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A PROGRAM DEFINITION STUDY

FOR

RAIL-HIGHWAY GRADE CROSSING IMPROVEMENT

Prepared for

FEDERAL RAILROAD ADMINISTRATION

U. S. Department of Transportation

Washington, D. C.

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16. Abstract

~~This study~~ The report describes in general terms the present status of grade crossing inventories, improvement programs and other significant considerations. It identifies available information with respect to the cost of accidents and motor vehicle operations, as well as the preparation of estimates of the number of crossings in classes related to the volume of train movements and the volume of vehicle traffic. From these estimates, the number of crossings at which improvements would yield benefits in excess of costs was estimated, together with the reduction in accidents which those improvements could be expected to bring.

It develops a five-year program of study related to policy formulation, program administration and research; also, it identifies and describes projects which can be initiated as action programs, research and special studies. This includes a recommended program to correct data deficiencies and develop a comprehensive information system.

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FOREWORD

Significant amounts of money are expended each year for safety improvements at rail-highway grade crossings. Considerable research has also been conducted. In spite of these efforts, there is a clear need for a more systematic and well-defined approach to "the rail-highway grade crossing problem."

The study contained herein is the first such systematic attempt to provide the desired approach. We believe it to be a very valuable effort, although not necessarily the only input which will be evaluated and considered in attempting to define and implement a long-range research program. Until such program has been approved by appropriate levels, it must be recognized that the instant study is not necessarily the official policy and program of the Federal Railroad Administration.

Appreciation is expressed to the many memebers of the railroad industry and state and local agencies who contributed their expertise and their views to this study. The project was conducted for the FRA by Alan M. Voorhees and Associates, Inc. of McLean, Virginia, under the direction of Mr. David W. Schoppert.

R. N. Whitman

R. N. Whitman, Administrator
Federal Railroad Administration

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CHAPTER I

INTRODUCTION AND SUMMARY

This is the report of a program definition study which had as its objectives:

> To develop a program of study related to policy formulation, program administration and research covering the next five years (calendar 1970 and 1975); and
>
> To identify and describe projects which can be initiated within the next six months for the action programs, research and special studies.

The study included the identification of available information with respect to the costs of accidents and motor vehicle operations, as well as the preparation of estimates of the numbers of crossings in classes related to the volume of train movements and the volume of vehicle traffic. From these estimates, the number of crossings at which improvements would yield benefits in excess of costs was estimated together with the reduction in accidents which those improvements could be expected to bring.

During the course of the study, deficiencies in available information were observed in every facet of the problem. Some of these are serious and require immediate attention. Others are troublesome but not critical. The recommended program lists projects to deal with these in order of their urgency and to reduce errors in estimates by progressively refining the non-critical information base.

With respect to warranted improvements, it is estimated that there are 30,000 crossings where train and traffic volumes justify immediate improvements. These improvements would cost about $580 million and would yield net benefits of roughly $6 billion. Using techniques developed in an earlier study, it is estimated that the improvements would also reduce accidents to one-half the number which would be expected if no improvements were made. The estimates are based on an "available" sample of crossings which cannot be assumed to be strictly representative of all crossings in the country. It was expanded with care to agree with known totals and those elements which could be were checked against other estimates and were found to be in good agreement. It was, therefore, concluded that the estimates developed in this report are sufficiently representative of the nation as a whole to be used for preliminary planning purposes.

While the estimates are preliminary, they reflect a general order of magnitude which suggests that a substantially increased program is needed to arrest and reverse the upward trend in grade crossing accidents, and that such a program would be justified. Although there has been significant reduction in accidents in the past, it is clear that within the past eight to ten years efforts have been successful only in retarding increases in accidents and not in achieving a major reduction. A much larger program together with greatly expanded and well directed research will be needed to achieve even modest reductions in accidents.

One reason why so many improvements have been found to be economically justifiable may be the values assigned to accident costs. The values used in this study are in line with more recent estimates of accident costs, particularly the cost of fatal injuries. The costs used were based on the potential earnings of the persons fatally injuried. The values were taken from estimates widely recognized as valid. They put grade crossing safety on an equal footing with other programs aimed at prolonging life or improving productivity.

Another feature of the estimates was the use of a discount rate, following guidelines of the Bureau of the Budget, which provides a basis for putting the program on an equal footing with other investments which the federal government might make.

The costs at a railroad crossing include not just those related to collisions but to motor vehicle and train operation. No reliable information on train operating costs were found but motor vehicle operating costs were available from the Bureau of Public Roads. The cost and benefit calculations do not include any allowance for reduction in train operating costs. An early project in the recommended program would develop such information.

As a result of the calculation of potential costs and benefits from different types of improvements it became clear that the vast majority of crossings do not have sufficient volumes of trains and vehicles to warrant the installation of available devices such as automatic flashing lights and gates. The benefits those devices bring in terms of reduced accident costs at crossings with a low probability of vehicle-train collisions do not make them an attractive investment at their present initial and recurring costs. This finding helps to define a need for a new device or devices which has low initial and recurring costs and which can significantly reduce accidents at locations with relatively low hazard.

The recommended research and development program includes projects to develop appropriate devices and treatments for crossing in these categories.

The general level of fact gathering and reporting on such essential things as the number of crossings in existence, the accidents which occur at them, and the scale and results of improvements leaves a great deal to be desired. The process is plagued with inconsistent definitions, divided responsibilities and exemptions from reporting requirements. The result is that an uninitiated person can draw incorrect conclusions from incomplete data published by, and appearing to carry the concurrence and endorsement of, the federal government. Accidents which do not result in fatalities or personal injuries or in damages to railroad property amounting to more than $750 are not reported. Grade crossing accident costs sustained by railroads are included with costs caused by other types of train accidents. More than one railroad company may report inventory data pertaining to a single crossing.

The recommended program includes projects designed to correct these deficiencies and develop a comprehensive information system for the Federal Railroad and Highway Administrations. Some improvement has been made in gathering and coordinating information in the past two years, largely as a result of the coordinated program of the Department of Transportation.

Finally, there are serious issues of finance and support for a major public works program to improve operation and reduce hazards at rail-highway grade crossings. Most of the crossings in need of improvement are on roads not eligible for federal aid. If even modest proportions of the total cost were assigned to the railroads, their ability to participate in a sustained program may not be adequate to the need. Substantial benefits may be possible from the closing of crossings as part of an overall improvement program, but closings may be difficult or impossible to obtain in many locations because of local pressures to keep crossings open. Accordingly the recommended program includes demonstrations of total improvement projects in cities to develop working relationships, measure costs and benefits and show how the legal, financial and social problems can be solved.

In addition to the estimated number of crossings which now warrant improvement there will continue to be a need for new grade separation and protection in the years ahead. This need will come from the following sources:

1. New crossings.

   The expanding urban areas require new roads and streets to serve new development. It is estimated from Transport Statistics that about 2700 new crossings were opened in the five year period from 1962 to 1966. In addition to roads and streets built simply to serve new development, relocations of old roads and wholly new ones produce a need for rail-highway crossings.

2. Growth in vehicular traffic.

   The growth in vehicular traffic is expected to increase at a rate between 4. 0 and 5. 0 percent. While this increase will be felt uniformly over the road and street system it will result in many crossings reaching the point where protective devices are warranted. Precisely how many crossings will reach the warranted condition is a matter for speculation. However, improvement of the information system should provide better estimates of this number. Additionally, if the cost of automatic devices could be reduced by 10 percent another large increment of the total would immediately become eligible for improvement. Both improvement of the information system and research to find devices which can be installed and maintained at costs below present levels are recommended in this report.

3. Special conditions.

Examples of special cases which produce needs for new grade separations and protective devices are:

- corridors where high speed train service is instituted. Some corridors which would benefit from high speed train service have already been identified, others will develop over the next several decades.

- areas (particularly in or near the hearts of cities) where major environmental improvements are needed. Railroad trackage is often located in these areas in such a way that access is impaired. Even when accidents are not a serious part of the problem, the conflicts between rail service on the one hand and street access, land use and urban design on the other can only be satisfactorily resolved by major improvements designed as an integrated set of systems.

CHAPTER II
BACKGROUND

GENERAL BACKGROUND

This chapter describes in general terms the present status of grade crossing inventories, improvement programs and other significant considerations. This study involved the preparation of estimates of the number of crossings in various categories in an attempt to better define the numbers and kinds of improvements which could be undertaken in the near future. The estimating techniques are also explained in this chapter.

Research covering the probability of a vehicle-train collision has been conducted and reported by many organizations and individuals. The results are generally consistent with respect to the major factors which influence the probability of a collision. They are also generally consistent with respect to the relative effectiveness of grade crossing protective devices. The studies, for the most part, were concerned with limited samples of crossings. They do not describe the total grade crossing inventory nor do they identify specific groups of crossings which should have some type of improvement.

The general situation is also reasonably well known. There are approximately 225,000 grade crossings in the United States. Of these about 45,000 have some special kind of protection. Accidents at crossings result in 1500 to 1800 deaths, 3500 to 4000 injuries each year and economic losses in excess of 300 million dollars.

Between these two extremes - the broad, general statistics and detailed analyses of individual crossings - there is a void which has never been dealt with explicitly.

As a result, alternative approaches to grade crossing improvements on a programmed basis have not been evaluated. Until recently, no effort has been made to establish on a national basis, the number of crossings located on federal aid routes, on state routes and local roads. Benefits other than safety are certain to accrue to road and rail users from elimination, separation and improved signalization of grade crossings. But the information has never been assembled in the past in such a way that these benefits could be estimated.

RAIL-HIGHWAY GRADE CROSSING ESTIMATES FOR THE UNITED STATES

The number of rail-highway grade crossings in the United States is available from several sources. The most widely recognized source is the annual summary published in Transport Statistics which is based on reports by individual railroad companies. The report may be subject to some error due to double reporting and mis-interpretations of terms used. The most recent tabulation shows a total of 213,723 crossings on Class I railroads as of December 31, 1967. In addition it is estimated that there are approximately 11,250 crossings on Class II railroads, bringing the total to 225,000 for the nation.

A second source is a tabulation prepared by the Bureau of Public Roads. It is based on inventories and estimates prepared by State Highway Departments. This tabulation is incomplete because some states have not inventoried all roads and streets. However, it provides reliable information for some states and for most of the federal aid systems.

The two sources were used to develop an estimate of the number of crossings by different administrative systems. BPR figures were used where available and supplemented by the Transport Statistic table. The resulting totals for each system are shown below.

ESTIMATED NUMBER OF GRADE CROSSINGS

Federal Aid Primary System	Federal Aid Secondary System		Roads and Streets Not on Federal Aid System
	On State Highways	On Local Roads and Streets	
14,420	14,630	18,060	177,890

The total 225,000 crossings include 43,869 with active protection such as gates and flashing light signals while 181,131 have no special protective devices. The sample on which this study was based was expanded to these control totals.

The expansion was done by dividing the total crossings by location, urban or rural. The total road and street mileage in the United States divides urban-rural as follows:

	Miles	Percent
Urban	521,203	14.03
Rural	3,183,711	85.97
TOTAL	3,704,914	100.00

The total mileage in the States providing sample data divided urban-rural only:

	Miles	Percent
Urban	36,216	9.09
Rural	360,210	90.91
TOTAL	396,426	100.00

It was, therefore, assumed that these States were more rural in character than the United States as a whole and a factor of 1.53 was applied to the urban crossings to adjust for this difference.

Next it was assumed that the inventories made by the States on their federal aid systems included crossings with both Class I and II railroads since the two are hardly distinguishable to an inventory crew, the difference being more one of finance than operations. Therefore, the Bureau of Public Roads data were used for federal aid routes. Where no inventory or estimate was available, one was made using factors from States in the same B. P. R. Region.

The final control then was on the number of crossings with automatic gates, flashing light signals and other types of protection including crossbuck signs. The proportions of these were determined from ICC statistics. It was assumed that Class II road crossings had the same distribution of protective devices as Class I. This gave the following estimated totals against which to expand the sample.

Federal Aid Primary Highways	
Automatic Gates	1720
Flashing Light Signals	4792
All Other Types of Protection	7908
	14420
Federal Aid Secondary Highways	
Automatic Gates	3927
Flashing Light Signals	5615
All Other Types of Protection	23148
	32690
Non-Federal Aid Roads	
Automatic Gates	2248
Flashing Light Signals	25567
All Other Types of Protection	150075
	177890

Appropriate expansion factors were developed for each of these categories and then applied to the sample. The expansion yielded a total of 225,040 crossings, only 40 more than the original estimate. Other totals checked very well with the original estimates and no attempt was made to adjust for the very minor discrepancy of 40 crossings in the expanded total.

The Sample

The sample of 14,956 crossings was drawn from inventories made by five states.[1/] The inventories included detailed information about each crossing including the number of tracks, train movements and vehicle volumes, the type of protective devices and administrative system. These data were converted to a common base and summarized in various ways. The summary of greatest interest involved the classification of the road and rail elements according to function. This classification was necessarily preliminary because the actual road and rail routes were not identifiable. The exercise was useful in that it demonstrates the distribution of crossings across different systems. In the absence of detailed route information, the rail system classification was developed as described below.

Classification of Railroads

The information which was available did not permit a functional classification of the rail system. Such a classification would require a quite detailed inventory of the entire system which in turn would require extensive field data collection and assembly of information from several sources. The approach which was used was simpler and was based on the number of mainline tracks and the daily train volume. These two

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[1/] Minnesota, Maryland, Oregon, Tennessee, Wyoming factors were readily available and together they express the general use of the railroad at the crossing. Six volume classes were selected after inspection of the basic information. They were:

Volume Class	Train Volume*
1	0 to 2
2	3 to 5
3	6 to 10
4	11 to 20
5	21 to 40
6	over 40

These were further divided into 18 groups by using the number of main-line tracks. Three general categories were established. (1) Those with no main tracks, generally devoted to switching movements; (2) those with one main track and no passing track; and (3) those with two or more main and passing tracks.

By looking at the total inventory in this breakdown, it is possible to estimate the number of crossings on very important rail lines and to estimate the number which might have to be improved in one way or another to achieve objectives with respect to certain systems.

Protection Types

The crossings were classified into four basic protection types. The four types selected were:

Crossbucks and Other Crossing Identification Signs. - This type includes all crossings which had no special protective devices or traffic control features.

*Average number of railroad movements per day.

Flashing Light Signals. - This type include crossings with either flashing lights or wigwags.

Automatic Gates With Flashing Light Signals. - This type includes those with manual gates.

Others. - This type included crossings with stop signs, flagmen and various other devices which did not fit the three categories described above. Approximately one-third of these crossings had stop signs. The other two-thirds had a variety of devices. In the samples, the expected accidents for this group were predicted using frequencies for stop signs. Individual crossings might have higher or lower accidents, but the results reflect a reasonable estimate of the accidents expected at these crossings.

Classification of the Highway System

The highway element of each crossing was classified according to function by a combination of traffic volume and administrative system. While this, like the rail classification, is an imperfect method, it can be used to gain insights into the number of crossings on roads of different importance.

A more specific classification of highways and streets could be made when the proposed functional classification of all roads and streets is complete. In the meantime, the results of this classification serve as an example of the technique and can be used to estimate the number of crossings on each administrative system and in different volume classes.

The combined classification of train and vehicle volumes was used in the calculation of potential accidents for each protective type.

Administrative classes used were:

- federal aid primary
- federal aid secondary
- non-federal aid

Motor vehicle volume classes were:

Volume Class	Range of Volumes
1	0 to 500
2	501 to 1000
3	1001 to 5000
4	5001 to 10000
5	10001 to 20000
6	over 20000

Location

Crossings were further tabulated according to the type of area in which they were located. Thus separate tabulations were made for urban and rural areas.

RESULTS OF THE INVENTORY EXPANSION PROCESS

The inventory expanded to national totals was then arranged into a series of tables similar to the one shown in Table 1. That table shows the number of crossings in each cell of the table for urban crossings with signs only and different numbers of main tracks. Thus the numbers in each should be read.

TABLE 1

CROSSING IN URBAN AREAS
WITH CROSSBUCK SIGNS ONLY

HIGHWAY VOLUME CLASS

TRAIN VOLUME CLASS	1	2	3	4	5	6
1	8640 3860 150 12650	2000 820 40 2860	4410 1590 40 6040	1820 330 20 2170	1160 230 0 1390	70 100 0 170
2	440 1230 160 1830	150 280 20 450	230 460 50 740	100 70 0 170	180 0 0 180	0 50 0 50
3	690 1150 160 2000	50 150 20 220	380 370 50 800	100 80 0 180	130 40 0 170	50 0 0 50
4	90 740 260 1090	70 160 0 230	200 500 40 740	70 40 0 110	50 100 0 150	0 50 0 50
5	90 50 70 210	20 40 20 80	80 20 20 120	0 20 0 20	20 0 0 20	0 0 0 0
6	0 20 0 20	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0

000	- number of crossings with no main tracks
000	- number with one main track
000	- number with two or more
000	- total crossings

Similar tables were prepared for each protection type, for both urban and rural areas. In the analysis of accident frequencies and net benefits, the same format was used so that any number of crossings could be related to expected accidents, to potential benefits or to cost-benefit ratios and so on. The tables, therefore, provide a ready way to analyze different program levels and their possible costs and consequences.

Table 2 is a summary of the expanded totals by administrative system and protection type. Other tabulations are shown in the Appendix.

FEDERAL AID FOR IMPROVEMENTS

Grade crossing improvement projects on federal aid routes are eligible for federal funding either from regular matching funds or as special "G" projects.

Grade Crossing "G" Projects

Special projects are financed by the States from their regular Federal-aid apportionments by using the permissive provisions of Section 120(d), Title 23, U.S. Code. The Federal share of the cost of work financed under these provisions may amount to up to 100 percent of the total cost except that not more than 50 percent of the cost of the underlying right-of-way and property damages can be financed with

TABLE 2

ESTIMATED NATIONAL TOTALS EXPANDED FROM FIVE STATE SAMPLE BY ADMINISTRATIVE SYSTEM AND PROTECTION TYPE

	Protection Type				
	Signs Only	Flashing Lights	Gates	Other Types	Total
Urban					
Federal Aid					
Primary	2100	1570	910	2720	7300
Secondary	1290	2890	940	3050	8170
Non-Federal Aid	31520	20480	1890	24650	78540
Sub-total (Urban)	34910	24940	3740	30420	94010
Rural					
Federal Aid					
Primary	1740	3220	810	1330	7100
Secondary	12030	2730	2990	6770	24520
Non-Federal Aid	64720	5080	360	29250	99410
Sub-total (Rural)	78490	11030	4160	37350	131030
Urban & Rural					
Federal Aid					
Primary	3840	4790	1720	4050	14400
Secondary	13320	5620	3930	9820	32690
Non-Federal Aid	96240	25560	2250	53900	177950
TOTAL	113400	35970	7900	67770	225040

Federal-aid highway funds. Also, not more than 10 percent of the total annual Federal-aid fund apportionment to a State may be used in this manner.[1/]

Regular Matching Funds

These funds and the work represented relate to the regular Federal-aid highway funds apportioned to the States for the various highway systems. Participation in the costs of projects financed with these funds is at the normal matching ratio for that state.[2/]

Under these provisions funds are available for improvements on the Federal-aid system. Crossings involving roads and streets not eligible for Federal-aid represent about 80 percent of the total crossings in the country. Furthermore, a lower proportion of the crossings on "local" systems have automatic devices as can be seen by the following:

Percent of All Crossings Specially Protected with Automatic Devices

Category	Percent Within that System
Federal-Aid Primary System	45
Federal-Aid Secondary System	29
Non-Federally Aided Roads and Streets	16

To determine whether this in only the natural result of lower vehicle volumes on non-federally aided roads and streets, tabulations were made to show by percentages the highway classification of the warranted crossings now protected by signs only. The results are shown below.

1/ & 2/ Highway-Railway Grade Crossing Safety Program, U.S. Department of Transportation, March 1969.

Percentage of Crossings with Signs Only
Which Warrant Automatic Devices or Separations

	Urban	Rural	Total
On Federal Aid Systems	10	5	15
Not on Federal Aid Systems	61	24	85
	71	29	100

Of the 30,000 crossings which warrant improvements, only 470 or less than two percent, warrant grade separations. Projects financed with federal ABC funds over the past five years included 775 new structures and 1486 protection improvements. A program which would include only those projects which (based on average conditions at crossings) would yield net benefits in excess of costs would call for a substantial change in the locale of expenditures - that is from the federal aid system to the local system - and a shift in the types of projects undertaken - that is a larger proportion of flashing light signals and gates relative to the number of separation structures. The present ratio is about two devices to one separation. The proposed ratio would be about ten devices to one separation structure.

