item 34)

	Prevented Accidents (Table A.15)			Time Stream 4 Rail Industry Benefits @ 65,345/Accident (Table A.16)		
Parameter *	Nominal	High	Low	Nominal	High	Low
% Overdate	10%	8%	12%	10%	8%	12%
% Stabilized	25%	30%	20%	25%	30%	20%
Year						
1973	14.4	15.5	13.3	940,970	1,012,850	869,090
1974	13.4	14.4	12.3	875,620	940,970	803,740
1975	12.3	13.3	11.4	803,740	869,090	744,930
1976	11.3	12.2	10.4	738,400	797,210	679,590
1977	10.2	11.0	9.5	666,520	718,800	620,780
1978	9.2	9.9	8.5	601,170	646,920	555,430
1979	8.2	8.8	7.6	535,830	575,040	496,620
1980	7.1	7.7	6.6	463,950	503,160	431,280
1981	6.1	6.6	5.6	398,600	431,280	365,930
1982	5.1	5.5	4.7	333,260	359,400	307,120
1983	4.0	4.3	3.7	261,380	280,980	241,780
1984	3.0	3.2	2.8	196,040	209,100	182,970
1985	2.0	2.1	1.8	130,690	137,220	117,620
1986	.9	1.0	.9	58,810	65,350	58,810
1987	0	0	0	0	0	0
1988	0	0	0	0	0	0
1989	0	0	0	0	0	0

*These are the parameters associated with the nominal, high and the low values of the time streams. All the other parameters were judged insensitive or firm.

TABLE A.20: Time Streams 5 and 6: Societal Benefits (Item 33, Item 34)

Time Stream 5

Parameter*	Societal Benefits @ $235/Accident Nominal	High	Low
% Overdate	10%	8%	12%
% Stabilized	25%	30%	20%

Year	Nominal	High	Low
1973	$3,380	$7,290	$3,130
1974	3,149	3,380	2,890
1975	2,890	3,130	2,680
1976	2,660	2,870	2,440
1977	2,400	2,590	2,230
1978	2,160	2,330	2,000
1979	1,930	2,070	1,790
1980	1,670	1,810	1,550
1981	1,430	1,550	1,320
1982	1,200	1,290	1,100
1983	940	1,010	870
1984	710	750	660
1985	470	490	423
1986	210	235	210
1987	0	0	0
1988	0	0	0
1989	0	0	0

Parameter*	Civil Penalties (Table A.6) Nominal	High	Low
% Overdate	1%	1.5%	0.8%
% Found	5%	7%	3%

The entries for this time stream are identical with those of Time Stream 2

*These are the parameters associated with the nominal, high and the low values of the time streams. All the other parameters were judged insensitive or firm.

example, an assumption of 12 percent cars overdate (on repacking) produced high costs (Time Stream 1, Table A. 17) and low benefits (Time Stream 4 and 5, Tables A. 19 and A. 20). Examination of the other parameters (given at the head of each time stream) shows that this is the only common parameter with the possible exception of the percent overdate in Time Streams 2 and 6. A higher percent of cars in the overdate condition under the AAR rules would probably imply a higher percent overdate under FRA regulations.

It was decided to combine all of the "high" values for Time Streams 1, 2, 3 and 6 with the "low" values of Time Streams 4 and 5 and vice versa. A computer program was used to do all the arithmetic involved in telescoping the time series with variations in the inflation rate and the discount rate. The program is given in Table A. 21.

A. 7. 2 Results and Conclusions

The Office of Management and Budget has recommended the use of the single discount rate of 10% on all future dollar amounts expressed in constant dollars (all of the costs and benefits in this analysis have been expressed in constant dollars up to this point).

The effects of varying discount rates are shown in Table A. 22. Time Streams 1 through 3 are costs--railroad, railroad penalties and societal . Time Streams 4 through 6 are benefits -- railroad, societal and railroad penalties. The four cases are summarized in Table A. 23.