CURRENT EXPENDITURES

It would be difficult to determine how much is spent each year on rail-highway grade crossing projects. The amount of federal aid funds, plus that spent by others to meet matching provisions has been reported for the five year period 1963 to 1967 by the Department of Transportation. The total was $955, 124, 095 of which $593, 423, 474 were spent on projects on the Interstate Highway System.

Expenditures on Federally-Aided Rail-Highway Grade Crossing Projects for the Years 1963-1967

	Federal Funds	Total Funds
Primary Funds	$ 82, 338, 325	$108, 922, 650
Secondary Funds	69, 350, 372	89, 330, 439
Urban Funds	102, 971, 931	163, 447, 532
Sub-total	254, 660, 628	361, 700, 621
Interstate Funds	553, 044, 025	593, 423, 474
TOTAL	$807, 704, 653	$955, 124, 095

Source: "Federal-Aid Highway Railway Grade Crossing Projects", 1963-1967, U.S. Department of Transportation.

QUALIFICATION OF THE FINDINGS

The findings are based on the best available information. However, the techniques which were used to select warranted projects and expand the sample inventory to totals for the nation both have certain weaknesses and probabilities of error which should be kept in mind when interpreting the findings.

Sample Expansion

The sample used in this study was not "selected" in the sense that researchers prefer to use. It was, instead, an "available" sample and, it was therefore necessary to expand the sample by the use of as many factors as could be determined to assure that the totals would be reasonably representative of all crossings in the country. Those elements which could be were checked against other estimates and found to be in good agreement. It was, therefore, concluded that the expanded totals were sufficiently representative of the nation as a whole to be used for preliminary planning purposes. Even so, the finer breakdowns of the inventory, for example, the number of crossings with a certain type of protection with certain train movements and vehicle volumes are subject to large errors. The estimates can and should be improved over the next few years with a modest expenditure of funds and this will make possible more accurate planning information.

Costs of Operation

The information on costs of several elements of operation, device installation, accidents and construction was limited to national averages or to similar situations. Accordingly the benefits and costs are subject to some inaccuracy and costs at individual crossings might be significantly more or less than the averages used. With these limitations the estimates of costs and benefits are usable only for scaling national needs for planning purposes.

Estimating Costs and Benefits

In estimating costs and benefits for groups of crossings, average conditions were, of necessity, assumed for all crossings in the group. Special conditions, such as impaired sight distance, at any individual crossing could advance its need for improvement well above that of the group. It was noted, for example, that both flashing lights and automatic gates have been installed at crossings with very low train and vehicle volumes. It is probable that these are crossings with unique conditions which pose unusual hazards rather than that devices have been installed at inappropriate crossings.

Gates

The fact that half-road gates do not appear as warranted from this analysis should not be construed as evidence that they should not be used. There are a number of factors which make gates preferable to flashing light signals at a particular crossing. These factors have to do primarily with the fact that gates are a positive indication which require a driver to remain stopped until it is safe for him to proceed while flashing light signals although requiring the driver to make a full stop, leave the determination of when it is safe to proceed to each driver. There are many situations where a driver either cannot make such a determination or where a substantial portion of drivers are likely to misjudge the hazard. One obvious situation is restricted sight distance along the track from the stopped position.

Other situations include heavy train activity in the vicinity of the crossing or other distractions which could lead drivers to misjudge the hazard or fail to see a train approaching the crossing. High train speeds are another factor which, because of the limit of driver capabilities to judge the rate of closure, would make a gate installation desirable.

Finally, multiple trackage can result in train-meeting situations commonly referred to as a "scissors" in which a driver who has waited for a train from one direction cannot see another train approaching from the opposite direction. The driver can therefore conclude that the crossing is clear when the first train has passed, even though the second is approaching. If he starts to cross at that time he may be struck by the second train.

RESPONSIBILITY FOR CROSSING IMPROVEMENTS

The history of grade crossing improvements reveals a gradual shift in the responsibility for improvements from the railroads to the general public. This shift has been noted in the paper "The Division of Responsibility for the Elimination and Protection of Highway-Railroad Grade Crossings" which is available through the Federal Railroad Administration. Some key points from the paper are:

- In the course of the history of the grade crossing safety problem the changes in Federal and State policies have clearly demonstrated public acceptance of the concept of public responsibility for the elimination and protection of grade crossings.
- The original concept that railroads have the primary or sole responsibility, financial or otherwise, for the elimination or protection of grade crossings has gradually changed, particularly in situations where Federal participation or Federal funds are involved. On the Federal-aid highway system projects the railroads are required to pay a maximum of up to 10 percent of the cost of constructing grade separations and installing grade crossing protection.
- At the state level there also have been very significant changes in the old concept of railroad responsibility. The

present trend in many states is towards assuming a substantial degree of public responsibility for the elimination and the protection of grade crossings. Some states have already taken action, legislative or otherwise, to relieve the railroads of the major financial responsibility for such safety projects. Ten states have established grade crossing protection funds to assist in the costs for grade crossing protection, because they have recognized that the availability of funds is the controlling factor in determining the number of crossings which will be eliminated or protected. Several states also are participating in the maintenance costs for grade crossing protection.

- Notwithstanding the gradual change in policy the states could require the railroads to bear the entire responsibility for safety at grade crossings, as they did many years ago when the problem arose.

CHAPTER III

FORMS OF GRADE CROSSING SAFETY INSTALLATIONS INITIAL, RECURRING AND USER COSTS

INTRODUCTION

Grade crossing safety installations come in many forms, broadly classified as protective devices or grade separations. The protective devices may be active or passive, and a complete list of them would fill this page. For the purposes of the present study, the focus was on a few major categories of grade crossing safety installations: crossbuck signs, flashing light signals, automatic gates, grade separations, stop signs and others.

Grade crossing safety installations have other impacts than simply prevention of accidents. Grade separations, for instance, eliminate the motor vehicle operating costs of slowing down, possibly stopping, and accelerating at a grade crossing and simultaneously eliminate the delay to vehicle passengers.

Cost Factor Development

The majority of cost factors included here reflect averages that are representative of the general magnitude of the true costs that may be involved. As is generally the case where averaging techniques are utilized, much information is lost at both ends of the averaged spectrum. When necessary, we employed relatively gross factors that are subject to further validation, rather than purposely omitting their usage until they may be refined and verified. Such gross factors reflect the diversity of the degree of sophistication of system components and the variation in the physical and environmental characteristics of the site. The cost factors reflected herein, we believe, provide a reasonable point of departure from which to pursue interim project objectives of the Federal Railroad Administration.

Protective Devices

The average installation costs of both crossbucks and automatic protective devices are reflected in Table 3. For this analysis, it is assumed that advance warning sign requirements are essentially the same for both. The active device costs represent theresults of a 30 month survey conducted by the Bureau of Public Roads of approximately 450 crossings which was completed in 1968.

It will be noted that the total cost of separate installation of flashing light signals followed by the addition of automatic gates is greater than installation of gates with flashing lights. Information obtained from the AAR indicates that more recently "light" gate arms are being marketed that are more easily adapted to existing flashing light signal masts without requiring replacement of masts and foundations. This type of innovation may significantly influence the cost differential reflected in Table 3. For the cost calculations of this report, when flashing light signals exist, the cost of installing automatic gates was assumed to be $19, 875.

Recurring Costs

Shown in Table 4 are the annual recurring cost estimates for active protection at grade crossings.

TABLE 3

INITIAL COSTS OF PROTECTIVE DEVICES AT A CROSSING

A.	PASSIVE	
	Crossbuck Signs[1]	$150.00
	Stop Signs[2] (Additional Cost)	50.00
B.	ACTIVE[2]	
	Flashing Light Signals	$10,675.00
	Automatic Gates Added	19,875.00
	Subtotal: Separate Installation	(30,550.00)
	Flashing Light Signals and Automatic Gates	24,111.00

TABLE 4

RECURRING COSTS OF PROTECTIVE DEVICES
(Adjusted to 1968 $)

		AVE. (Per Annum)
A.	GENERAL SITE MAINTENANCE[1] (ALL)	$120.00
B.	ACTIVE[2]	
	Flashing Light Signals	
	Single Track	$690.00
	Multiple Track	880.00
	Flashing Light Signals and Automatic Gates	
	Single Track	$1,035.00
	Multiple Track	1,250.00

[1] Based upon estimates obtained from the AAR, and includes maintenance other than that of the crossing protection. Hence, it also applies to passively protected sites.

[2] Reflect State of Virginia annual costs, 1950 Code (amended 66).

General site maintenance applicable to all grade crossings is intended to reflect those costs incurred to maintain the physical roadway pavement or other roadway surface in the crossing area. The active device recurring costs, as shown, are representative of established costs for the State of Virginia. These costs compare very favorably with adjusted data compiled for a 1961 AAR study that covered 30 diverse locations in North America.

Grade Separations

The initial costs developed for average grade separations represent the most detailed classification available. These data, obtained from the Bureau of Public Roads, reflect the cumulative total national funding authorizations for grade separations for the period 1963-1967, and embody order of magnitude estimates of various crossing classifications and types. An initial distinction is made between highway approach costs and structure costs. A further breakout is effected by road classification: interstate, primary, secondary and urban roads. A third classification is obtained by differentiating between urban and rural, and a combined weighted average of both. Finally, a distinction is made as to whether the structure is a highway over railroad, as opposed to a railroad over a highway. The following table and appendices summarize the cost data so structured.

Appendix D-1 - Separation highway approach costs by road classification. (Appendix D)

Appendix D-2 - Rural, urban and combined structure costs by road classification and type. (Appendix D)

Table 5 - Rural, urban and combined total initial separation costs by road classification and type.

In this particular cost category the average maintenance cost (adjusted to 1968 dollars) for railroad over highway structures was estimated at approximately $170. For want of any similar estimate for highway spans, it was assumed that recurring maintenance costs for the highway over railroad structure would be roughly equivalent.

This cost is probably low. It is another indication of the lack of solid, verified, obtainable information about relatively simple cost elements. Fortunately for this study, this cost element was small relative to other costs and probably did not materially affect the cost and benefit calculations.

In calculating the discounted costs and benefits, estimates were made of the respective "useful" service lifetimes of the installations. Service life for accounting purposes is generally viewed as the number of years elapsing from an asset's acquisition to its final disposal.

TABLE 5

RURAL AND URBAN TOTAL INITIAL SEPARATION COSTS
(1968 Dollars)

Classification	Type[1/]	Rural	Urban	Weighted Average
INTERSTATE	A	$483,000	$ 868,000	$600,000
	B	605,000	1,000,000	855,000
PRIMARY	A	294,000	455,000	322,000
	B	374,000	959,000[2/]	425,000
SECONDARY	A	252,000	259,000	265,000
	B	328,000	384,000	351,000
URBAN	A	N/A	508,000	508,000
	B	N/A	518,000	518,000

[1/] Types involve: A- Highway over railroad; B - Railroad over highway

[2/] Representative of only 2 structures

As may be expected, a wide variance existed between service lifetime estimates. This is understandable due to the broad spectrum of materials that could conceivably be involved. As a result of coordination with the Office of the Chief of Engineers, U. S. Army, the BPR, FRA, and the AAR, it was concluded that the following represent realistic estimates of service lifetimes of averagd devices and separations as shown by past experience:

Crossbucks and stop signs	7 years
Flashing Light Signals and Automatic Gates	30 years
Grade Separation Structures	50 years

Areas of Further Study

The areas for further study of grade crossing safety installations may be conveniently grouped into short-term and long-term requirements.

Short-Term Requirements. - It will be vital for future, more disaggregated work to employ stratifications of automatic device and separation by the degree of sophistication and by the factors comprising the physical environment.

Long-Term Requirements. - Investigation of land use impacts relative to grade separations is properly a long-term analysis because of the higher priority of other tasks. This refers to the economic implications to surrounding site environs as the result of addition of separations and the consequent changes of land values in the area. Establishment of on-going cost and effectiveness investigations for new devices and techniques, such as flashing advance beacons, impact attenuation devices, and so forth, should also be considered.

Vehicle Operating Costs

The costs of operating motor vehicles and trains are influenced by the existence of grade crossings in several ways. The study included an examination of each of these and attempts were made to develop cost factors for each element. The individual elements of costs were:

For Motor Vehicles

- the cost of slowing down when approaching a crossing which includes time lost and increased operating costs due to deceleration and acceleration.
- the cost of stopping for a train which includes both the cost of time lost and operating costs.
- the cost of delays due to construction when a grade separation is being built. This may be circuitous travel over a detour or interruptions of traffic at the site.
- the cost of delays to traffic resulting from accidents.
- the cost of stopping at stop signs. This applies to all vehicles using the crossing and although the costs are small to each individual user, they are substantial in total.

For Trains

- the costs of stopping when an accident occurs. It has been estimated that each train involved in an accident is delayed about one hour for minor accidents and two hours in the event of fatal injuries to motorists or train crews.
- the costs of operating at slower than possible speeds due to the presence of unprotected grade crossings.

Reasonably good data were available for motor vehicle operating costs and the value of time to highway users. These have been developed for use in economic evaluations of alternative highway improvements and are available in various publications. The Appendix on Operating Costs describes the sources, assumptions used and formulation of the cost analysis.

No reliable information was obtained for train operating costs and the value of time saved or lost by trains of different types. In the absence of reliable estimates it was concluded that these cost elements would not be included in the cost and benefit analysis.

It would appear that such costs could be generated by research studies and possibly they could be obtained through the cooperation of railroad operating companies.

The cost factors used and their sources are described in detail in the Appendix on Operating Costs. The principal elements of operating cost were the value of time lost for passenger cars and commercial vehicles. These were \$1. 56 and \$6. 04 per hour respectively. The mix of traffic was obtained from the Bureau of Public Roads studies and is also described in the Appendix.

CHAPTER IV

GRADE CROSSING ACCIDENTS

INTRODUCTION

Accidents are an inherent danger of the highway-rail grade crossing environment. The various grade crossing safety installations have as their major purpose a decrease in the number of accidents, as well as a possible reduction in their severity.

It may be useful, in an analysis of how to effectively prevent accidents, to establish a separate category for the train-involved accidents and for the non-train involved accidents, because different means of preventing each type of accident may then be tried and tested separately for their effectiveness. However, the accident cost generated at a crossing is the sum of the cost of each accident, regardless of cause. For the purposes of this study, an average cost per accident at crossings was derived for the train-involved accidents and an average cost for non-train involved accidents, and then the frequency of accidents was examined to determine how it varies over the different types of safety installations. Combining these two gives accident costs at particular types of crossings based on the various protective devices, a major component in determining warrants and priorities.

Ideally, the cost data on grade crossing accidents should come from grade crossing accident experience, not from observations of highway accidents in general. However, the generation of the ideal data remains to be accomplished by an on-going information system for grade crossings, since the data presently available is scanty, and reliance had to be placed to some extent on highway accident experience.

Monetary Evaluation

The accidents prevented by safety installations are benefits that should properly be evaluated in monetary terms. If not, then there remains an unavoidable ambiguity as to which installation for a given crossing is warranted, or most cost-effective, since the various effectiveness measures, such as the reduction in the number of persons killed, the reduction in the number injured, and the reduction of accidents at crossings, cannot be related to one another by a common denominator. Money value is an appropriate common denominator. Unfortunately, some values are not as accurate as we would like them to be, and there remains an ambiguity as to which amount to assume for a saved life, for instance, or for pain and suffering prevented. However, by using certain theoretical and empirical developments, these values can be approximated. Furthermore, the sensitivity of the results to changes in these values can be tested.

Definitions and Components

Most of the previous studies[1/] consider the cost of accidents in two parts: direct and indirect costs. In a 1949 formula of the Highway Research Board, direct costs are defined as the sum of damage to property, medical and legal expenses, and the value of worktime lost. The main item which constitutes indirect costs is the expected earnings of persons permanently eliminated from the labor force because of death or total disability.

1/ See e. g., Department of Public Works and Buildings, State of Ill, "Cost of Motor Vehicle Accidents to Illinois Motorists", and R. N. Smith and T. N. Tamburri, "Direct Costs of California State Highway Accidents," Traffic Department, State of California.

Most of the indirect or external costs of an accident are intangible in character. Human suffering involved is a salient example. Time lost by the users of railway and highway at the time of an accident can also be included in this category. Some attempts in the wrong direction have been made to measure these intangible costs. For example a number of studies include in their computation, compensations and damages awarded by the courts, which are very inaccurate measures of the psychological suffering involved. In most cases the payments amount to pure transfers from one individual to another, and their inclusion in the cost to society is an exaggeration. It is conceivable that the legally responsible party suffers psychologically as much as the innocent!

The value of life, however, may be estimated economically, at least, to provide a minimum measure for the loss of a human being. The components or categories of accident costs that were used are work-time lost (because of temporary or permanent disability or because of death), medical and hospital costs, property damages[1/], and the administration expenses of accident insurance. The latter is included because any amount is a diversion of administrative talent, which is directly attributable to the accident environment.

Costs Per Accident

Economic Value of Life. - Numerous studies have estimated the economic value of life, under a diversity of concepts. It is not the purpose

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1/ We have not accounted for damages to the protective devices at the crossings, but this should be developed in the future.

of this study to reconcile all the concepts that have been used to obtain the diversity of estimates presently in existence. One such concept which is realistic and defensible was selected and applied. Other researchers may substitute other values if desired.

The precise value of life used in a cost-benefit study is important. Given many crossings and many different devices, a change in the assigned value of life of 25 percent, for instance, may change the selection of the warranted device at 5 percent of the warranted crossings. It may be worth the effort to verify this statement at a later date in a sensitivity analysis.

Only one value of life was used in this study. It is derived from the calculation of discounted expected lifetime earnings.

Gross lifetime earnings have been tabulated on a national basis according to age, sex, color and education.[1/] For reasons given elsewhere, a national average was used, not regional or state averages. These values have been used for a number of studies by HEW, so their use by the FRA is not unusual, and makes for uniformity among government agencies.[2/]

[1/] Dorthy P. Rice and Barbara S. Cooper, "The Economic Value of Human Life", American Journal of Public Health, Vol. 57, No. 11, (November 1967), pp. 154-66.

[2/] For examples of the use of the gross earnings concept by HEW, see their Disease Control Programs publications "Arthritis", September 1966; "Selected Disease Control Programs", September 1966; Motor Vehicle Injury Prevention Programs", August 1966; "Cancer", October 1966; and "Estimating the Cost of Illness", Health Economic Series No. 6.

Using the Rice-Cooper tables, the estimated average expected loss from a death in a railroad crossing accident for 1964 was $86,000.[1] The method of calculation is as follows. Regrouping the Rice-Cooper age groups slightly, an expected loss of earnings for both males and females may be estimated by multiplying the discounted earnings figures of Rice and Cooper by the distribution of age of the driver in vehicle-train accidents.[2] (More properly, the latter distribution should be the age distribution of those killed at railroad grade crossings, for train involved as well as non-train involved accidents. Those distributions are not available at this time and are part of the "information gap".) The expected loss for males was approximately $93,000 each, and for females, $57,000. It has been estimated that 82 percent of the drivers in vehicle-train accidents were males, while 18 percent were females.[3] Thus, an approximation of the expected minimum loss to society of a person killed at highway-rail grade crossings is $86,000 (as of 1964).

The value of work time lost was estimated from other studies to be $469 for the average non-fatal injury. When these figures were adjusted

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[1] The value of $20,000 used in the Voorhees study, op. cit., and the Newnan study, op. cit., apparently is derived from the American Association of State Highway Officials, Road User Benefit Analysis for Highway Improvements, 1960, p. 143. The values on that page of the AASHO report are for three age brackets and for males and females and, from their low order of magnitude, appear to be derived from a net earnings concept, although it is not indicated how the figures were derived.

[2] Voorhees Study, op. cit., p. 7, Table 1.

[3] Ibid., p. 7, Table 3.

to 1968 dollars, added to insurance overhead, property damage and medical costs, the average accident costs were:

- for train involved accidents, $20,165.
- for non-train accidents, $1,655.

How these values were developed and verified is explained in detail in Appendix A.

CHAPTER V
WARRANTS AND PRIORITIES

INTRODUCTION

The use of Planning, Programming, and Budgeting (PPB) Systems has been widely accepted by government agencies. That is to say, decision makers have found it fruitful to employ benefit-cost or cost-effectiveness techniques as one of several considerations to guide them in their decision-making responsibilities. However, the application of PPB systems has been different for various agencies, both in points of basic methodology and of implementation. The differences in application arise because of differences in the very nature of the problem confronting different agencies and because of different user requirements.

The highway-rail grade crossing environment represents the intersection, both physically and in responsibility, of two Federal agencies, the Federal Railroad Administration and the Federal Highway Administration. FHWA employs a method equivalent to the benefit minus cost (or net benefit) criterion, where the benefits and costs are in discounted terms (or their equivalent annual cash flows).

In this report warrants were derived from the net benefit criterion. Thus, the results of this study are compatible with those which would be produced by the use of FHWA procedures. Priorities may be inferred from the values of the ratio method or the net benefit measure; they are not essential to this study.

Ranges of Input Values and Procedures

Traffic Levels. - The six traffic codes for each, the motor vehicle traffic and the train traffic, represent the ranges of traffic means as shown in Tables 6 and 7. The mean values for each code were employed for the accident and delay cost calculations. The train traffic is the number of railroad movements rather than the number of trains.

TABLE 6

AVERAGE DAILY MOTOR VEHICLE TRAFFIC (ADT)[1/]

ADT Code	ADT Range	ADT Mean Values
1	0-500	137
2	500-1,000	699
3	1,000-5,000	2,006
4	5,000-10,000	6,906
5	10,000-20,000	13,477
6	over 20,000	25,289

TABLE 7

AVERAGE DAILY TRAIN TRAFFIC (TT)[1/]

TT Code	TT Range	TT Mean Values
1	0-2	1
2	3-5	4
3	6-10	7
4	11-20	16
5	21-40	28
6	over 40	132

[1/] Calculated from the five State sample of crossings.

Accident Costs. - The accident frequencies were taken from the Voorhees study NCHRP 50, as modified for automatic gates and flashing light signals in the urban area (See Appendix A). Also, the accidents on grade separations were calculated separately.

The average cost of a train-involved accident is $20, 165. 00 and on a non-train involved accident, $1, 655. 00. Table 8 indicates the range of costs calculated for the lowest highway and train volumes and for the highest.

TABLE 8

ANNUAL COST OF ACCIDENTS PER CROSSING

Train-Involved	Lowest Volumes	Highest Volumes
Crossbucks:		
Urban	$15. 34	$248, 546
Rural	15. 34	246, 757
Stop Signs:	29. 67	93, 012
Flashing Light Signals:		
Urban	. 95	20, 082
Rural	3. 58	75, 613
Automatic Gates:		
Urban	. 31	6, 586
Rural	. 74	15, 692
Non-Train-Involved		
Automatic Gates:	27. 00	24, 722
Other Protective Devices:	12. 13	21, 977
Grade Separations:	29. 37	5, 421

Delay and Operating Costs. - The delay and operating costs employed are shown in Table 9. Delay costs represent the cost of time lost due to stopping or operating at lower speeds than those which would normally prevail. Operating costs are those costs associated with operation of the vehicle. For slowing down, the estimates are based on the assumption of a 5 mile per hour reduction in speed starting from 55 miles per hour for rural areas and 35 miles per hour for urban areas. The delay costs are far less significant than the motor vehicle operation costs. For slowing down, operation costs are four to seven times the delay costs for an urban area, and five to thirteen times for a rural area.

The high cost of stopping for stop signs renders them economically unattractive. These costs were used as the basis for the calculation of operation costs of stopping for trains independent of Stop Signs, by taking the fraction that stop for each highway and train volume code. For the lowest volumes 0.07 percent of the motor vehicles stop, and for the highest volumes, 1.87 percent stop.

The delay costs for separations are initial costs only (covering a period of ten months). We assumed that construction took ten months and was completed in one calendar (or fiscal) year, so that part of the delay costs need not be discounted.

Initial and Recurring Costs of Crossing Installations. - Table 10 shows the initial and recurring costs and the average service lives of the installations.

TABLE 9

ANNUAL COST OF DELAYS
AND MOTOR VEHICLE OPERATIONS PER CROSSING

Delay Costs	Lowest Volume	Highest Volume
Slowing Down:		
Urban	$ 27.29	$ 11,948
Rural	29.07	19,051
Stopping for Stop Signs:		
Urban	408.04	75,321
Rural	783.08	144,549
Construction Delay Costs for Separations:		
Urban	27.87	6,969
Rural	32.38	8,092
Operating Costs		
Slowing Down:		
Urban	186.02	46,435
Rural	362.79	97,176
Stopping for Stop Signs:		
Urban	852.59	157,380
Rural	2,027.2	374,204

TABLE 10

INITIAL AND RECURRING COSTS OF INSTALLATIONS

	Initial Costs	Service Lives (Yrs.)	Annual Recurring Costs[1]
Crossbucks	$ 150	7	$ 0
Stop Signs	50	7	0
Flashing Light Signals	10, 675	30	905
Automatic Gates Added to Flashing	19, 875	30	1, 263
Automatic Gates and Flashing Light Signals	24, 111	30	1, 263
Grade Separations:			
Urban:			
2 Lanes[2]	513, 000	50	
4 Lanes[2]	868, 000	50	
Rural:			
2 Lanes[2]	300, 000	50	
4 Lanes[2]	483, 000	50	

Discounting. - Table 11 gives the discount factors utilized to derive the present worth of the various cost flows. These factors were applied to the annual cost figures or initial cost figures to derive the present worth.

1/ The recurring costs leave out the $120 for roadway maintenance for devices. The $50 maintenance costs for grade separations is the difference between its maintenance cost of $170 and the $120.

2/ Two lanes are assumed for an average daily highway traffic below 5, 000 four lanes above 5, 000. The four lane cost comes from the interstate highway experience.

TABLE 11

DISCOUNT FACTORS TO OBTAIN PRESENT VALUES[1]

Category	Net Discount Rate[2]	Discount Factor
Accident, Delay and Operating Costs:		
Urban	5.2	17.706
Rural	5.8	16.2127
Recurring Maintenance Costs:	10	
Existing Device, Recurring Installation Costs:		
7 Year Life:	10	1.453
30 Year Life:	10	0.2417
New Device:		
7 Year Life:	10	2.036
30 Year Life:	10	1.038

Incorporated is the equalization of service lives to fifty years. We assumed that if a device was already in existence at a crossing, it had lived one-half its useful life. For existing crossbucks and stop signs, we assumed that after 3-1/2 years they are to be replaced, then to be replaced every 7 years up to the 45.5th year. We accounted for the

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[1] Assumes 50 year cash flow.

[2] This is the discount rate of 10 percent less the growth rate, where appropriate.

difference in 45.5 + 7 = 52.5 years and the 50 years of the grade separation by taking only the fraction (4.5)/7 of the original cost as the 45.5th year's outlay to replace the device.

Similarly, after 15 years the existing flashing light signals and automatic gates are replaced, and the final investment (year 45) is only 1/6th of the original capital outlay. Because of the limited effect of the discount factor as fifty years are approached, this approximation is accurate enough.

The accident, delay, and motor vehicle operation costs are assumed to grow according to the urban and rural growth rates of motor vehicle milage. Train traffic was assumed to remain constant, a condition that should be investigated more fully in future research.

The ten percent discount rate employed yields more conservative estimates of warrants than would a five percent discount rate, for example.

Warrants. - Warrants were derived with respect to the existing device. That is, benefits were defined as the accident, motor vehicle operation and delay costs saved over the existing device. The costs are defined as the initial and recurring costs of the devices over that of the present device. All costs and benefits presented below are in discounted terms.

The warrants are shown cell by cell in the train traffic-highway volume matrix, for both the urban and rural environments. The warrants are also shown with respect to the existing device, because the existing device represents a sunk cost, which changes the warrants slightly (by recommending that the device be left in if it is already there, although it would not be recommended if not already there--that is, for some of the marginal cells).

Using the net benefit criterion, for each cell, that grade crossing safety installation is warranted which maximizes net benefits, as long as the net benefits are greater than zero (if zero or less it does not pay to install a new device). Tables 12 through 21 give the warrants with the respective benefit/cost ratio and net benefit values which may be useful to determine priorities. The values in each cell refer to the average crossing in that cell. The total number of warranted improvements was derived by counting the number of crossings in each cell.

A quality that one may seek is that the tables should not recommend upgrading a crossing presently with crossbucks to flashing light signals, for example, and then having the table for flashing light signals recommend grade separations for crossings in that cell. The net benefit criterion achieves this quality; that is, the grade separation will be originally warranted if it is warranted compared to flashing light signals as the existing device.

It was assumed that no crossing was to be downgraded. Average statistics were employed, which presumably have distributions around them. Thus, in those cases where the net benefit criterions indicated that downgrading would have been the best improvement, special characteristics at the crossings were presumed to exist which warranted the special protection they presently have.

The tables which follow show the number of crossings which warrant improvements by type of existing protection and by location -- urban and rural. In addition to the number of crossings, the tables show the type of improvement, the cost-benefit ratios, and the net benefits for an average crossing in that train-vehicle volume group. A summary tabulation at the bottom shows the number of crossings included in the table.

These tables deserve a word of explanation. In the higher volume groups the net benefits and the benefit-cost ratios appear to be very large. In some cases they are so large that the reader might immediately ask why a grade separation was not warranted. In fact, grade separations would produce net benefits in many cases where flashing lights and automatic gates are shown. However, the automatic devices yield larger net benefits. The "warranted" device gives the greatest return on the investment. Other devices or grade separations would also produce benefits in excess of costs. Thus, the figures developed by this analysis are useful only in scaling the national situation. Many factors at each crossing would enter into the decision of which alternative to employ in actual situations. For example, some combination of grades and abutting property development might make a separation much less costly than the average cost used in this analysis while other combinations would result in very much higher costs. In the first case a separation might be more desirable than lights or gates while in the second case the cost of a separation might exceed the benefits it would produce.

Using the tables:

The tables which follow show the number of warranted improvements for urban and rural crossings with different types of existing protection.

The highway volume class is across the table and the railroad movements class along the side. Within each cell in the table is shown the recommended improvement, the net benefits per crossing and the estimated number of crossings. These are shown in the following way:

- recommended improvement is shown in the upper left corner, encoded as:

  FL - automatic flashing light signals
  AG - automatic gates with flashing lights
  GS - grade separation

  If no change is recommended there is no indication in the upper left corner of the cell.

- number of crossings is shown in the upper right corner.
- benefit-cost ratio is shown in the second line.
- net benefits per crossing are shown in the third line of numbers.

Examples of these are:

FL 120
1.1
7410

Recommended improvement is flashing light signals
There are an estimated 120 crossings in this class
The benefit-cost ratio is 1.1
Net benefits per crossing are estimated to be 7410 dollars

From these figures can be calculated the initial costs and total benefits from the warranted improvements. The initial costs for various types of improvements can be found in Chapter III. In general however, the calculations can be made by using the following:

- for new flashing light installation, \$10,700
- for new automatic gates with flashing light signals, \$24,100
- for grade separations,

  The average costs for four lane structures on the Interstate System were used. They are:

  Rural - \$480,000

  Urban - \$868,000

The costs of separations are higher than the past experience would indicate but they allow for higher standards proposed for new structures and for possible right-of-way and damages. Additionally, they represent road-over-rail costs. In many cases road-under-rail designs may be required. The use of the high estimates allows for a mix of the two types.

TABLE 12

NET BENEFITS AND NUMBER OF CROSSINGS
BY TRAIN AND HIGHWAY VOLUME CLASS FOR
URBAN CROSSINGS WITH CROSS BUCK SIGNS
AS THE EXISTING DEVICE

HIGHWAY VOLUME CLASS

TRAIN VOLUME CLASS	1	2	3	4	5	6
1	12,640	2,850	6,030	2,180	1,390	FL 160 1.54 10,810
2	1,830	430	710	FL 190 1.87 17,270	FL 180 3.52 49,930	FL 50 6.18 102,740
3	2,000	230	800	FL 190 3.27 45,100	FL 170 6.15 102,260	FL 50 10.81 194,680
4	1,080	230	FL 740 2.24 24,510	FL 110 7.48 128,600	FL 140 14.07 259,240	FL 50 24.72 470,490
5	220	FL 70 1.37 7,410	FL 120 3.91 57,770	FL 20 13.09 239,930	FL 20 24.62 468,550	AG 0 1.97 8,462,50
6	FL 20 1.70 13,810	FL 0 6.48 108,610	AG 0 10.27 346,280	AG 0 34.38 1,246,350	AG 0 64.61 2,375,150	GS 0 6.59 4,858,160
	17,790	3,810	8,400	2,690	1,900	310

SUMMARY: NO. OF CROSSINGS:

N.C.	-	32,620
F.L.	-	2,280
A.G.	-	0
G.S.	-	0
TOTAL		34,900

TABLE 13

NET BENEFITS AND NUMBER OF CROSSINGS
BY TRAIN AND HIGHWAY VOLUME CLASS FOR
URBAN CROSSINGS WITH STOP SIGNS
AS THE EXISTING DEVICE

HIGHWAY VOLUME CLASS

TRAIN VOLUME CLASS	1	2	3	4	5	6
1	FL 1310 1.02 290	FL 560 5.06 76,160	FL 1360 14.52 253,650	FL 480 49.98 918,970	FL 240 97.52 1,811,000	FL 20 182.95 3,414,050
2	FL 560 1.09 1,770	FL 220 5.10 76,880	FL 510 14.63 255,690	FL 160 50.34 925,749	FL 50 98.19 1,823,600	FL 10 184.10 3,435,690
3	FL 810 1.17 3,260	FL 390 5.14 77,600	FL 530 14.74 257,730	FL 90 50.70 932,929	FL 90 98.86 1,836,190	FL 50 185.26 3,457,330
4	FL 560 1.41 7,710	FL 260 5.25 79,760	FL 480 15.06 263,861	FL 200 51.78 952,868	FL 170 100.87 1,873,980	FL 60 188.72 3,522,250
5	FL 290 1.73 13,640	FL 150 5.40 82,631	FL 140 15.50 272,032	FL 50 53.23 979,987	FL 30 103.56 1,924,370	GS 0 5.16 3,616,830
6	FL 70 4.47 65,083	FL 10 6.73 107,551	AG 80 10.46 343,111	AG 70 35.65 1,256,590	AG 10 68.66 2,453,640	GS 0 6.98 5,191,810
	3,600	1,590	3,100	1,050	590	140

SUMMARY: NO. OF CROSSINGS:

N. C.	-	0
F. L.	-	9,910
A. G.		160
G. S.		0
TOTAL		10,070

TABLE 14

NET BENEFITS AND NUMBER OF CROSSINGS
BY TRAIN AND HIGHWAY VOLUME CLASS FOR
URBAN CROSSINGS WITH **"OTHER" DEVICES**
AS THE EXISTING DEVICE

HIGHWAY VOLUME CLASS

TRAIN VOLUME CLASS	1	2	3	4	5	6
1	2,620	1,130	2,710	960	470	40
2	1,130	460	1,020	320	FL 110 1.19 3,510	FL 20 2.09 20,370
3	1,610	780	1,080	FL 200 1.11 1,970	FL 190 2.08 22,210	FL 110 3.65 49,710
4	1,130	530	970	FL 400 2.53 28,620	FL 350 4.75 70,320	FL 120 8.34 137,760
5	580	310	FL 300 1.32 6,010	FL 110 4.42 64,160	FL 70 8.31 137,140	GS 0 1.30 263,170
6	FL 150 3.58 48,360	FL 30 2.19 22,240	AG 100 3.71 98,280	AG 150 12.41 413,730	AG 40 23.30 808,800	GS 0 3.42 2,105,340
	7,220	3,240	6,180	2,140	1,230	290

SUMMARY: NO. OF CROSSINGS

N.C.	-	17,850
F.L.	-	2,160
A.G.	-	290
G.S.	-	0
TOTAL		20,300

TABLE 15

NET BENEFITS AND NUMBER OF CROSSINGS
BY TRAIN AND HIGHWAY VOLUME CLASS FOR
URBAN CROSSINGS WITH FLASHING LIGHT SIGNALS
AS THE EXISTING DEVICE

HIGHWAY VOLUME CLASS

TRAIN VOLUME CLASS	1	2	3	4	5	6
1	650	160	1450	1250	120	40
2	790	430	1170	1050	680	150
3	190	700	2890	1660	800	70
4	610	830	2660	1290	580	90
5	580	500	1170	370	160	0
6	130	320	980	AG 300 2.27 33,070	AG 100 4.23 84,100	GS 30 1.96 824,310
	2,950	2,940	10,320	5,920	2,440	380

SUMMARY: NO. OF CROSSINGS:

N.C.	-	24,520
F.L.	-	0
A.G.	-	400
G.S.	-	30
TOTAL		24,950

TABLE 16

NET BENEFITS AND NUMBER OF CROSSINGS
BY TRAIN AND HIGHWAY VOLUME CLASS FOR
URBAN CROSSINGS WITH AUTOMATIC GATES
AS THE EXISTING DEVICE

HIGHWAY VOLUME CLASS

TRAIN VOLUME CLASS	1	2	3	4	5	6
1	130	60	380	280	100	10
2	80	30	260	120	50	30
3	140	50	310	110	120	30
4	90	40	290	50	20	0
5	50	0	160	50	50	GS 0 1.00 4,240
6	100	20	240	150	150	GS 0 1.75 640,760
	590	200	1,640	760	490	70

SUMMARY: NO. OF CROSSINGS:

N. C.	-	3,750
F. L.	-	0
A. G.	-	0
G. S.	-	0
TOTAL		3,750

TABLE 17

NET BENEFITS AND NUMBER OF CROSSINGS BY TRAIN AND HIGHWAY VOLUME CLASS FOR RURAL CROSSINGS WITH CROSS BUCK SIGNS AS THE EXISTING DEVICE

TRAIN VOLUME CLASS	HIGHWAY VOLUME CLASS 1	2	3	4	5	6
1	39,880	3,020	4,110	270	GS 10 1.27 130,250	GS 30 2.38 666,960
2	11,870	310	420	FL 90 1.28 5,620	GS 0 1.40 194,590	GS 0 2.61 781,510
3	8,810	440	970	FL 0 2.25 24,710	GS 0 1.53 258,930	GS 0 2.85 896,060
4	6,510	220	FL 210 1.53 10,580	AG 0 3.36 89,980	GS 0 1.93 451,950	GS 0 3.56 1,239,700
5	690	0	FL 180 2.68 33,400	AG 0 6.12 191,080	GS 0 2.46 709,320	GS 0 4.50 1,697,890
6	FL 320 1.27 5,350	AG 30 3.15 80,390	AG 90 8.98 297,450	GS 0 3.71 1,314,540	GS 0 7.07 2,939,790	GS 0 12.70 5,668,900
	68,080	4,020	5,980	360	10	30

SUMMARY: NO. OF CROSSINGS:

N. C.	-	77,520
F. L.	-	800
A. G.	-	120
G. S.	-	40
TOTAL		78,480

TABLE 18

NET BENEFITS AND NUMBER OF CROSSINGS
BY TRAIN AND HIGHWAY VOLUME CLASS FOR
RURAL CROSSINGS WITH STOP SIGNS
AS THE EXISTING DEVICE

TRAIN VOLUME CLASS	HIGHWAY VOLUME CLASS 1	2	3	4	5	6
1	FL 2,880 2.09 20,390	FL 390 10.65 181,000	FL 800 30.55 554,510	FL 60 105.19 1,954,110	GS 40 9.22 3,971,170	GS 0 17.29 7,875,410
2	FL 1,610 2.07 20,130	FL 180 10.57 179,670	FL 220 30.35 550,700	FL 30 104.50 1,942,030	GS 10 9.22 3,975,080	GS 0 17.31 7,882,740
3	FL 2,050 2.06 19,860	FL 190 10.50 178,320	FL 560 30.15 546,890	FL 10 103.81 1,929,140	GS 0 9.23 3,978,990	GS 0 17.32 7,890,060
4	FL 1,560 2.02 10,080	FL 310 10.29 174,320	FL 270 29.53 535,450	AG 50 53.30 1,896,480	GS 10 9.26 3,990,700	GS 0 17.37 7,912,050
5	FL 570 1.96 18,030	FL 60 10.00 168,980	FL 60 28.72 520,200	AG 0 52.61 1,871,680	GS 0 9.29 4,006,320	GS 0 17.43 7,941,360
6	FL 340 1.48 8,940	AG 70 4.72 134,810	AG 50 13.54 454,860	GS 0 4.90 1,886,640	GS 0 9.57 4,141,710	GS 0 17.95 8,195,410
	9,010	1,200	1,960	150	60	0

SUMMARY: NO. OF CROSSINGS:

N.C.	-	0
F.L.	-	12,150
A.G.	-	170
G.S.	-	60
TOTAL		12,380

TABLE 19

NET BENEFITS AND NUMBER OF CROSSINGS
BY TRAIN AND HIGHWAY VOLUME CLASS FOR
RURAL CROSSINGS WITH **"OTHER" DEVICES**
AS THE EXISTING DEVICE

HIGHWAY VOLUME CLASS

TRAIN VOLUME CLASS	1	2	3	4	5	6
1	5,760	800	1,610	140	GS 100 1.24 114,070	GS 0 2.32 637,730
2	3,220	360	440	50	GS 20 1.26 126,660	GS 0 2.37 661,350
3	4,120	390	1,120	30	GS 0 1.29 139,260	GS 0 2.42 684,980
4	3,120	630	560	100	GS 20 1.37 177,030	GS 0 2.56 755,860
5	1,150	130	120	0	GS 10 1.47 227,390	GS 0 2.76 830,360
6	700	140	120	GS 0 1.22 104,440	GS 0 2.37 663,860	GS 0 4.45 1,669,370
	18,070	2,450	3,970	320	150	0

SUMMARY: NO. OF CROSSINGS:

N.C. -	24,810
F.L. -	0
A.G. -	0
G.S. -	150
TOTAL	24,960

TABLE 20

NET BENEFITS AND NUMBER OF CROSSINGS
BY TRAIN AND HIGHWAY VOLUME CLASS FOR
RURAL CROSSINGS WITH **FLASHING LIGHT SIGNALS**
AS THE EXISTING DEVICE

TRAIN VOLUME CLASS	HIGHWAY VOLUME CLASS 1	2	3	4	5	6
1	770	290	840	240	GS 10 1.27 129,620	GS 0 2.39 657,280
2	680	210	930	60	GS 0 1.33 158,070	GS 0 2.50 708,760
3	310	300	890	200	GS 90 1.39 186,520	GS 0 2.61 760,250
4	930	350	660	80	GS 10 1.57 271,860	GS 0 2.93 914,710
5	280	190	370	AG 30 1.93 24,230	GS 0 1.82 385,650	GS 0 3.37 1,120,650
6	1,110	AG 370 1.14 3,620	AG 740 3.24 58,330	GS 50 2.03 485,870	GS 10 3.90 1,371,850	GS 0 7.14 2,905,520
	4,080	1,710	4,430	660	120	0

SUMMARY: NO. OF CROSSINGS:

N.C.	-	9,690
F.L.	-	0
A.G.	-	1,140
G.S.	-	170
TOTAL		11,000

TABLE 21

NET BENEFITS AND NUMBER OF CROSSINGS
BY TRAIN AND HIGHWAY VOLUME CLASS FOR
RURAL CROSSINGS WITH **AUTOMATIC GATES**
AS THE EXISTING DEVICE

HIGHWAY VOLUME CLASS

TRAIN VOLUME CLASS	1	2	3	4	5	6
1	270	240	610	80	GS 10 1.33 155,950	GS 0 2.50 701,230
2	390	280	350	0	GS 0 1.37 171,830	GS 0 2.57 730,630
3	230	220	350	30	GS 0 1.40 187,710	GS 0 2.63 760,040
4	370	210	160	80	GS 0 1.50 235,360	GS 0 2.82 850,260
5	70	20	30	0	GS 0 1.64 298,880	GS 0 3.07 965,890
6	40	30	90	GS 10 1.45 210,720	GS 0 2.82 849,430	GS 0 5.26 1,985,340
	1,370	1,000	1,590	200	10	0

SUMMARY: NO. OF CROSSINGS: N.C. - 4,150
F.L. - 0
A.G. 0
G.S. 20
TOTAL 4,170

CHAPTER VI
INFORMATION SYSTEM

INFORMATION

The Federal Highway and the Federal Railroad Administration have been assigned the task of administering the national program for the reduction of grade crossing accidents. These two administrations have the consultative advice of the National Transportation Safety Board and continuing liason with the Office of the Secretary of the Department of Transportation. The DOT Action Group composed of representatives from all affected organizations in the Department has developed an eleven point program for grade crossing safety. Two of the points to be accomplished are particularly relevant:

- a more accurate national inventory of the grade crossing situation.
- improvement of accident data collection and enforcement.

The need for these have been adequately demonstrated in the present as well as in previous studies. The following sections deal with the method of acquiring the information and the attendant effort and costs of collecting the information.

Data Requirements and Flow

Before defining the level of effort required to establish and operate the inventory and information system the data to be collected need to be specified.

For each railroad crossing, the following list contains the basic data required to carry out meaningful benefit-cost studies to measure needs and to evaluate progress. Since past studies have been hampered by the lack of this information, the need for an information system capable of generating this data is obvious. The required data is given with a minimum of notation or explanation and is organized according to:

- physical features of a crossing
- train and motor vehicle data
- accident data

The data requirements vary according to the user. The list below is a general one; state and local governments are expected to have little need for much of certain portions of the data, while other portions would not be needed for federal programming. The following list outlines the total information requirements. Something short of this list will still provide useful information. A workable goal such as the following list may guide efforts to acquire a uniform information and inventory system.

Physical Features of a Crossing

- Location by Identification Number.
- Administrative Classification: State, County, Municipal, Federal Aid Primary, Federal Aid Secondary, Non-Federal Aid.
- Protection Type - This information should be in sufficient detail to include the precise location and types of the following installation:

- none (specify by notation)
- stop signs
- cross buck signs
- other passive signs
- advance warning signs
- flashing light signals
- cantilever flashing light signals
- wigwags
- automatic gates
- manual gates
- flagmen
- audible signals
- others (specify)
- circuit characteristics

• Railroad Tracks

  - number of main-line tracks
  - number of passing tracks (sometimes called sidings)
  - number of other tracks
  - use of other tracks

• Highway Data - Each highway approach should be considered separately, if necessary, to obtain the following data:

  - number of lanes
  - pavement width
  - shoulder widths and type
  - type of surface
  - divided or undivided
  - degree of access control
  - angle of crossing, (using uniform measuring techniques)

- safe approach speed, by quadrant
- stopped sight distance
- approach gradient
- pavement markings

- Crossing Length and Width
  - type of surface
  - condition of surface

- Adjacent Land Use Characteristics
  - industrial
  - commercial
  - residential
  - rural

- Motorist Distractions

- Illumination
  - at the crossing
  - near the crossing

Train and Motor Vehicle Data

The following information should be collected:

- Average number of railroad movements daily, scheduled and unscheduled, by time period (e. g., by hours of the day).

- Speed of trains
  - average speed
  - number daily under 70 miles per hour
  - number daily 70 miles per hour or over

- Average length of trains
- Average daily traffic of highway vehicles (ADT) by day and night periods
- Composition of ADT
  - autos
  - trucks
  - buses
  - proportion carrying hazardous materials
  - other
- Legal and average actual vehicle speed
  - speed profile

Accident Data

- Identify crossing by identification number
- Accident type
  - vehicle-train
  - no train involved
  - other
- Train, if involved
  - number involved (one or two or more)
  - speed
  - length
  - direction
  - type
    - . passenger
    - . freight
    - . switching
    - . work
  - light engine

- type of movement
  - . through
  - . standing
  - . backing
  - . switching
  - . leading unit not a locomotive
- location - train hit vehicle (or pedestrian or vehicle hit which part of train)
- relation to schedule
- extent of damage

- Vehicle, if involved
  - number of vehicle(s) (one, or two or more)
  - type of vehicle(s)
  - age of vehicle(s)
  - speed if in motion, whether stalled or stopped, if not in motion
  - defects
  - windows (up or down)
  - extent of damages
  - restraint equipment in place

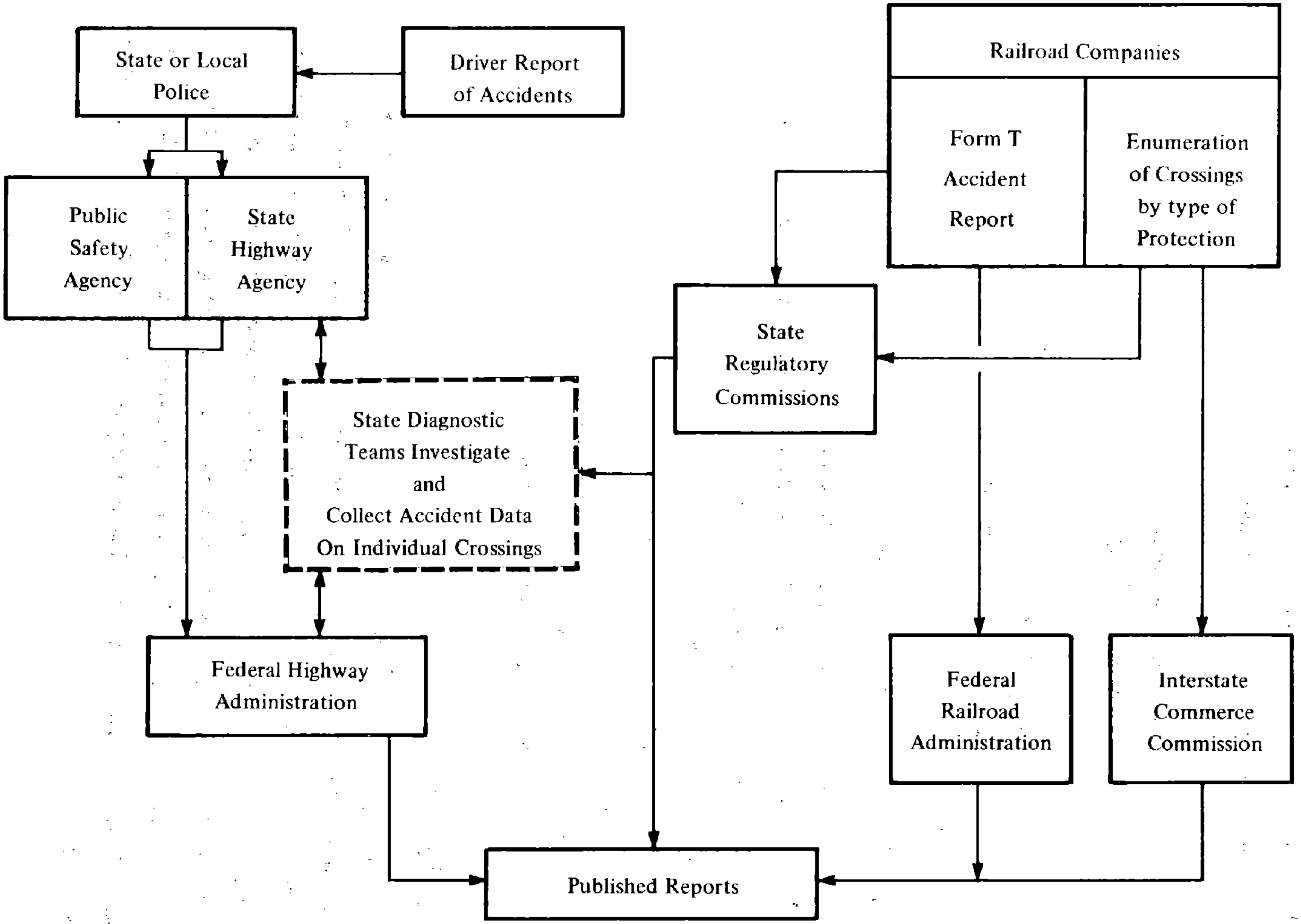
- Person(s)
  - driver(s) for each involved
    - . physical defects, if any
    - . prior accident experience
    - . alcohol content
    - . whether using restraint equipment
  - passengers and pedestrians
    - . number

- members of train crew injured
- for each person(s) involved
  - . age
  - . special circumstances
  - . fatigue factors, if any
  - . sex
  - . severity of injury
  - . number of days of work lost
  - . occupation

- Physical Circumstances
  - highway approach and quadrant
  - type and location of fixed objects, if involved, and costs of repairs or replacement
  - audible signals used
  - date and time of accident
  - weather
  - distracting elements
  - condition of protective device

Data Flow

The highway-rail grade crossing data presently available comes from several diverse sources. Figure 1 portrays the existing data flows. As seen in this figure there is a routine investigation of all accidents by the state or local police, depending upon the respective jurisdiction. These accidents are normally reported to the state highway agency or the state public safety agency. Not all accidents are reported, however, and it depends upon the particular arrangements in each state as to which ones are.



EXISTING ACCIDENT DATA FLOW

Figure 1

Grade crossing accidents in many states are not afforded special analysis. Several state agencies responsible for the collection and handling of grade crossing accident information restrict their summary reports to train-car collisions, not including those accidents which occur because of the existence of the crossing but which do not involve the presence of a train. A significant factor is this variance in reporting practices among states. Thus, as the data flows to the Federal Highway Administration, it is extremely difficult, if not presently impossible, to employ these sources for grade crossing accidents analysis.

State diagnostic teams, usually under guidance of the Federal Bureau of Public Roads, in several states make a conscientious effort to analyze the grade crossing environment for potential improvements. They gather much of the data suggested above for many crossings in their states, the crossing inventory being obtained from on-site investigations and the accident data from police records and special investigations. Although the information and results of analyses are passed on to the Federal Highway Administration, at present this source of information is not sufficient for national planning purposes because only a few states participate fully in the program. Also each state has different emphasis and coverage of crossings and each does not especially attempt to coordinate its activities with those prescribed by the Federal Highway Administration.

The railroad companies play an important role in the present information system. They enumerate grade crossings broadly by type of protection and report this information to the Interstate Commerce Commission. There is some duplication and possible omission of crossings, however, because of the complex nature of railroad operations and joint usage and ownership of trackage. This information is but a first step toward the completion of a grade crossing inventory.

Railroad companies submit grade crossing accident reports to the Federal Railroad Administration on report Form T and Supplement to Form T. While most states have adopted the Form T and Supplement for their own information purposes, some states require additional information from the railroad companies. Other states have adopted their own report forms, which may or may not require more information than the Federal Form T.

The "T-Form", though comprehensive in many respects, is deficient for grade crossing analysis for several reasons. First, the criteria for reporting a grade crossing accident on Form T are such that not all accidents are reportable. An accident is reportable only if one of three conditions hold: (a) an injury occurs which is disabling for more than twenty-four hours; (b) a fatality occurs; or (c) the property damage to track, equipment and roadbed is greater than $750. Thus, a train-car collision in which the car is totally destroyed and the driver is not injured is not reported on Form T if minor damage occurs to railroad equipment.

A reason the grade crossing accident data reported by railroad companies is deficient for planning purposes is that no cost figures are given for damages to non-railroad property. Also, the fact that many accidents result in liability suits or claims against the railroad companies hinders free disclosure of facts, particularly during the period immediately following the accident but sometimes even longer.

In summary, certain sources which have traditionally been involved with data collection have developed extensive data files, principally for their own uses. Given the lack of uniformity, the variability and the lack of control in the essential elements of the data collection process, it is clear that much of the inventory and accident data is incomplete, non-representative, and inaccessible for analysis to guide grade crossing investments.

Recommended Data Flow

As a means of providing a usable, reasonably complete information system, it is recommended that:

- a single, joint committee of the Federal Railroad Administration (FRA) and the Federal Highway Administration (FHWA) assume the responsibility for uniform data collection, and
- a thorough, uniform, consistent grade crossing inventory be accomplished.

At present the DOT Action Group is in the process of undertaking these recommendations. It is taking steps to structure a data collection system. It may recommend that the responsibility for data collection and processing be assigned to a single agency, perhaps in the Federal Highway Administration. Hopefully the following pages will assist in the speedy completion of the goal of a national grade crossing inventory and information system.

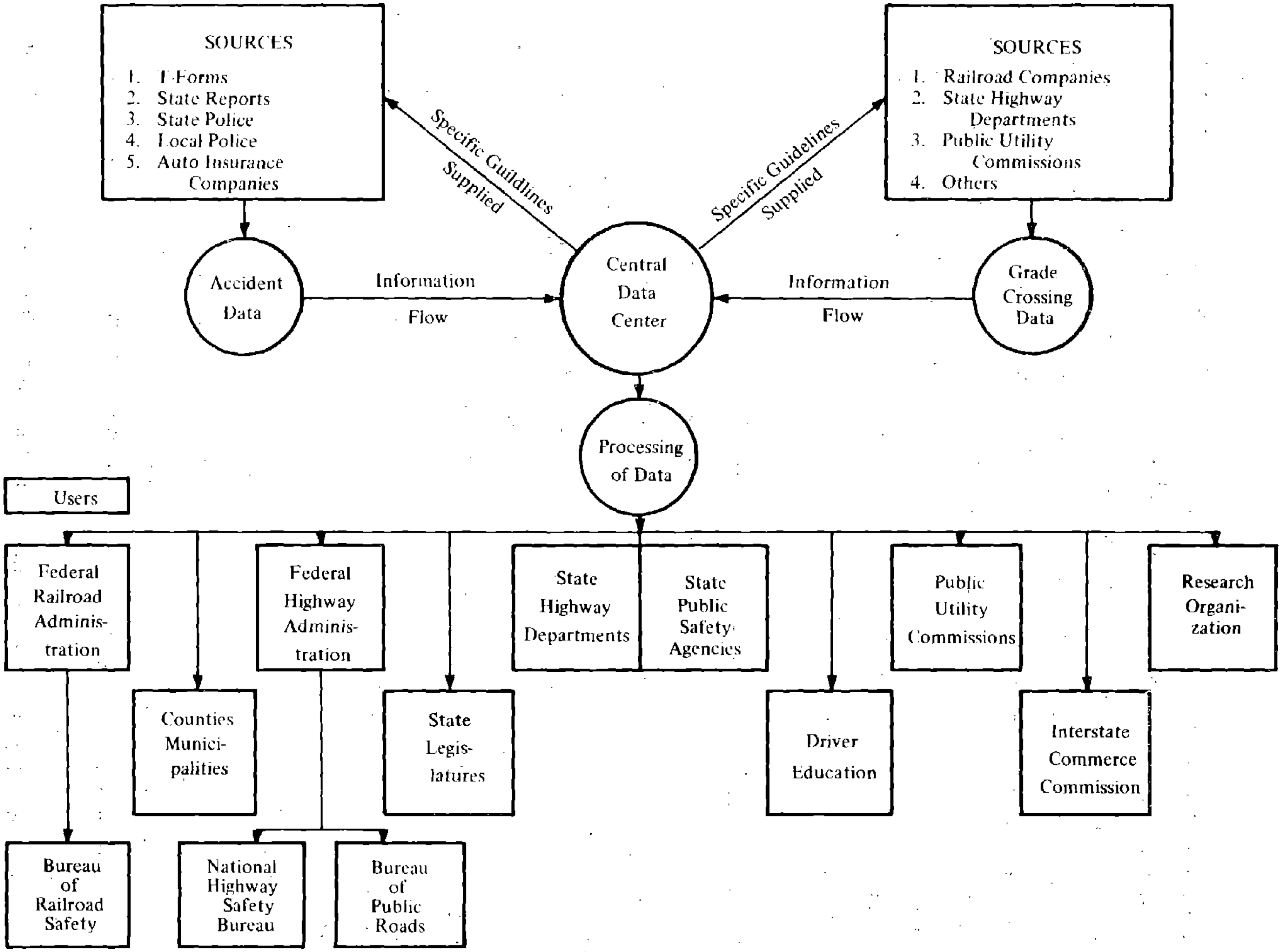
The two recommendations involve many corollaries. The first recommendation involves consideration of the flow of data and methods of data processing and dissemination, while the second involves the question of how the inventory is to be conducted. Both recommendations involve an expenditure. Estimates of the costs are given in the next section.

In the ultimate analysis, most states treat grade crossings on an individual basis and few have an overall program with clearly defined goals. A national program with general goals as established by a joint committee would be of great benefit for planning at the national level. Establishment of goals may also be of benefit to the states: though goals of states will differ even with the existence of national goals, their goals may be better defined in reference to the national goals.

Central Data Center

It is recommended that a standardized inventory of grade crossings be assembled and placed in a data storage system for easy retrieval. It is essential that the crossing inventory data be handled in a manner that will permit high speed direct correlation with accident records data, a vital link missing today. To accomplish these tasks, a central data center should be set up. The specific guidelines for the collection of grade crossing inventory and the accident data should be supplied by the data center. A procedure manual, developed by the joint committee, should insure the desired data qualities of a useful inventory system.

Such a system is diagrammed in Figure 2, with arrows showing the flow of guidelines and the subsequent information flow. The inventory and accident data are combined in one system. Such a system is presently being planned.