TABLE A.21: Computer Program Used to Find Present Values

```
.TY CB4.F4
      DIMENSIØN S(6,17,3),F(4,6),D(4,6),PV(6,3),XSIGN(6),CE(3)
      DATA XSIGN/1.,1.,1.,-1.,-1.,-1./
      DATA NRATES,IVALS,NYEARS,NTIMES/4,3,17,6/
      DATA F/3*10.,0.,5.,0.,5.,0.,3*10.,0.,3*10.,0.,3*10.,0.,5.,0.,
     15.,0./
      DATA D/13.,13.,10.,3.,13.,13.,10.,3.,13.,13.,10.,3.,13.,13.,10.,
     13.,13.,13.,10.,3.,13.,13.,10.,3./
      DATA (S(1,J,1),J=1,17)/12000.,1058000.,975000.,893000.,811000.,
     1729000.,647000.,565000.,483000.,401000.,319000.,237000.,155000.,
     273000.,3*0./
      DATA (S(1,J,2),J=1,17)/12000.,1675000.,1544000.,1414000.,1284000.,
     11154000.,1024000.,895000.,765000.,635000.,505000.,376000.,
     2246000.,116000.,3*0./
      DATA (S(1,J,3),J=1,17)/12000.,695000.,641000.,587000.,533000.,
     1479000.,425000.,371000.,317000.,263000.,210000.,156000.,102000.,
     148000.,3*0./
      DATA (S(2,J,1),J=1,17)/0.,1281000.,1180000.,1081000.,982000.,
     1883000.,783000.,684000.,585000.,486000.,386000.,287000.,188000.,
     289000.,3*0./
      DATA (S(2,J,2),J=1,17)/0.,2690000.,2478000.,2270000.,2062000.,
     11853000.,1645000.,1437000.,1228000.,1020000.,811000.,603000.,
     2395000.,186000.,3*0./
      DATA (S(2,J,3),J=1,17)/0.,615000.,566000.,519000.,471000.,423000.,
     1376000.,328000.,201000.,233000.,185000.,138000.,90000.,43000.,
     23*0./
      DATA (S(3,J,1),J=1,17)/148196.,90745.,83604.,76575.,69546.,
     162517.,55488.,48459.,41430.,34401.,27372.,20343.,13314.,6285.,
     23*0./
      DATA (S(4,J,1),J=1,17)/944350.,878770.,806630.,741050.,
     1668916.,603336.,537760.,465620.,400040.,334460.,262320.,196740.,
     2131160.,59020.,3*0./
      DATA (S(4,J,3),J=1,17)/1016990.,944350.,872210.,800076.,721380.,
     1649242.,577100.,504970.,432830.,360690.,281990.,209860.,137720.,
     165580.,3*0./
      DATA (S(4,J,2),J=1,17)/872214.,806630.,747610.,682030.,
     1623010.,557430.,498410.,432830.,367250.,308230.,242650.,183620.,
     2118040.,59020.,3*0./
      DØ 999 I=1,17
      S(3,I,2)=S(3,I,1)
      S(3,I,3)=S(3,I,1)
      DØ 998 J=1,3
      S(5,I,J)=S(4,I,J)*.003583
      S(4,I,J)=S(4,I,J)*.996417
      S(6,I,J)=S(2,I,J)
998   CØNTINUE
999   CØNTINUE
```

Table A.21 (continued)

```
C...LØØP ØN CASES(RATES).
      DØ 50     K=1,NRATES
      WRITE(6,1)K
1     FØRMAT('1CASE ',I1)
      WRITE(6,6)
6     FØRMAT('0 TIME',T10,'INFLATIØN',T20,'DISCØUNT',T45,'PRESENT VALUE'
     1/' STREAM',T13,'RATE',T22,'RATE',T35,'NØMINAL',T50,'HIGH',T65,
     2'LØW')
C...LØØP ØN TIME STREAMS.
      CE(1)=0.
      CE(2)=0.
      CE(3)=0.
      DØ 100     I=1,NTIMES
      FF=F(K,I)/100.
      DD=D(K,I)/100.
      PV(I,1)=0.
      PV(I,2)=0.
      PV(I,3)=0.
      DØ 60     L=1,IVALS
      PV(I,L)=0.
C...LØØP ØN YEARS.
      DØ 200     J=1,NYEARS
      PV(I,L)=PV(I,L)+S(I,J,L)*(1.+FF)**(J-1)/(1.+DD)**(J-1)
200   CØNTINUE
      PV(I,L)=PV(I,L)*XSIGN(I)
      CE(L)=CE(L)+PV(I,L)
  60  CØNTINUE
      WRITE(6,4)I,F(K,I),D(K,I),(PV(I,M),M=1,3)
4     FØRMAT(I4,T13,F4.1,'%',T22,F4.1,'%',T30,F12.0,3X,F12.0,3X,F12.0)
100   CØNTINUE
      WRITE(6,5)CE
5     FØRMAT('0',T17,'NET CØST =',T30,F12.0,3X,F12.0,3X,F12.0)
 50   CØNTINUE
      STØP
      END
```