RECOMMENDED DATA FLOW

Figure 2

The National Highway Safety Bureau plans to develop a data center, and it is probable that this center will be able to satisfy all of the Department of Transportation's total data processing and handling requirements. It may take five or six years for the center to become completely operational. In the meantime, FRA and FHWA should begin the crossing inventory and accident data collection according to the data flow suggested in Figure 2. This effort should speed the completion of the data center and allow the economies of scale of the center to be reaped early for the grade crossing inventory.

Highway-Rail Grade Crossing Identification

This study has pointed out the need for a grade crossing identification system, whereby both train-involved and non-train-involved accident data may be corrolated with the physical features of a crossing. The crossing identification code should be able to (1) uniquely identify a crossing, (2) provide some general information useful for easy reference and (3) be acceptable to users of the system.

It is recommended that the following fourteen digit code be used for identification:

Digits	Reference
1 - 2	State
3 - 6	Railroad Line
7 - 11	Mile Post Designation
12 - 14	Highway Number

The first two digits refer to the 50 states, the District of Columbia and Puerto Rico.

The next four digits represent the railroad line. For major railroad systems the first two digits would identify the name of the railroad and the next two would identify a particular line. For smaller railroads the first three digits would identify the name and the fourth would identify a particular line.

The next five digits represents the mile post designation on the line to the nearest hundredth of a mile. The railroad lines are to be established from railroad hub to railroad hub, the originating hub to be designated. Then the mile post designation would correspond to the mile posts established along the railroad line and used on railroad valuation maps. In those few locations where mile post designations exceed 999 another line designation would be used to identify the additional mileage (a crossing on line 1 at M. P. 1004.56 would be designated 20456).

Many railroad companies presently employ some sort of mile post designation system. Their systems should be used to the extent it is feasible. However, such a system is not employed by all railroads; more than one railroad may operate on the same line; and some lines are owned by non-operating companies. Hence, it is necessary to design the system compatible with the railroad companies yet one that is complete. The name of the railroad company may be obtained by reference to a table look-up; it is not necessary and may be confusing to use initials or other letters as part of the identification number itself. The final three digits reference the highway. These three digits may be alphameric. They shall designate administrative classes of highways similar to the codes used for internal purposes by many state highway departments. The highway name and number (as it appears on maps and roadside signs)may be obtained by looking it up in a table. Actually, the eleven digits used above will uniquely identify the grade crossing, but the highway number is important for easy reference to the appropriate highway system. Also, the three digits reserved for the highway code serve as an internal check of consistency for the identification number.

It is essential that this identification number or one similar be established in the near future and with wide coverage, because very much of the future development in the analysis of grade crossing safety depends upon its establishment.

Cost of Collecting Data

There are approximately 225,000 crossings in the nation; it is estimated that only 36 percent of those crossings have a complete inventory. There is partial data available at the remaining crossings. The Bureau of Public Roads has obtained information on the number of states with complete and partial inventories of crossings, and their inventory forms. We need two definitions as the basis for estimates of the cost of collecting the inventory data.

- The term complete inventory is defined for those crossings which have most of the required data. The extent of this data may need to be refined, e.g., in supplying a uniform method for the identification of the crossing, etc.
- The term partial inventory of crossings is defined for those crossings which have only a part of the required data. This partial inventory of the crossings is different in different states depending upon the user requirements.

For the purpose of cost estimation, the partial inventories are condensed into complete inventory equivalents. Ten states have a complete inventory of crossings conducted by their highway departments. Three states have a complete inventory for all but their urban crossings (outside the jurisdiction of the state investigators) which are estimated at 25 percent of their crossings. Eleven states have a complete inventory of 25 percent of the crossings, supplied by Public Utility Commissions. Finally, 25 states have a 20 percent complete crossing inventory (or its equivalent) as supplied by railroad companies. We base the cost estimates upon these 48 states.

It is estimated that to obtain the complete inventory for a single crossing that presently does not have one, it costs approximately $44, and that it will cost $20 per crossing to collect the data for those crossings that already have a complete inventory. These costs are primarily labor costs to visit the sites. The total cost of the initial inventory is estimated at $7.6 million. (Who is to pay this cost is a matter for the respective agencies to decide.)

It may not be necessary, however, to thoroughly inventory each and every crossing. Rather as a suggestion, all crossings should be counted and categorized, but only a sample of them need to be examined in detail. The size of the sample will determine both the cost of the inventory and the reliability of the data. Due to the high cost of constructing and maintaining a complete inventory, the sampling approach should be investigated before the inventory is begun. The appropriate sampling techniques need to be specified.

Keeping the inventory up to date may require annual or other periodic reporting of significant changes by the several agencies responsible for this information.

Cost of Additional Information on Grade Crossing Accidents

The most appropriate way of filling gaps in the accident data is to obtain the collaboration of the various sources; e.g., the state and local agencies. With some changes in their data processing, insurance companies might be able to furnish data on non-railroad property losses. But in our calculations below we have taken the present practices of the insurance industry as fixed, with little or no input into the information system, at least for the near future. The cost comes from organizing the existing data sources, given a workable crossing identification system.

Given the compilation of other crossing data defined above, the first cost is to collect and process the data from each of the diverse sources. For a central computer, one fortran statement (a statement which tells the computer how to read the data) should suffice for the description of a crossing accident. In the data processing industry, a fortran statement costs between ten and fifteen dollars. The computation cost of crossing accidents would be somewhere between \$37,000 and \$56,000.

Obtaining the accident cost to non-railroad property would probably double the previous figure, making the total cost for data processing approximately \$100,000.

The third and most essential part is the coordination of all reporting efforts, prior to data processing. In our judgment this task should require initially one man-year for every five states. At a cost of \$10,000 per man-year, this would produce a figure of \$100,000.

The total cost of crossing-accident information is then expected to be around \$200,000. This figure represents the initial costs to establish the accident inventory system. The recurring costs should be less, but how much less depends upon the success of the initial effort.

Inventory Design Concepts - Objectives

For efficient and economical system development, the following requirements must be satisfied:

- maximum capability in responding to the system user.
- capability of handling large volumes of input data.
- minimum number of files and storage volumes.
- standardization of data formats.
- quantitative analysis of data accuracies.
- generalized multipurpose programming system.

System development encompasses the design of the Highway-Rail Grade crossing inventory file and the design of the programming system at the federal level. There are certain states which have the data facilities available and thus have the option to process the data themselves with the guidance from the Central Data Center. The Federal computer programming system should accept the information from all the available sources of data. As the data come into the system, they will be manipulated by a set of computer programs. These programs will standardize the data format and edit the data for consistency and reliability. Data processed through a set of compiler programs is supplied to all the various user agencies.

Program Design Specification

To satisfy the requirements of the users, three main types of programs will be required:

- data file maintenance program
- retrieval program
- report program

Each of these types of programs is discussed on a systems level.

The maintenance program system will serve three functions:

- control of the specific routines required in the file maintenance operation.
- file creation
- file updating

The control function of the program will be performed by analysis of an input parameter card. This analysis will determine the type of data being processed, the specific manipulation required, and the proper program routines to handle these tasks. In addition to making this determination, the control section of the program will call in the particular routines required and maintain an effective flow through the entire system. The input to the program will be in the form of punched cards or magnetic tape. The output will be a corrected data base on magnetic tape or whatever storage device is decided. For file maintenance, the storage media containing the current data base will also be an input to the program.

Editing and error checking will be performed to ensure that only valid records or data are entered into the data base. A listing will be provided of all records or data found to be in error. When file maintenance is being performed, printouts will be made to indicate the following changes:

- for additions of a new record, the entire record will be printed.
- for the correction of a field, both the old and new contents of the field will be printed.
- for the deletion of a field or record, the deleted portions will be printed.
- for all actions, a listing of the input parameters will be provided.

The inputs to the data file maintenance programs are as follows: the header (parameter) card which indicates the type of action to be taken and the card types that contain the grade-crossing accident and cost information. A unique identification code will be associated with the records on the file. This code has been discussed above.

Outputs of the program will include control and error printouts. The error and control listings will be made to provide a visual indication of all actions against the file as well as the necessary information for error corrections. The updated master file will be in the same format as that of the input master file. A new master file will always be an output of the maintenance program.

The retrieval programs will answer special-purpose requests of data from the data base (i. e., those requests which cannot be practically satisfied by use of the standard reports produced from the file.) The program must have the capabilities of reading request cards, performing the functions required to edit these requests, searching the master file for those records which satisfy the criteria, and generating an answer tape. The answer tape will be input to the report programs.

The report program system will be utilized to produce the catalogues of the data base and the special reports generated in response to retrieval requests. These programs will select the desired data fields to be printed and control the output format. For each separate type of output format, a different program is needed. The programs should be written in a standard report programming type language. They will be maintained on a library tape and will be utilized under control of a simple executive control program. The input to the program will consist of parameter cards and the previously defined file records. The parameter card will contain the program request number, setup information and other needed elements. The executive routine will allow more than one report to be run at one time.

Software Requirements

Three general points may be made in reference to software:

- There must be language and equipment compatibility across the present computing systems and any proposed computer configuration.
- Programs must be written for independent utilization of component parts as well as utilization within an integrated system.

- A modular approach to software development is essential. This last requirement results in a minimum amount of software modification when additional requirements are imposed on the system.

Summary

A unified, comprehensive grade crossing inventory can be developed using the existing data flow as a point of beginning. Complete accident information may be combined with the proposed inventory information of crossings to provide a solid basis for decisions to invest in grade crossing safety installations. It is estimated that a complete inventory system would cost $7.6 million to establish and, given that, $200,000 would be required to obtain the relevant accident data from all the existing sources.

Some type of inventory system should be accomplished. A joint effort of FRA and FHWA vested in a single authority (most likely one of the two agencies) would be the most effective means of accomplishing the type of inventory system envisioned. Since decisions are, among other things, a function of the quality and availability of information, the capability to provide timely, accurate information will directly affect the quality of these decisions.

CHAPTER VII
PROGRAM DEFINITION

INTRODUCTION

The future program recommended as a result of the analysis of the present program consists of five major components. They are:

- Inventories and Usage
- Economics of Grade Crossing Improvements
- Financing Grade Crossing Improvements
- Research and Development for Grade Crossing Protection
- Demonstration Projects

The following describe the objectives of each program and lists the projects which comprise the program. Projects are classified as short- and long-term with more detailed descriptions for the early projects. (See Table 22 for the summary tabulation with fiscal year expenditures.)

PROGRAM GOALS

The program goals are developed for the next five-year period (fiscal years 1970, 1971, 1972, 1973 and 1974). They are not listed in priority order since they are regarded as equal.

- Reduce grade crossing accidents by 25 percent. This is in keeping with a long-range goal of reducing accidents by fifty percent.
- Develop devices for the reduction of accidents at rail-highway grade crossings with low vehicle and train volumes.

TABLE 22

ESTIMATED PROJECT COSTS (IN THOUSANDS) FOR EACH YEAR

PROGRAMS AND PROJECTS	1969	1970	1971	1972	1973	1974	BEYOND
	FISCAL YEARS						
INVENTORIES AND USAGE							
Upgrading the Estimate		25	5	5	5	5	
Functional Classification of Railroads		25					
Uniform Inventory Procedures			30				
Re-inventory Crossings				FHWA	FHWA	FHWA	FHWA
ECONOMICS OF GRADE CROSSINGS AND SEPARATIONS							
Economics of Grade Crossing Devices		40					
Computer Programs			20				
Inventory Data Research			50	25	25	25	
Economics of Grade Separation				70	70		
Systems Approach to Grade Crossing Imp.				80			
Economics of Signal Actuating Devices					35		
RESEARCH AND DEVELOPMENT							
Models of Dynamics of Grade Crossings	FHWA	FHWA	FHWA	FHWA	FHWA	FHWA	FHWA
Human Factors			275	300	300		
More Effective Treatment of Low Hazard Crossings							
Sign Testing	FHWA	FHWA	FHWA	FHWA	FHWA	FHWA	FHWA
Audibility and Visibility		100	50				
Sight Distance		25	60				
Detection Equipment		50	100	150	200	200	
New Low Cost Devices		10	100	100			
CAPITAL IMPROVEMENTS							
Federal Aid Systems	FHWA	FHWA	FHWA	FHWA	FHWA	FHWA	
Non-Federal Aid Systems		50,000	50,000	50,000	50,000	50,000	
Demonstration Projects		20,000	20,000	20,000	20,000	20,000	

- Complete an accurate inventory record of all grade crossings, record of accidents at grade crossings and summary of costs for use in policy formulation.
- Generate improved cost and benefit information as a basis for selecting improvement projects of merit (by Fiscal 1971).
- Emphasize improvements at all crossings with two or more mainline tracks.
- Conduct demonstration projects in selected communities with the objective of eliminating unnecessary crossings and providing protection for all crossings which are allowed to remain.

INVENTORIES AND USAGE

Objectives

The objective of this program is to establish an accurate, comprehensive base of information which describes the physical location and character of rail-highway crossings.

Although inventories are now available for crossings on the Federal Aid System, only partial information is available for those on local roads and streets where 80 percent of the total are located. The type of crossing, the type of highway in both functional and administrative terms and the type of railroad should be known. The number of railroad movements and the volume of vehicle traffic over each crossing are essential items.

Purpose

The purpose is to provide information for planning and for measuring progress over the years. This information is needed at all administrative levels, local, state and federal. It must be uniform in content and coverage. While the collection and updating is properly a local or state responsibility, there is also a substantial federal interest, and in the interest of uniform definitions and methods, there should be a federal contribution to the program.

One of the ingredients of the inventory is the classification of railroads by function. No fixed procedure has been developed for classifying railroad lines; therefore, an early project in this program would establish such a method.

The specific projects included in this are:

Closing the Estimate

The objective of this project is to develop the best possible information on grade crossing inventory for interim planning purposes. The Bureau of Public Roads has obtained from most highway departments inventories or estimates of the number of crossings by administrative system. These would be collected and the actual inventory information would be put into a common format for tabulation in the manner developed in this Program Analysis. As new inventories become available, they could be added to the base data. Estimates could be made of the number of crossings not fully inventoried and by this technique more precise information could be used for planning purposes. The individual tasks are as follows:

Task 1 - Assemble inventory data from individual State Highway Departments.

Task 2 - Reformat all information to a common base.

Task 3 - Develop expansion factors using the best available estimates of control totals for the number of crossings on different systems, in urban and rural areas and with different types of protection.

Task 4 - Expand the sample and tabulate by crossing characteristics and systems.

Task 5 - Make revised estimates of the number of crossings warranting improvement.

Task 6 - Update each six months as new estimates, inventories and reports of changes become available.

Tasks one through five are estimated to cost $25, 000. Task six is estimated to cost $5, 000 per year.

Methods for Functional Classification of Railroads

The objective of this project is to develop a method for describing railroad lines according to the function they serve. The reason for doing this is to determine whether there are specific systems where grade crossing improvements would produce significant benefits in terms of increased operational efficiency. A companion study on railroad operating costs would provide cost information which could be used to estimate potential benefits.

This project should be undertaken jointly with the operating railroad companies. The tasks involved are:

Task 1 - Develop alternative descriptions of functional types.

Task 2 - Take selected examples of railroad lines and apply the definitions as a test to determine their appropriateness.

Task 3 - Select the most appropriate definitions and test them by attempting to classify rail lines from data regularly submitted by the railroad companies in reports to state and federal regulatory commissions.

Task 4 - Describe the changes in reports which would be required to make and update classified inventories of the railroad system.

Task 5 - Select the best classification system and develop a manual of definitions and methods for its application.

The cost of this project should not be very large, depending on the degree of participation by the railroad operating companies. The use of an advisory committee to guide the study, provide example material and estimates should not involve additional costs. Total cost is estimated to be $25,000.

Uniform Inventory Procedures

The Problem. - Recent rail-highway grade crossing inventories by several states have revealed significant differences from the number of crossings thought to exist there. The number of crossings by type of protection and type of road is essential for planning, for measuring changes in conditions, and for determining performance.

Inventories are essentially state and local functions. However, uniformity of data or compatibility, as a minimum, is necessary for national statistics.

The project would develop procedures for making uniform inventories and for converting existing inventories to a uniform format.

Project Objectives. - The objectives of this project are:

- To develop methods of uniform inventories of rail highway grade crossings in all states.
- To develop a method for uniquely identifying every rail-highway grade crossing.
- To prepare an inventory manual for use by states, cities, counties, and rail operating company personnel describing the techniques.

Related Activities. - This project is part of a coordinated program for securing comprehensive accurate inventory information. Other projects in the program include the functional classification of highways and completion of all inventories. Reporting of grade crossings by the railroad operating companies also provide information which is valuable in verifying and updating inventory information.

Task Description

Following are the tasks which will be required:

- Develop a grade crossing identification system.
- Analyze existing inventory data and identify inconsistencies and gaps in data. Two of these are in the definition of sight distance and the manner of recording it.

- Develop new procedures to correct inconsistencies.
- Develop procedures to collect missing information.
- Develop procedures for field identification of crossings in accordance with Task 1 above.
- Develop up-date methods to maintain inventories.
- Prepare an inventory manual for use by all jurisdictions for the purpose of up-dating all inventories.
- Prepare estimates of the cost for collecting and up-dating inventory data. These estimates should take into account the existing status of inventories in various states and should identify the expenditures required by states, counties and cities.

The estimated cost of this project is $30,000.

THE ECONOMICS OF GRADE CROSSINGS

Economics of Grade Crossing Protective Devices

The Problem. - Lack of much site-specific information, wide-spread misunderstanding of the elements involved, and the absence of information regarding techniques of economic analysis have all obstructed effective research in the economics of protective devices. It is hoped that the present study is a step in the right direction regarding the techniques of analysis, and that an on-going inventory system may provide the much-needed site-specific accident and environmental information. If the inventory system is to be useful, the on-going research is needed.

Objectives. - The purpose of this project is to accumulate and use more reliable data for all elements of grade crossing operation and improvement, and to refine the techniques of economic analysis to this particular application.

For the inventory research, the data should be examined in its disaggregated form, by states and regions, since this disaggregation will supply vital information. Before the inventory data is gathered, however, a computer program should be constructed that will process the data and examine the warrants and priorities in this disaggregated form.

Related Efforts. - There have been several studies on the economics of grade crossings, and each one, including the present study, does not pretend to be "the" definitive study. This study has pointed out that perhaps the Poisson model should be carried to its logical conclusion as a method of predicting accidents at grade crossings, but it may not be worthwhile to do this until more accident and crossing inventory data becomes available. The methods of analysis of previous studies, as indicated in the text, are open to question and/or refinement.

Components and Outputs of the Study. - The study may be conveniently divided into three components, model development, computer programming and inventory data research.

- Model Development - The specification of a model of how the data is to be utilized and the relationships among variables required to derive warrants and priorities, on a disaggregated basis, must be spelled out so that when the data becomes available, the data processing will not create a crisis situation. The model development may include an investigation into alternative forms of the accident prediction equations, either by using existing data or by formulating hypotheses to be tested by the inventory data, or both.

  The output of the model is a plan to utilize the expected inventory data. The plan should be computerized.

- Computer Program - The computer program should be developed and tested on simulated data in anticipation of the large amount of data processing involved using the expected inventory data. The program should translate the data from each of the various sources and display it in convenient, summary fashion for executive review, as well as converting the data into proper form for the necessary research.

- Inventory Data Research - A necessary adjunct to the implementation of the information system is the establishment of an on-going research effort to make use of the new information as it is generated. It may be on-going only in the sense of an annual exercise when new annual data becomes available. With an efficient and encompassing information system, it is envisioned that this task could and should begin with the very first set of data obtained. The research is expected to interact with the information system to assist in the logical evolution of the information system.

Phasing. - The model development is a task for the short-run, as well as the computer programming, so that full advantage of the inventory system may be had. The inventory data research is, of course, intermediate and long-range in scope.

Effort. - The following are estimates of the man-months of effort envisioned for the three separate tasks:

- Model Development, 10-13 man-months, depending upon the scope;

- Computer Programming and Testing: 3-5 man-months;

- Inventory Data Research: Initial research with first batch of data, 10-13 man-months; on-going research, one-man, one-half time, being seasonal.

The Economics of Grade Separation

The Problem. - This study is to determine those conditions under which grade separations are economically justified. The conditions should be shown with concrete examples, or demonstration projects, such as in the Northeast Corridor. It may be relevant to examine the British and the Japanese experience.

The study should account for the following benefits and costs:

- Accident Costs - The accident costs at structures need to be compared with the accident costs at grade crossings with the next best alternative protective device.
- Delay Costs - Grade separations eliminate delay entirely. This should be compared with the next best alternative, so the delay costs for the next best alternative must be calculated. These delay costs include both motor vehicle operation costs and driver delays, when either stopping for a train or slowing at the crossing. In special locations, such as switching yards, the delay to the train may also be a factor.
- Operating Costs - Grade separations normally have a highway gradient which causes excess costs for the vehicle as opposed to a flat grade. These costs must be compared with the vehicle operating costs of slowing at the crossing if it were protected with active or passive devices.
- Costs of Separations - Because of the wide range of costs of constructing grade separations - ranging from $200, 000 to over $2 million - an explanation of the variance is necessary to avoid applying average figures to crossing situations when the average figures have little significance. For instance, an urban versus a rural location, topographical condition, and the railroad and

highway functional use would vitally affect meaningful estimates of grade separation costs.

- Land Development - It is very likely that even though grade separations may occupy more land than other protective devices, they may increase the number of alternative uses of land in the neighborhood, thus possibly producing a positive net benefit. The magnitude of this benefit should be estimated.

Objective of the Study. - This study has as its objective the compilation of a comprehensive fact book that will be useful for planning investments for grade separations. The situations under which grade separations are warranted will be made explicit in parameter form, so that judgments as to warrants may be made site-specific, with the parameters varying due to differences in measurements and costs of the various sites.

Related Efforts. - A study on the economics of grade separation appears necessary because of the inadequate treatment given to it in the literature. Also, there has been a systems approach.

The Newnan study,[1/] which is one of the few studies on the economics of grade separation, concluded that grade separations are usually not economically justified. This conclusion may be challenged upon a number of grounds, but perhaps the most cogent is that it shows grade separations to be uneconomical for the average crossing. But it is the above average crossing, with high average daily vehicle and train

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[1/] Newnan, Donald G., An Economic Analysis of Railway Grade Crossings on the California State Highway System, Stanford University, Report EEP-16, June 1965.

traffic, at which one would expect the benefits to approach or exceed the costs of grade separations. For the research of grade separation economics, the appropriate question that should be answered is, what are the conditions under which grade separations are economically justified.

The Tirrell study,[1] although focusing explicitly on grade separations, was confined to one crossing situation. Also, this study may be questionable on a number of methodological considerations. It represents, however, a pioneering attempt to employ the kinds of factors relevant for the grade separation decision.

One study indicated that accidents on bridges are extremely high as compared to other sections of the highway.[2] This hypothesis should be investigated in a systematic and thorough way, since that study focused on but a few bridges in the State of Ohio, and may have dealt with only those of rather narrow width.

Users of the Fact Book. - It is envisioned that the fact book will be capable of indicating whether separations are warranted on an individual basis. Thus, the parameters must be inclusive enough to allow any specific site to be evaluated. Anyone contemplating construction of a separation, then, should be able to use this fact book. Members of the Federal Railroad Administration, the Highway Research Board, or state regulatory agencies may employ this fact book as they deem fit.

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[1] Op. Cit.

[2] See Harold Keiser, "Traffic Accidents on Highway Bridges on Rural State Highways in Ohio," Highway Engineering Conference, Ohio State University, Proceedings 10, November 1956, pp. 119-24.

Tasks and Required Effort. -- The following are the basic components, or substudies, that appear to be required:

- Task 1 - Develop accident cost data pertaining to grade separations. Expected level of effort: 3 to 6 man-months.
- Task 2 - Examine the costs of separations, using either engineering data or a study of past bids to derive those conditions which cause the costs to vary. Expected effort: 4-6 man-months.
- Task 3 - Development of shipping impacts for highway users of a change in speed (or delay). This entails following the recommendations given in Chapter V. Expected effort: 4-5 man-months.
- Task 4 - A land development study to find the net value of neighboring land as changed by a grade separation structure. Expected effort: 5-8 man-months.
- Task 5 - Development of the Fact Book for individual grade crossings, with examples. Expected effort: 8-9 man-months.

Systems Approach to Grade Crossing Improvements

A systems approach analyzes the economics of grade crossing improvements for a system of crossings along a given railroad line. It examines the potential benefits and costs of improving, possibly closing, crossings in the system.

An example would be a railroad line passing through a small town, where there are three crossings, each presently protected by crossbucks. Each crossing may be considered to be in need of improvement, but the cost of effective improvement is not justified by the estimated benefits at one crossing alone. However, some improvements may be warranted when all three are considered together. Assume that the crossings are close together, and that a suggested systems approach is to close two crossings and improve the remaining one, for example, by installing automatic gates or a grade separation. In such a case the delay and motor vehicle operation costs may be increased slightly, but there may also be a reduction in the number of grade crossing accidents because traffic is now traveling through the protected crossing. With a separation, the total delay time may even be reduced. Further, benefits may accrue to the railroad in the form of an increased legal operating speed or increased operational freedom. All these benefits may justify the improvement to the one crossing. The basic problem, as brought out by this illustration, is to specify the costs and benefits. A set of guides should be developed, specifying details of the following items:

- The expected delay patterns for motor vehicles and their consequent costs.
- The reduction in accidents and their costs.
- The changes in land value resulting from grade separation and closing crossings.
- The benefits accruing to the railroad.

These four items become the tasks, then, in the systems approach. It is estimated that the effort for the first task may range from 3 to 5 man-months; the second, 2 to 4 man-months; the third, 3 to 5 man-months; and for the latter, 10 to 12 man-months. The fourth task is difficult, since it must encompass all the steps noted in Appendix B.

The successful application of the systems approach requires the demonstration that the results achieved by analyzing a systems of crossings cannot be achieved by analyzing each crossing separately. Only then may local jurisdictions be willing to close one or a few crossings for the sake of overall improvement. It must be made clear, in applying this approach, that the entire system is to be completed as planned; otherwise, the improvements are not warranted and should not be initiated (based upon the economic considerations), and agreements may have to be made to that effect before initiation of the changes. If non-economic factors are to interfere, and possibly dominate, the systems approach based upon economics alone should not be undertaken for a given locale.

Economics of Signal Actuating Devices

Signal actuating devices control the operation of automatic gates and flashing light signals at grade crossings upon the approach of a train. Rather than having the crossing protective device activated only when the train is at a single, fixed distance from the crossing, as is typically the case today, automatic predictor devices account for the speed of the train and the distance of the train from the crossing, and start the protective devices at a reasonably uniform time in advance of the train movement over the crossing, regardless of the speed of the train so that while adequate advance warning is given, total motor vehicle delay time is reduced. Other types of circuitry controls may be installed to prevent unnecessary signal operation during switching movements or similar train activity not constituting straight through movements.

The problem is to determine the conditions under which these control devices are warranted. The solution to this problem involves two factors: consideration of the desirability of maintaining the integrity of the protective installations by eliminating the motorists disregard for its warnings when they are frequently false; and the economic considerations of the costs of the devices and the value of the delay time of motorists. The problem is to determine, first, whether any of the more sophisticated devices are economically warranted over the standard actuating device and, second, if so, which one is warranted under which conditions.

The study would investigate the rather special circumstances of crossings at or near switching yards and industrial plants and at junctions of spur and mainline tracks. The study will require special data on possible delay patterns, perhaps obtained by physical measurements and observations taken from a sample of actual locations.

Expected effort: 5-9 man-months.

RESEARCH AND DEVELOPMENT

Long Term Basic Studies Program

The purpose of this program is to develop basic principles about behavior at rail-highway grade crossings. The results of the studies will be used in five to ten years to provide solutions which cannot now be foreseen. There are two important sub-programs.

Models of the Dynamics of Crossing Conflicts. - This work is already underway in the Federal Highway Administration and should be continued. Costs and schedules for the work were not developed in this study but are available from the Bureau of Public Roads.

The purpose of that program is the development of a model of the crossing situations so that any crossing can be studied in detail and changes in certain factors can be readily evaluated. This will permit much greater flexibility in approaches and the pre-testing of alternative solutions once the model is fully operational.

Studies of Human Factors Related to the Operation of Motor Vehicles Across Rail-Highway Crossings. - The purpose of this program is to develop facts with respect to the behavior, capabilities and limitations of drivers. The program will consist of:

- A study design to develop precise study plans for each of the following.
- A study of driver vision, surveillance and monitoring.
- A study of driver response times and accuracy of perception of complex problems.
- A study of driver solutions to the impending conflict problems.

A total of five years should be allowed for completion of this program with $1,000,000 allotted for funding. Initial funding of $75,000 in fiscal 1970 for the study design will be required. The results of that study may result in upward or downward revision of the total funds required and will provide fiscal year allocations for the total program.

Near Term, Early Payoff Projects

The purpose of this program is to develop early solutions to some of the more critical problems with high probability of early results, particularly with respect to the reduction of accidents.

Improved Devices for Lower Priority Crossings. - The purpose of this program is to improve old, or develop new, devices for crossings with low train-vehicle volumes. These seem to constitute about 70 percent of all the crossings in the country and are the scene of about 25 percent of all the accidents. Conventional devices such as flashing lights and automatic gates are too costly for such crossings. Therefore, less costly devices must be developed.

The total program consists of three projects:

- Testing Alternative Signs and Passive (Non-automatic) Devices - The purpose of this project is to determine the effectiveness of new signs which give more precise and explicit information about rail-highway grade crossings. Some of this testing is already underway and is being done by State Highway Departments in corporation with the Bureau of Public Roads. The program should be continued and carefully monitored to assure reporting of results.

- Improving the Audibility and Visibility of Trains - The purpose of this project is to develop realistic measures of the visibility and audibility of trains and to develop ways to improve those characteristics. The project is already underway with fiscal year 1969 funds.

- Investigating the Effect of Sight Distance at Rail-Highway Grade Crossings - The purpose of this project is to determine the effect of sight distance on accidents. Previous studies have been hampered by the lack of appropriate information on sight distance. This study would collect specific information and through the use of time-space relationships like those developed in Report NCHRP

50 develop safe approach speeds for highway vehicles. Based on these factors and the historical accident records of selected crossings, the relationship between sight distance and frequency of accident occurrence would be developed.

The results of this study would be used to specify inventory procedures and to determine the costs which are warranted for the removal of sight obstructions. The study is closely related to the project on audibility and visibility.

CAPITAL IMPROVEMENTS

It was estimated that there are over 30,000 existing crossings where improvements would produce benefits in excess of costs. Many of these crossings could be financed from current federal aid apportionments but those on roads and streets not eligible for federal aid must be financed from current local and private sources. This recommended program would make federal funds available for such improvements. The need is not limited to existing crossings. New crossings are required due to the construction of new roads and streets and to relocations of old roads. Past expenditures of federal aid funds were often related to such new needs.

The recommended level of funding is \$50 million per year. This amount with modest local and private matching would provide about \$300 million dollars over the next five years. This together with federal aid highway funds should be adequate to meet most of the urgent needs.

URBAN DEMONSTRATION PROJECTS

The purpose of this recommended program is to undertake significant improvement projects which include grade separation of major crossings, automatic gates and flashing light signals and crossing closures to produce benefits in train and motor vehicle operation, as well as accident reductions.

These projects would essentially be applied to rail lines through a city or a defined corridor through an urbanized area.

They would include data collection and evaluation to determine the actual costs and benefits realized. The amount of funds which could be productively spent for such projects is difficult to estimate. However, assuming that several should be undertaken to cover different types of situations and that a single grade separation might cost $1, 000, 000 or more, it is estimated that up to $20, 000, 000 could be spent annually for this purpose.

The projects should probably be on a scale of five to ten million dollars each to have significant impact on an area.

Each project should include some closing of crossings and the analysis of the project should include the techniques used to close and keep them closed. Guarantees that no new grade crossings will be opened nor old ones re-opened must be obtained to assure that anticipated benefits will, in fact, be realized.

APPENDIX A

GRADE CROSSING ACCIDENT FACTORS

A. INTRODUCTION

1. Accident Environment

Accidents are an inherent danger of the highway-rail grade crossing environment. The various grade crossing safety installations have as their major purpose a decrease in the number of accidents as well as a possible reduction in their severity. This appendix derives the accident cost factors employed in the present study and suggests future developments in improving the prediction of such costs.

It may be useful in an analysis of how to effectively prevent accidents to establish a separate category for the train-involved accidents and for the non-train-involved accidents, because different means of preventing each type of accident may then be tried and tested separately for their effectiveness. For the purposes of this study, we shall first derive an average cost per train-involved accident and an average cost per non-train-involved accident, and then examine for each of these categories how the frequency of accidents varies over the different types of safety installations. Combining these two gives accident costs at particular types of crossings having various protective devices, a major component in determining warrants and priorities.

Ideally, the cost data on grade crossing accidents should come from grade crossing accident experience, not from observations of highway accidents in general. However, the generation of the ideal data remains to be accomplished by an on-going information system for grade crossings, since the data presently available is scanty and reliance has been placed, to some extent, on highway accident experience.

2. Monetary Evaluation

The accidents prevented by safety installations are benefits that should properly be evaluated in monetary terms. If not, then there remains an unavoidable ambiguity as to which installation for a given crossing is warranted or most cost effective, since the various effectiveness measures, such as the reduction in the number of persons killed, the reduction in the number injured, and the reduction of accidents at crossings, cannot be related to one another by a common denominator. Money value is an appropriate common denominator. Unfortunately, some values are not as accurate as we would like them to be, and there remains an ambiguity as to which value to assume for the value of life, for instance, or for pain and suffering. However, by using the latest theoretical and empirical developments, we may, in a sense, approximate these values. Furthermore, we may test the sensitivity of the results to changes in these values. This should be done at a later date.

3. Definitions and Components

Most of the previous studies[1/] consider cost of accidents in two groups: direct and indirect costs. According to a 1949 formula of the Highway Research Board, direct costs are defined as the sum of damage to property, medical and legal expenses, and the value of work time lost.

1/ See, for example, Department of Public Works & Buildings, State of Illinois, "Cost of Motor Vehicle Accidents to Illinois Motorists," and R. N. Smith and T. N. Tamburri, "Direct Costs of California State Highway Accidents," Traffic Department, State of California.

The main item which constitutes indirect costs is the expected earnings of persons permanently eliminated from the labor force because of death or total disability.

Most of the indirect or external costs of an accident are intangible in character. Human suffering involved is the salient example. Time lost by the users of railway and highway at the time of an accident can also be included in this category. Some attempts in the wrong direction have been made to measure these intangible costs. For example, a number of studies include in their computation compensations and damages awarded by the courts, which are very inaccurate measures of the psychological suffering involved. In most cases, the payments amount to pure transfers from one individual to another, and their inclusion in the cost of society is an exaggeration. It is very conceivable that the legally responsible party suffers psychologically as much as the innocent!

There is no substantive way to assign dollar values to pain and suffering; hence, it was left out of our analysis. The value of life, however, may be measured economically to provide a minimum value to the loss of a human being. We are leaving out of our analysis the cost of time delay when an accident occurs, because we have only fragmentary evidence on it at this time, but this should be included at a later date.

The components or categories of accident costs that we shall use are work time lost (because of permanent disability or because of death), medical and hospital costs, property damages, [1/] and the administration expenses of accident insurance. The latter is included because any amount paid to

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[1/] We have not accounted for damages to the protective devices at the crossings, but this should be developed in the future.

insurance companies in excess of the loss of traffic accidents is a diversion of administrative talent, which is directly attributable to the accident environment.

B. COST PER ACCIDENT

1. Economic Value of Life

Numerous studies have estimated the economic value of life under a diversity of concepts. It is not the purpose of this study to reconcile all the concepts that have been used to obtain the diversity of estimates presently in existence. We shall select and apply one such concept which we feel is realistic and defensible. Other researchers may substitute other values, if desired.

It is important that some finite value be assigned to life. If it is decided not to incorporate the value of life in the benefit-cost calculations, then the investment decisions thus obtained may very well be different from decisions obtained while using a value of life. Since all benefits are not accounted for and the value of life may be a sizeable benefit, the cost-benefit calculation that does occur is simply a waste of time. Likewise, if the value of a life is infinite, then the cost-benefit calculation is not necessary, since the decision then should be to eliminate all grade crossings by whatever means appropriate. Hence a finite value of life should be used; otherwise, the cost-benefit calculation is both unnecessary and devoid of meaning.

The precise value of life used in a cost-benefit study is important. One can easily imagine that at a given crossing, for two given protective devices, there will be a certain value of life so that below it one device is warranted, yet above it, the other is warranted. Given many crossings and many different devices, a change in the assigned value of life of 25 percent, for instance, may change the selection of the warranted device at 5 percent of the warranted crossings. It may be worth the effort to verify this statement at a later date in a sensitivity analysis.

Only one value of life was used in this study. It is derived from the calculation of the discounted expected lifetime earnings.

a. Lifetime Earnings Concept

Two basic approaches to valuing human life have been advanced — the utility approach and the product approach. The utility approach attempts to measure the value of the utility foregoing upon death. Schelling's approach is essentially a utility approach whereby, from the point of view of the individual, the value of life may be indicated by the amount a person would pay to prolong his life. [1/] As indicated by Gary Fromm, many practical and theoretical difficulties prohibit the use of Schelling's approach. [2/] Likewise, the utility approach of Michael Jones-Lee is based on many assumptions (such as diminishing marginal utility of income) so that his method has limitations in its theoretical as well as its practical applications. [3/] Fromm's own method is the utility approach carried to its logical end. [4/] The monetary worth

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1/ Schelling, Thomas C., "The Life You Save May Be Your Own," in Problems in Public Expenditure Analysis, Washington; Brookings Institution, 1966, pp. 127-62.

2/ Fromm, Gary, "Comments" on Schelling's paper; Ibid., pp. 166-176.

3/ See Michael Jones-Lee, "Valuation of Reduction in Probability of Death by Road Accident," Journal of Transport Economics and Policy, January 1969, pp. 37-47.

4/ Fromm, Gary, Economic Criteria for Federal Aviation Agency Expenditures, Federal Aviation Agency, Final Report, June 1962, pp. VI20-22.

of a person is the summation of the values the deceased represents to himself, his family, the community, his employer, the Government, and the agency responsible for the accident investigation. His calculations are, for the most part, admittedly arbitrary. For this reason alone — that it requires assignment of monetary values to utility in an arbitrary way — we have avoided the utility approach in this study.

The "product" approach values life as the discounted sum of the socially valuable output a person produces in his lifetime. Assuming no exploitation of workers and full employment, this output may be measured by the wages earned. [1]

One school of thought uses net earnings, while the other uses gross earnings in calculating the economic value of life. The net concept values only those earnings saved after consumption by the person. But it is the purpose of savings to provide for future consumption, albeit for different members of society than the deceased person. Thus the net earnings concept focuses only on future, and ignores present, consumption. On the other hand, gross earnings focuses on both present and future consumption. For that reason, and because we are a consumption-oriented society, in this study we have used the gross earnings concept as the basis for the economic valuation of human lives.

b. The Valuation

Gross lifetime earnings have been tabulated on a national basis according

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[1] The condition of no exploitation ensures that the worker is paid the value of his marginal product. Without the assumption of full employment, if a person dies, his output may be produced by a person replacing him who was formerly unemployed; hence, there is only the loss of the transition according to the product approach. However, unemployment may be of the structural type, whence the replacement does have an opportunity cost even in the presence of measured unemployment.

to age, sex, color, and education.[1/] For reasons given elsewhere, we used a national average, not regional or state averages. These values have been used for a number of studies by HEW, so their use by the FRA is not unusual and makes for uniformity among government agencies.[2/]

Under the Rice-Cooper tables, we estimate the average expected loss from a death in a railroad crossing accident for 1964 as $86,000.[3/] The method of calculation is as follows: Regrouping the Rice-Cooper age groups slightly, an expected loss of earnings for both males and females may be estimated by multiplying the discounted earnings figures of Rice and Cooper by the distribution of age of the driver in vehicle-train accidents.[4/] (Most properly, the latter distribution should be the age distribution of those killed at railroad grade crossings, for train as well as non-train-involved accidents. Those distributions are not available at this time and

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1/ Dorothy P. Rice and Barbara S. Cooper, "The Economic Value of Human Life," American Journal of Public Health, Vol. 57, No. 11 (November 1967), pp. 1965-66.

2/ For examples of the use of the gross earnings concept by HEW, see their Disease Control Programs publications, Health Economic Series No. 6, as follows:

"Arthritis," September 1966
"Selected Disease Control Programs," September 1966
"Motor Vehicle Injury Prevention Programs," August 1966
"Cancer," October 1966
"Estimating the Cost of Illness"

3/ The value of $20,000 used in NCHRP 50 is derived from the American Association of State Highway Officials, Road User Benefit Analysis for Highway Improvements, 1960, p. 143. The values on that page of the AASHO report are for three age brackets and for males and females, and from their low order of magnitude, appear to be derived from a net earnings concept, although it is not indicated how the figures were derived.