TABLE A. 22: Effects of Inflation and Interest on Net Cost (Item 35, Item 36)

CASE 1

TIME STREAM	DISCOUNT RATE	NOMINAL	PRESENT VALUE HIGH	LOW
1	10.0%	4784227.	7568600.	3147809.
2	13.0%	5187206.	10892408.	2458870.
3	10.0%	557488.	557488.	557488.
4	10.0%	-4880516.	-4509333.	-5259288.
5	10.0%	-17550.	-16215.	-18912.
6	13.0%	-5187206.	-10892408.	-2458870.
	NET COST =	443649.	3600539.	-1572903.

CASE 2

TIME STREAM	DISCOUNT RATE	NOMINAL	PRESENT VALUE HIGH	LOW
1	10.0%	4784227.	7568600.	3147809.
2	10.0%	5778012.	12132993.	2735108.
3	10.0%	557488.	557488.	557488.
4	10.0%	-4880516.	-4509333.	-5259288.
5	10.0%	-17550.	-16215.	-18912.
6	10.0%	-5778012.	-12132993.	-2735108.
	NET COST =	443649.	3600539.	-1572903.

CASE 3

TIME STREAM	DISCOUNT RATE	NOMINAL	PRESENT VALUE HIGH	LOW
1	8.0%	5165422.	8172305.	3398282.
2	11.0%	5568653.	11693377.	2637265.
3	8.0%	590186.	590186.	590186.
4	8.0%	-5195141.	-4800475.	-5598283.
5	8.0%	-18681.	-17262.	-20131.
6	11.0%	-5568653.	-11693377.	-2637265.
	NET COST =	541786.	3944753.	-1629946.

CASE 4

TIME STREAM	DISCOUNT RATE	NOMINAL	PRESENT VALUE HIGH	LOW
1	8.0%	5165422.	8172305.	3398282.
2	8.0%	6239631.	13102305.	2950692.
3	8.0%	590186.	590186.	590186.
4	8.0%	-5195141.	-4800475.	-5598283.
5	8.0%	-18681.	-17262.	-
6	8.0%	-6239631.	-13102305.	-29
	NET COST =	541786.	3944754.	-16

TABLE A.23: Net Cost Summary

Case	Description	Discount Rate		Net Cost ($000,000)					
				Rail Industry			Total		
		Prevailing	For Penalties	Nominal	High	Low	Nominal	High	Low
1	Baseline Case	10%	13%	5.09	13.95	.35	.44	3.60	-1.57
2	Inflating Penalties	10%	10%	5.68	15.19	.62	.44	3.60	-1.57
3	Lower Discount Rate	8%	11%	5.54	15.07	.44	.54	3.94	-1.63
4	Inflating Penalties	8%	8%	6.21	16.47	.75	.54	3.94	-1.63

Step 37: Calculate Net Cost

In Case 1, the baseline case, the 10% discount rate was used except for the civil penalties whose assumed slower rate of invlation was accounted for by assuming a higher discount rate of 13%. In Case 2, all of the costs and benefits were discounted at 10%. Cases 3 and 4 are the same as Cases 1 and 2, except that the prevailing discount rate is 8% and the slower inflation rate is accounted for by an 11% discount rate.

The nominal net cost in every case is about one-half million dollars. The high values ran around $4 million and its low values are a negative $1. 6 million (net benefit). However, the net cost to the rail industry is positive in every case.

The results presented in this appendix indicate that strict enforcement of the repacking safety regulations is marginally cost effective. The net cost is nominally about $1/2 million dollars. Uncertainty considerations give a range of $4 million net cost to $1. 6 million net benefit. However, the net cost to the railroads is nominally $5 million to $6 million with an uncertainty range of $16 million to $0. 35 million. Once again, it is important to realize that even though most of these net costs are from civil penalties, which are technically transfer payments, these inequities cannot be rectified by redistribution without their losing their intended purpose of motivating compliance with the safety standard.

Item 37 Table A. 23 (Net Cost)

The net cost to the railroads and the total net cost are still to be balanced by the decision maker's unquantifiable and exogenous considerations which may well tip the scales one way or the other. As was pointed out in the body of this manual, the purpose of economic impact analysis is to provide the decision maker with detailed information on quantifiable items in his decision making process.