4/ Op. cit., p. 7, Table 1.

are part of the "information gap.") The expected loss for males is approximately $93,000 each, and for females, $57,000. It has been estimated that 82 percent of the drivers in vehicle-train accidents were males, while 18 percent were females. 1/ (More appropriately, we should use males killed versus females killed at crossings.) Thus an approximation of the expected minimum loss to society of a person killed at highway-rail grade crossings is $86,000 (as of 1964).

Assuming the 11 percent growth in the value of earnings for the period 1964 through 1967, as does the National Safety Council, 2/ this figure is updated to 1967 as $95,288.

2. Opportunity Cost Concept

The real cost of accidents is the total opportunity cost of economic resources either destroyed or diverted by accidents. If we assume near-perfect markets, the scarcity price of these factors may be taken as

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1/ *Ibid.*, p. 7, Table 3.

2/ In R. W. Hooker, "Traffic Accident Costs and Effectiveness of Highway Safety Expenditures in Wyoming," 1968, Appendix D, the NSC estimates of the value of human life are $30,685 for 1964 and $34,068 for 1967. On the other hand, for the same cost component we have a 1964 estimate of $86,000. Assuming the growth factor which applies in our figures is the same as the NSC estimates, we have:

$$\frac{34,068}{30,685} = \frac{x}{86,000} \quad \text{or}$$

$$x = 86,000 \times \frac{(34,068)}{(30,685)} = 95,288 \text{ dollars}$$

their approximate opportunity cost. For example, if an ambulance were not rushed to an accident scene, it could have been used to transport a heart patient with no less usefulness. It is the money measure of an alternative like this that forms the cost of the ambulance service.

By similar reasoning, we include in accident costs the value of service flows rendered by dentists, physicians, lawyers, mechanics, etc. that are diverted from other uses. Very often what is wasted in an accident is not the flow of a particular service but the long-term, anticipated utilization of a durable factor which has a present value reflecting its expected future use. Demolition of a vehicle is a loss of this type. The market value of a passenger car shows not only the value of its use for a month or a year, but it expresses the worth of its lifetime utility.

The costs included in our accounting scheme are, then, values of immediate and future goods lost, as measured by the market prices of the factors of production. These costs may be labeled direct, internal, or, preferably, tangible costs.

3. A Question of Equity

We employed average statistics in calculating benefits and costs associated with the various devices. For the value of life, then, one aggregate value applies over the entire country. But expected future earnings may be calculated for regions and for states, and we wish to give ample warning of the possible consequences of this approach. What disaggregated earnings implies is that people in a rich state are more valuable than those in a poor state; hence, according to the use of the discounted earnings streams, more funds ought to be spent preserving their lives than the lives of poor people, other things the same. This is clearly a consideration of equity and outside the normal purview of economics. It is simply unfortunate that we cannot find another surrogate for the value of human life that does not vary from person to person and (hence) from state to state and region to region. We give due warning to researchers who disaggregate the value of life for the purpose of Federal decision-making to consider the consequences of the technique.

4. Cost Factor Development

a. Non-Train-Involved Accidents

From the National Safety Council statistics, we derived the cost per fatality, the cost per non-fatal injury, and the property damage costs in property-damage-only accidents. They are shown in Exhibit A-1 and are categorized by work time lost, insurance overhead, property damage, and medical costs. The work time lost per fatality is our measure of the value of life derived previously.

EXHIBIT A-1: AVERAGE COSTS BY CATEGORY AND BY SEVERITY CLASS, 1967

	Fatal (per fatality)	Non-fatal (per injury)	Property Damage Only (per accident)
Work Time Lost	$ 95,288	$ 469	$ N/A
Medical Costs	395	357	N/A
Subtotal	$ 95,683	$ 826	$ N/A
Insurance Overhead	3,672	1,006	$ 144
Property Damage	640	340	218
Total	$ 99,995	$ 2,172	$ 362

Source: Derived from the National Safety Council, Accident Facts, 1968, and the value of life calculation.

These figures are for highway accidents in general. As yet there does not exist a comparable set of statistics for grade crossing accidents. Consequently, they indicate the costs per severity class we employed. To make these unit costs grade crossing specific, we employed the results of a ten-year study of non-train-involved grade crossing accidents in Illinois[1/] which found that for each accident there were 0.01 deaths, 0.2 injuries, and 1.0 occurrence of property damage. Considering the cost of a fatality[2/] and the cost of an injury as foregone earnings and medical expenses only, a fatality is valued at $95,683 and an injury at $826.[3/] The property damage cost per accident is equal to the sum of insurance overhead plus the property damage, or $533.[4/] The property damage and insurance overhead are not included in the cost per fatality and per injury to avoid double-counting. Property damage costs vary over a wide range. Although $533 appears low, it is based on the best information available at this time.

The expected economic loss from a non-train-involved accident is then

(0.01) x $95,683 + (0.2) x $826 + (1.0) $533 = $1,655.

This is the figure used in the present study.

1/ See NCHRP 50, p. 63.

2/ Burial expenses should not be included, for they are inevitable and have to be paid eventually.

3/ Cf. Exhibit A-1. For a fatality, $95,288 + $395 = $95,683, and for an injury, $469 + $357 = $826.

4/ ($3,400 (Insurance Overhead) + $3,900 (Property Damage))/13.7 accidents = $533. From National Safety Council, Accident Facts, 1968.

b. Train-Involved Accidents

From a Minnesota study[1/] comes the severity of train-involved accidents: 0.2 deaths, 0.6 injuries, and 1.0 occurrence of property damage per accident. Data supplied to FRA by the railroads was not employed due to the bias caused by their reporting requirements. The railroads report an accident only when there is a serious injury or when the damage to the train is $750 or more. Thus we have excluded damage to the train until unbiased data becomes available. Using the same per unit costs as above, then, the expected economic loss from a train-involved accident we used is

$$(0.2) \times \$95,692 + (0.6) \times \$826 + (1.0)\ \$533 = \$20,165$$

C. PROJECTING FREQUENCY OF ACCIDENTS

1. Estimating the Probability Law of Rail-Highway Grade Crossing Accidents

A grade crossing accident is a chance event. In order to rank various crossings, one must derive the probability distribution of this event at each location or for similar locations in addition to estimating operating costs and accident costs.

a. Historical Sketch

Because of a lack of reliable data rather than the lack of refined techniques, earlier attempts at resolving the uncertainty problem have concentrated on devising hazards indexes. As it has been argued by

[1/] NCHRP 50, p. 63.

Rothrock and others, [1] these indexes are not appropriate for allocating funds among competing crossings. Primarily, the ranking they lead to is not based on economic considerations, and the resulting ordering is not cardinal.

Most hazard indexes are weighted averages of diverse factors of the general form:

$$I_H = \sum_i a_i X_i \tag{1}$$

These factors, X_i's, are related to traffic of motor vehicles and trains as well as to the physical characteristics of the environment where the grade crossing is situated. Some of them are: vehicles per day, trains per day, sight distance, train speed, approach grade and condition, approach angle, and attention factor.

The weights, a_i's, are assigned in a very subjective manner without any statistical justification. For example, a North Carolina study attaches the weights of 10, 20, and 30, respectively, to the number of trains travelling at less than 30 mph, between 30 through 49 mph, and faster than 50 mph, in trying to compensate for the higher risk involved with the faster trains.

It was a most natural step, with the accumulation of pertinent data, to go from hazard indexes to statistical models, and estimate the a_i coefficients. If we replace in the above formula I_H by K, the number of accidents

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[1] See NCHRP 50, Appendix A, for a recent summary of many approaches to grade crossing accident prediction.

observed, and add to the right-hand side a stochastic term to show the probabilistic nature of this event we obtain:

$$K = \sum_i a_i X_i + \epsilon \tag{2}$$

which is a general linear relationship with a's now treated as unknown parameters. The estimates of the a's may be obtained by ordinary least squares. One of the most referred to studies, done by Peabody and Dimmich is a model of this sort.

The specification of their basic model is:

$$K = a_o X^{a_1} Y^{a_2} P^{a_3} e^E \tag{3}$$

where K is the number of accidents in a five-year period,

X, daily highway traffic,

Y, daily train traffic,

P, the protection coefficient,

E, the error term.

The protection coefficient was developed for groups, G_i, by type of protective device from the formula:

$$P_i = \frac{1}{N_i} \sum_{G_i} \frac{XxY}{100xK} \tag{4}$$

where N_i is the number of crossings in the group.

Having K as part of the independent variable P as well as the dependent variable builds in correlation by definition. The resulting statistical fit is, then, inflated so that the equation appears to explain more than it actually does. However, the important point here is the lack of a probability model using equations such as (2) to explain accidents.

b. Theoretical Basis

If we believe that accidents are distributed in a given way, then we should employ that information to guide us in estimating accidents.

An appealing distribution is the Poisson distribution, and the logic behind it is as follows. Accidents either happen or they do not happen at a given point in time, and there is a probability attached to each event, a situation known as a Bernoulli trial. A sequence of independent Bernoulli trials over time or over different grade crossings leads to the binomial distribution. The binomial distribution, in turn and under certain conditions, may be approximated by the Poisson distribution. We may further justify the Poisson distribution by assuming that automobiles arrive at the grade crossing according to the Poisson distribution, thus giving rise to non-train-involved accidents that are Poisson distributed. And assuming that trains also arrive according to an independent Poisson distribution as well, the train-involved accidents are Poisson distributed.

What are the implications for estimation if we assume the Poisson distribution? Let us examine several alternative ways of applying the distribution. Assume for the moment that the only factor which affects grade crossing accidents is the type of protective device. Let there be N_i crossings with the i the protective device.

Let Y_{ij} be the number of accidents taking place at the jth crossing ($j = 1, 2, \ldots N_i$) with the ith protective device. Then

$$P\left\{Y_{ij} = k\right\} = e^{-\lambda_i} \lambda_i^k \frac{1}{k!} \qquad (5)$$

It follows that the expected number of accidents is

$$E\left[Y_{ij} \right] = \sum_{k=o}^{\infty} k \, e^{-\lambda_i} \frac{\lambda_i^k}{k!} = \lambda_i \qquad (6)$$

Given the cost per accident, C, it is now possible to estimate the expected loss, L_i, of rail-highway grade crossing accidents by type of protection:

$$E\left[L_i \right] = C \, E\left[Y_{ij} \right] = \lambda_i C \qquad (7)$$

This formulation may be expanded to allow for differentiation among crossings with the same protective device. Such an approach to the problem would account for differences such as the volume of car and train traffic and the physical environment. For example, if we have detail on cost data by a severity classification, C_s, assuming that the probability distribution for each class of severity is Poisson within the previous groups by protective device, then the expected loss becomes

$$E\left[L_i \right] = \sum_s C_s E\left[Y_{ijs} \right] = \sum_s \lambda_{is} C_s \qquad (8)$$

Up to this point we have developed our argument on sets of crossings without incorporating the time element. The above types of cross-section analyses are not focused on prediction and force us to ignore certain relevant factors. In what follows, we develop a comprehensive model which may be refined further for future application to rail highway grade crossing accidents.

Assume that grade crossing accidents are independently Poisson distributed at each individual crossing designated by j. Let Y_{ij} be the number of accidents in the ith time interval at the jth crossing

$$P\left\{ Y_{ij} = k \right\} = e^{-\mu_j t} \frac{(\mu_j t)^k}{k!}$$

$$= e^{-\lambda_j} \frac{\lambda_j^k}{k'!}, \quad \text{where } \lambda_j = \mu_i t \tag{9}$$

In this formula, μ_j is the rate of accident per unit of time t, and t is the number of time intervals (seconds, minutes, days, etc.) during which we observe the crossing. The subscript j of μ_j expresses the fact that the accident rate will be different from crossing to crossing, depending on the number and level of the various factors involved. We can estimate the mean rate of occurrence of accidents as $\sum Y_{ij}/t$, where t is the total number of time intervals during which the crossing was observed.

From past experience, we expect the λ_j's to be different depending on the motor vehicle and train traffic per unit of time, grade, and angle of approach, type of protective device installed, and so on. These various explanatory variables, X_s, may contain some human elements as well.

We may assume a linear (or log-linear) form of the hypothesized relationship as

$$\lambda_j = a_o + a_1 X_1 + \text{-----} + a_m X_m, \tag{10}$$

where the X's are the explanatory variables. We may substitute the right-hand side of equation (10) for λ_j in equation (9) and apply the maximum likelihood principle to estimate the coefficients. Alternatively, we could take the square root of the numbers of accidents per time interval which are approximately normally distributed, average these square roots within a crossing and regress this average on $X_1, ---, X_m$, with coefficients different from those of (10). There is a slight simplification of the usual regression analysis in that the variance is known but, of course, the number of time intervals per crossing must be roughly equal to ensure constant variance. The square root of the accident means that each crossing may be regressed on the explanatory variables by the maximum likelihood principle, which is equivalent in this normally distributed case to least squares.

c. Future Research

We have examined the implications for estimation when assuming a specific type of probability model, the Poisson distribution. Instead of the Poisson distribution, however, we may have considered a negative binomial distribution for accidents. The negative binomial is a two-parameter distribution as opposed to one for the Poisson distribution. It allows for a larger "tail" than the Poisson.

Chi-square "goodness of fit" tests may be applied to discover which distribution is appropriate. Then the logical implications for estimation may be developed and applied. These things we suggest for future work.

2. Implementation

For our accident calculations, we used the equations of the NCHRP 50.[1/]

[1/] Ibid., pp. 56-59, Equations 30 through 39 and 44 and 46.

(The train-involved accident equations have a scaling factor deleted in the report, so the accidents are to be multiplied by 1,000.) The equations cover non-train-involved accidents as well as train-involved accidents.

In NCHRP 50, the regression coefficients for automatic gates and flashing light signals in urban areas each were 0.32.[1/] This means that automatic gates and flashing light signals both have the same accident rates in urban areas, a surprising result. This result may have been due to randomness alone, so we recomputed the coefficients using more recent data from the inventories of Minnesota and Maryland.[2/]

The coefficients we derived were 0.23 for flashing light signals and 0.08 for automatic gates. This means that both automatic gates and flashing light signals have less expected accidents than would be the case with the earlier coefficients, and that automatic gates are almost three times as effective as flashing light signals in reducing accidents in urban areas.

D. AREAS OF FUTURE STUDY

1. Inventory Components of Cost Data

The most pressing information requirement for accident cost calculations is accurate site-specific accident data: the number killed, number injured, and even the total number of accidents at crossings. In particular, those accident data should pertain to each crossing, or a sampling

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[1/] Ibid., p. 61; The "B" factors are the regression coefficients.

[2/] In the previous calculations, there were 361 flashing light signals (at urban crossings) and 83 automatic gates, and in our recent calculations, there were 410 flashing light signals and 73 automatic gates. Thus the number of observations remains about the same.

of crossings, so that it may be determined how accidents vary over different categories with different protective devices, over states, over regions, and so on.

We strongly suspect, but have limited information on, the possibility that the severity of accidents is affected by the type of protective device used. In other words, it appears that not only do better protective devices reduce the probability of accidents, but they also appear to reduce the probability of serious accidents in a greater proportion. For example, from Table A-7, page 78 of NCHRP 50, automatic gate installations reduce the number of accidents by an average of 72 percent, yet they reduce the number of people killed by 92 percent. In other words, about 26 percent of all accidents involved death before the installation of automatic gates, but only 7 percent of the yet lower number of accidents involved death afterward.

Further justification of the hypothesis comes from California data. Of 178 crossings in Southern California over the period 1961-66, accidents were reduced 49 percent upon the installation of automatic gates. But the number of people killed was reduced a dramatic 80 percent.[1/] Thus if the severity of accidents were taken into account, there would be further justification for more expensive devices, such as automatic gates. The development of this data, then, should give an added dimension to the economics of grade crossings.

1/ James W. Mulgrew, et al., "California Rail-Highway Grade Crossings," mimeograph, Transportation Division, California Public Utility Commission, p. 3.

It would be appropriate to develop data on categories of accidents. The analysis of the train-involved accident data in NCHRP 50[1/] illustrates the potentialities for discovering, and trying to correct, the causes of grade crossing accidents. For vehicles, categories such as vehicle-pedestrian, vehicle-fixed object, and vehicle-vehicle may be useful in an analysis to find ways to minimize the cost of accidents at crossings.

2. Model Development and Verification

Weaknesses in existing models have been pointed out above. There does appear to be a model, derived from the Poisson or another distribution, that should generate better results than prior models by accounting for the distribution of accidents at crossings.

The data gathered in a crossing inventory should add immeasurably to the ability to verify or reject hypotheses, such as the sight distance hypothesis. Standard statistical methods may be applied to test the hypothesis that the severity of accidents varies with type of protection and other conditions at a crossing. These are the same methods that may be used to test whether different protective devices produce statistically significant differences in frequencies of accidents. These tests have not been carried out to date.

[1/] Op. cit., Chapter 1.

APPENDIX B

VEHICLE OPERATION AND DELAY COST FACTORS

A. MOTOR VEHICLE OPERATIONS

1. Introduction

To assess motor vehicle operation impacts, the existence of a grade crossing is considered as an impediment to the otherwise uninhibited flow of motor vehicle traffic. The grade crossing represents a bottleneck to both the commercial and non-commercial traffic "pipeline." It imposes incremental operating costs and time delay losses on the pipeline users. Motor vehicles normally slow down at a crossing, regardless of the presence of a train, and when a train is present, they must stop. Although it may be the case that automobiles slow down more at crossbucks, for example, than at automatic gates (because of the reassurance gates give the driver), we did not account for this difference due to the lack of relevant data.

Warrants are assigned, in part, upon the consideration of costs of the delay at the crossing, and it is our purpose here to develop several of the relevant costs. However, for all but stop signs, the same delay costs apply to each protective device we examined; hence, the delay costs do not determine the warrants among these, for the costs are constant. The delay costs are applicable, however, in considering the alternative of grade separation, whence the excess delay costs virtually disappear. Our study of delay costs, then, is properly a component of the economics of grade separation.

But the delay cost factors developed here do have applicability for studying the economics of various predictor devices which activate a crossing device, such as automatic gates, upon the approach of a train. Several such devices account for the speed and the distance of the train from the crossing, making it possible to reduce delay time compared to the standard device, which activates the protective device only when the train is a given uniform distance from the crossing, regardless of its speed. The economics of these devices, including safety factors, is an area for future study.

2. Component Specification

a. Vehicle Characteristics

(1) Type

We classified motor vehicles as either passenger or truck. For purposes of cost-benefit calculations, we assumed that all passenger vehicles are non-commercial in nature, and conversely, that all trucks are commercially oriented.

Since operating costs of vehicles are classified as a function of gross weight, the following weight categories offer a representative range of vehicle types that were utilized in the cost calculations:

- Passenger Vehicle — 4,000 pounds
- Single Unit Truck — 12,000 pounds
- Combination Truck — 40,000 pounds

(2) Mix

Since different types of vehicles generate widely varying operating costs, it was necessary to estimate the vehicle mix that could reasonably be expected to use the average grade crossing. In the absence of any existing empirical data in this area, it was concluded that nationwide averages of miles traveled by vehicle type and road classification would provide the best estimates for vehicle mix. Because buses of all types represented less than one percent of total passenger vehicle miles traveled, this category was simply incorporated in total passenger mileage. For purposes of cost-benefit calculations, the rounded averages shown in Exhibit V-1 were utilized.

EXHIBIT V-1: VEHICLE MIX RATIOS (PERCENT)

	4,000 pounds (passenger)	12,000 pounds (single unit)	40,000 pounds (combination)
Rural	77	19	4
Main	76	18	6
Local	78	20	2
Urban	85	13	2
Weighted Average	80	16	4

Source: Motor Vehicle-Miles, 1967, as reflected in "Distribution Management Tips," Transportation and Distribution Management, January 1969, p. 8.

(3) Volume

While only one vehicle may incur an exceedingly small fragment of operating costs (as little as a fraction of a cent) in transiting a grade crossing, the cumulative effect of all traffic passing such a crossing during a year may be of considerable magnitude. Therefore, it is essential to employ the average daily traffic expected to transit all grade crossings subject to evaluation. The magnitude of ADT provides an extremely influential parameter by which a potential grade separation is judged either economical or not warranted. For the calculations, see the chapter on warrants and priorities.

b. Speed Characteristics

The principal cause of additional motor vehicle operating costs at grade crossing sites is a speed cycle change. If, for example, a vehicle is proceeding at a given speed and reduces that speed as the result of the presence of a grade crossing, its vehicle operating costs are greater than if it had maintained its initial speed. The effect of the change in speed is attributable only to the presence of the grade crossing. To calculate the operating costs and the delay times, we need estimates of the normal approach speed of vehicles prior to entry into the crossing area and estimates of the reduction in speed that takes place at the site.

(1) Approach Speeds

Individual approach speeds to various crossings are generally regulated by a combination of factors such as state and local speed limits, vehicle density, and human factors. However, until such time that individual sites may be surveyed for specific speed trends, the use of average national speed trends by road classification would provide the most tenable basis for our cost calculations. Data obtained for this purpose is provided in the Bureau of Public Roads periodical Traffic Speed Trends, April 1968. This speed data, collected by 35 States in 1967, reflects average speeds on "level, straight sections of main rural roads and on urban streets during off-peak periods of the day when traffic densities are low and drivers travel at their desired speeds." Since these speeds reflect optimum conditions such as off-peak periods and favorable weather conditions, it was concluded that some downward adjustment should be made to better reflect average general speed conditions experienced throughout the typical day at a grade crossing. Further contact with the Bureau of Public Roads substantiated this position and led to an arbitrary reduction of non-interstate highway speeds of roughly 10 percent. In the case of interstate highway speeds, it was concluded that such a reduction would not be required. The approach speeds are presented in Exhibit V-2.

(2) Reductions in Speed

Reductions in speed at grade crossings is an area in which very little data have been collected, tested, or evaluated. The only known data are an extremely limited number of observation sites (six), most of which possessed similar location characteristics.[1/] In this case, five of the six crossings observed in the Maryland and Virginia area were considered urban in nature with the remaining site assessed as distinctly rural (U. S. 15, Limekiln, Md.). These represent too small a sample for distinguishing urban and rural speed changes as well as for distinguishing differences in speed changes due to the given protective device. The average speed reduction for the six sites was 5.52 miles per hour. This may understate the speed reduction in rural areas, but it was judged better to use a conservative estimate. In the final analysis, speed reductions depend heavily upon the physical characteristics of the site, but we could not incorporate this into our study.

(3) Road Condition Characteristics

The physical condition and design characteristics of a given road have a great deal of impact on relative vehicle operating costs for speed cycle

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[1/] NCHRP 50, p. 23.

EXHIBIT V-2: AVERAGE VEHICLE APPROACH SPEEDS (1967 Rounded Averages)

Road Classification	Passenger Vehicle	Truck	All
Rural			
Interstate	64	56	62
Primary 1/	52	48	51
Secondary 1/	44	41	43
Urban			
Interstate	55	51	54
Primary 1/	43	40	43
Secondary 1/	31	29	30
Suburban			
Interstate	58	53	57
Primary 1/	48	44	47
Secondary 2/	40	37	40

1/ Reduced 10 percent. See text.

Source: Bureau of Public Roads, Traffic Speed Trends, April 1968.

changes. This is true of both grade crossings and separations. Separations change dramatically the original site conditions. If, for example, a pre-separation site originally had a level grade, the introduction of a grade separation usually involves a change in pavement gradient that will consequently increase operating costs for that portion of the road. However, in all calculations utilized in this analysis, we assumed a tangent, level grade in good condition. In the future, however, it may be preferable to include consideration of variations in these and other types of roadway conditions.

4. Other Vehicle Delays

In addition to time delays incurred in the course of normal speed reductions in grade crossing zones, there exist two other obvious types of vehicle delay that may be found within the crossing environment: stops required by the presence of a train at the site, and temporary delays due to traffic routing during the construction of a grade separation.

a. Waiting for a Train

When a train approaches and occupies a crossing, all motor vehicle traffic must stop. To approximate this, we employed the following simplistic method. Assume that, on average, train traffic and motor vehicle traffic flows uniformly throughout the day. Although this is not a very tenable assumption, it shall suffice until further work is done. Then the number of vehicles that must stop per train is equal to

$$\frac{ADT}{24} \times H,$$

where ADT is average daily traffic and H is the hours per train that vehicles cannot traverse the crossing.

To find H, we need the specifications of the "average train." In the development of this average length, it was assumed that the average train length was 70.1 cars plus a caboose and an engine. It was also assumed that the train mix is 75 percent freight, 25 percent passenger, and the average passenger train length was 1,000 feet.

70.1 x 60 feet	= 4,200	3 x 4,480	= 13,440
caboose	40	1 x 1,000	= 1,000
engine	240		14,440

$$\frac{14,440}{4} = 3,810 \text{ — use } 3,800$$

The average train speed is 20.4 miles per hour (from "Yearbook of Railroad Facts," 1969). Thus, the average train occupies a crossing 127 seconds. Assuming a 20-second lead time, the total delay at a crossing is 147 seconds, 04 0.041 hours.

b. Construction Delays

Since grade crossings will, in effect, be "charged" for vehicle delay time, it is reasonable to similarly charge potential grade separations with traffic delays that are normally experienced during their construction period at existing road networks. Two of the essential factors for calculation of this charge are duration of construction period and average delay per vehicle. Again, while these may vary widely under given circumstances, the following factors represent conservative average delay per vehicle. Again, while these may vary widely under given circumstances, the following factors represent conservative average estimates:[1/]

Average Delay Per Vehicle: 0.125 minutes

Average Construction Period: 10 months

It has been estimated that 80 percent of the separations for existing highways are built on new alignments so that no delay occurs during construction.[2/] Thus we reduced these delay costs by 80 percent.

3. Cost Factor Development

a. Excess Operation Costs

As was mentioned previously, the existence of a grade crossing represents an impediment to the otherwise uninhibited flow of vehicular traffic. The process of slowing down for a crossing involves additional costs over and above those costs that would be incurred while operating at a constant speed. The engineering calculations that support this statement are well documented in Robley Winfrey's Motor Vehicle Running Costs for Highway Economy Studies, November 1963. This publication (soon to be released in textbook form by International Textbook Company) on the general subject of highway economics, represents the most refined cost data on the subject made available to the study group. We employed the cost

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[1/] Stephen E. Tirell "An Economy Study of the San Antonio Road Crossings of Alma Street and the Southern Pacific Railroad, Mountain View California," in Applications of the Principles of Engineering Economy to Highway Improvement, Stanford University, Report EEP-8, March 1964, p. 92.

[2/] From the Bureau of Public Roads.

tables that reflect the dollar excess costs of speed change cycles by vehicle weight classification. The cost factors utilized to develop these tables include cost impacts of the following categories: fuel, tires, engine oil, maintenance and "use-related" depreciation. The speed change cycle profile that is the basis for excess running costs is defined as reducing from an initial approach speed and returning to that initial approach speed. The speeds and weight classes we employed are given previously, the speeds rounded to the nearest multiple of five miles per hour.

b. Delay Time Cost Factors

The hours of delay per vehicle are given in Winfrey's Tables, as well as the excess operating costs, for given speed cycle changes. In order for these delay times to become part of the cost-benefit calculus, a dollar value per unit of time must be imputed to them. The value of time may be calculated separately for passenger and commercial vehicles. For passenger vehicles, assumed to be automobiles only, the value of time has been indicated in the literature by the willingness to pay for travel time reduction. We used the latest empirical findings as the basis for the value of time for passenger vehicles. For commercial vehicles, one of several methods may be employed, but recent research has indicated that the "cost savings method" is a workable and intuitively appealing method.[1/] We updated the results of that method to 1967.

[1/] For a thorough discussion of methods as well as an annotated bibliography, see William G. Adkins, Allen W. Ward, and William F. McFarland; Value of Time Savings of Commercial Vehicles, National Cooperative Highway Research Program, Report 33, 1967. For a bibliography of studies through 1961, see Dan G. Haney, "History of the Value of Time," in Stanford Research Institute, The Value of Time for Passenger Cars: A Theoretical Analysis and Description of Preliminary Experiments, Final Report, Vol. I, May 1967, pp. 7-19.

When a grade crossing accident occurs, there will be a delay to the train and to vehicles. This delay factor was left out primarily because of the lack of adequate data.

(1) Value of Time Indicated by Willingness to Pay

For a passenger, relatively simple calculations show that the amount a person would pay to save given amounts of commuting time, given the opportunity to make a choice and the necessity of spending the money, is a money measure of the value of the person's commuting time. [1/]

[1/] The calculations are as follows, where we use a continuous approximation to typically discrete choices. Assume that the work week is fixed and the money income earned at work is constant, which is an approximation to short-run reality. Let U be the person's utility, a function of net earnings $Y-E$, where Y is earnings, and E, expenditures on commuting, and also a function of leisure time, T_L, under the assumption of a constant work week. Functionally, $U = U(Y-E, T_L)$. For maximum utility, as the basis of a rational decision concerning commuting expenditures, set the total derivative of U equal to zero, or

$$dU = -\frac{\partial U}{\partial (Y-E)} dE + \frac{\partial U}{\partial T_L} dT_L = 0.$$

Solving for dE/dT_L yields

$$\frac{dE}{dT_L} = \frac{\partial U}{\partial T_L} \Big/ \frac{\partial U}{\partial (Y-E)}$$

Now $\partial U/\partial T_L$ is the marginal value of leisure time, in utility terms, which is translated into money terms by the deflator, $\partial U/\partial(Y-E)$, which may be interpreted as the marginal utility of wealth. The term dE/dT_L is the marginal expenditure per unit of commuting time saved. It is positive since by assumption an increase in expenditures reduces commuting time which increases leisure time by an equal amount. For an optimum, it is equal to the money value of leisure time.

(2) Market is Imperfect

Therefore, in a free market where there are no externalities and anyone not willing to pay the price of commuting is excluded (called the "exclusion principle"), the marginal expenditure to save a unit of commuting time as observed in the market is equal to the money value of leisure time. There appears to be few externalities to cause the market mechanism to allocate inefficiently; that is, benefits or costs wrought on other commuters due to one person's delay are wrought on that person in commensurate amounts; thus all the costs and benefits will be incorporated into that person's commuting decision.

But the market is imperfect at grade crossings because the exclusion principle is not operative. One way to make it operative, for example, is to build an overpass and charge people a fee to cross over the tracks. However, the average delay to collect the fee would most likely be greater than the average delay at a nearby intersection without an overpass, and that plus the fee of going over the overpass rules out the possibility of applying the exclusion principle under most circumstances. In theory, though, we may conceive of a device that automatically and without cost subtracts the toll from a person's bank account as his automobile crosses the overpass. Thus such a market could theoretically be efficient, but such is not the case with our present technology.

In order for the government to make efficient allocation where the market mechanism operates inefficiently, it should attempt to simulate a perfect market where the exclusion principle applies. It may do this in a number of ways, and perhaps the most appropriate way for the purposes of this study is to examine the results of other studies which have empirically estimated the value of time in those cases where the exclusion principle is operative and the market better formulated.

(3) Value of Time is Approximately One-Half of Wage Rate

We used an approximation that has been employed as a rule of thumb by transportation planners and has been recently verified by Thomas E. Lisco, among others. [1/] The approximation is that the value of commuting time is one-half the average wage rate. We made appropriate adjustment for the non-working population as described below.

(4) Lisco's Analysis

A brief review of Lisco's analysis will show how he verified the approximation. Lisco's hypothesis was the following: given the modal split of, say, 60 percent of passengers using rapid transit and 40 percent using automobiles, what change in the mass transit fare will return the status to the 60-40 modal split if a change in transit time upsets the 60-40 split? The change in the mass transit fare divided by the change in commuting time thus derived is the value of commuting time at the margin, that is, for the marginal commuter.

Using a special econometric technique, probit analysis, he derives an equation, part of which is [2/]

$$Y = 1.379 - 0.0084\,\Delta T + 0.012\,\Delta M. + \ldots, \tag{1}$$

where Y is a binary variable denoting behavior as to alternative modes

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[1/] Lisco, Thomas E. "The Value of Commuter's Travel Time: A Study in Urban Transportation," unpublished Ph. D dissertation, University of Chicago, 1967.

[2/] Ibid, p. 51, Table 2, Problem 1.

(automobile or mass transit), ΔT is the transit time less the driving time (in 100's of a second), and ΔM is driving costs minus transit costs (in cents). Since the coefficient of ΔT is seven times the coefficient of ΔM, after accounting for the units of measurement of ΔT and ΔM, he concludes that the value of commuting time is $2.52/hour. [1/] Lisco accounts for the differences in comfort between modes; the other variables in the probit regression equation are income, age, and dummies for sex and the extent that spouses assist in commuting and/or working. Because incomes were fairly high in the Chicago suburb studies, Lisco concluded that the value of time ranges between 40 and 50 percent of the wage rate, and may go even higher. [2/] He experiences difficulty with the income variable, due perhaps to the statistical technique used, because in an experiment he found that the value of time decreased with increased incomes, contrary to one's expectations. [3/]

(5) Other Studies

Using a different technique, Beesley arrives at a similar conclusion, but indicates that the differences in earnings are positively correlated with the value of time. [4/] He concludes that "for workers earning at

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1/ Ibid, p. 52n. 1. Lisco presents a range of values, depending upon transportation cost assumptions and treatment of income.

2/ Ibid., p. 56.

3/ Ibid., p. 91.

4/ M. E. Beesley, "The Value of Time Spend in Traveling: Some New Evidence", Economica, May 1965, pp. 174-85.

about the average wage level . . . the value [of traveling time] is about one-third of their average wage . . . More highly paid people . . . place a higher value proportionately — between 42 percent and 50 percent."[1/] And by inference Claffey concludes that the value of time for car owners is about one-third of the average wage rate.[2/] Not surprisingly, these and other studies have provided a range of estimates, mostly in the range of 33 to 88 percent of wages.[3/]

(6) Relation to Wage Rate

The connection made between the value of time and the wage rate in all these studies was done by inference; that is, after calculating the value of time in money terms, it was then related to the wage rate as a proportion. This procedure has intuitive appeal[4/] and is useful in cost-benefit studies

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1/ Ibid, p. 182.

2/ Paul J. Flaffey, "Characteristics of Travel on Toll Roads and Comparable Free Roads for Highway User Benefit Studies," Highway Research Board Bulletin No. 306, 1961.

3/ See G. P. St. Clair and Nathan Liederer, "Evaluation of Unit Cost of Time and Strain and Discomfort Cost of Non-Uniform Driving," Highway Research Board Special Report No. 56, 1060, and Lawrence Lawton, "Evaluating Highway Improvements on Mileage-and-Time-Cost Basis," Eno Foundation, Traffic Quarterly, Saugatuck, Conn., January 1950, pp. 102-25. Lawton, however, goes as high as 88 percent of factory wages.

4/ See Leon N. Moses and Harold F. Williamson, Jr., "Value of Time, Choice of Mode, and the Subsidy Issue in Urban Transportation", Journal of Political Economy, June 1963, pp. 247-264. They explicitly take up the case of fixed working hours, using a discrete analysis. The result of fifty percent of the wage rate indicates that individuals would like to work more than the standard number of hours. This may be true, given the significant amount of "moonlighting" that actually occurs.

because the value of time varies over the years and over different regions of the country as wages change. Thus it is a convenient assumption.

While we used the approximation of one-half the wage rate for the value of time, if future estimates of costs and benefits of grade crossings become more refined and disaggregated, it may be worthwhile to use a range of estimates, from thirty to seventy percent of wages. Then those grade separations warranted with the sixty percent but not with the thirty percent figure should be scrutinized more closely, for they are on the margin of acceptance.

(7) <u>No Modifications for Purpose of Trip</u>

Commuting time has value for those who work because that time could be used for other activities. If we assume that commuting anywhere, whether to work or to other places, subtracts from one's leisure time and has itself no special value, then commuting delays have the same value whether going to one's place of employment or not. Even if one enjoyed leisurely driving of the automobile as a form of relaxation, the delay at grade crossings may be thought of as a postponement of this type of leisure time. Thus, for those who work, the value of delay time will be one-half the average wage, regardless of when the delay occurs at the grade crossing.

(8) <u>Modifications for the Non-Working Population</u>

Those who do not work for monetary returns, mostly housewives, do perform, for the most part, valuable services in the home or elsewhere and should be imputed an earnings rate. Then the same analysis applies to them as applied to those who earn money income.

(9) Summary Formula

Therefore, the value of time per person as suggested by the discussion above is

$$A = L\,(pw_1 + (1-p)\,w_2),$$

where A = Per capita value of time per hour

L = Ratio of value of time to earnings

w_1 = Hourly earnings of compensated persons

w_2 = Imputed hourly earnings of those people not compensated

p = Proportion of the population receiving remuneration

From the above discussion, $L = 0.5$. As approximations, $w_1 = \$2.67$,[1/] and $w_2 = \$1.00$.[2/] The value of p, the proportion of the population in

1/ This is the average hourly earnings of production or nonsupervisory workers on private non-agricultural payrolls, total, for 1967, from Handbook of Labor Statistics 1968, Bureau of Labor Statistics, p. 163.

2/ The imputed wage is based upon a number of factors. From the Handbook of Labor Statistics, pp. 217-19, the following wage rates are obtained for the following occupations (for the U.S.):

Nonsupervisory employees, women, in eating and drinking places (1967)	\$1.18
Nonsupervisory employees, women, in hotels and motels (1967)	\$1.29
In Nursing homes and related facilities (1965)	
Cooks	\$1.20
Kitchen helpers	\$1.06
Laundry workers	\$1.01
Nursing aides	\$1.00

An appropriate estimate would be a weighted average of these wage figures, weighted according to time spent on each task. Short of that, \$1.00 was selected as a conservative estimate to account for any differences in intensity of work when remuneration is not paid, and the 3.8 percent unemployment level in 1967.

the labor force, has remained within one percentage point of 60 percent since 1948,[1] so p=0.6. Therefore, we conservatively estimate A, the value of time for non-commercial passengers, as $1.00.[2]

It has been estimated that there are 1.56 passengers per automobile,[3] so the value of time per automobile is estimated at $1.56.

(10) Commercial Vehicles

The value of time we employed for commercial vehicles is a simple national average of the regional data presented by Adkins for the composite commercial vehicle: $5.51 per hour, which is based on the "cost savings method."[4] This figure is for 1965, and since it is comprised mostly of wages, we increased it by the growth rate of drivers wages, which increased 9.6 percent between 1965 and 1967.[5] Therefore, the implied value per commercial vehicle is $6.04 per hour.

1/ Handbook of Labor Statistics, p. 22.

2/ From the formula above, $1.00 = 0.5 (.6x$2.67 + .4x$1.00).

3/ Transportation Plan, Chicago Area Transportation Study, Final Report, Volume III, April 1962, p. 10.

4/ William G. Adkins, *et al.*, *op. cit.*, p. 2.

5/ Union Wages and Hours: Motortruck Drivers and Helpers, U.S. Dept. of Labor, Bulletin

(11) Value per Average Vehicle per Hour

Using the automobile-truck mix developed previously (grouping the two classes of trucks into one), the following are the values of time for the "composite vehicle":

	Vehicle Mix (Automobiles-Truck)	Value
Urban	85-15	$2.23
Rural	77-23	2.59
Combined	80-20	2.46

B. RAILROAD OPERATIONS

1. Introduction

In similar fashion to motor vehicle operations, the existence of a grade crossing may be viewed as an obstruction to otherwise unrestricted railroad running operations. In this respect, the cost categories and component specification requirements for rail operations are roughly the same as those called for by vehicle operation, with one major exception: the train "pipeline" is more limited in scope due to the requirement of running on a given, static track. Therefore, any restriction to running speeds may not only involve speed cycle changes and delay costs for the train transversing the crossing, but it also may possibly involve slower running speeds for all trains in the pipeline.

2. Component Specification

A cursory review of available data concerning "average conditions and specifications pertinent to railroad running operations revealed that the extremely diverse nature of train traffic characteristics has heretofore legislated against the development of such averages due to potential gross distortions that would most probably be wrought from such techniques. The paucity of available data sources from which to develop reliable averages in this respect further dissuaded a serious attempt to build a preliminary set of operating statistics within the frame of this analysis. Therefore, we shall discuss only the components that appear appropriate as major impacts of delay on train operation.

a. Train Characteristics

The following categories provide some idea of the desired data base for the development of delay impacts.

(1) Type of Train

It will be necessary to differentiate between the type of train and the type of service involved. By type of train, we mean passenger and freight classifications, with possible subclassifications. It will be of consequence, particularly relative to freight operations, to discern differences in the service performed by the train, e.g., running functions, switching functions, and branch-line functions.

(2) Composition of Train

Once train types and services are determined, it will be necessary to build the average type train as a function of the type of motive power used, e.g., diesel, and of the type and number of trailing cars (coaches, baggage, gondolas, boxcars, etc.) that it will move. These factors will have a significant impact on fuel consumption characteristics as well as revenue generation. It will further be necessary to distinguish the number of cars loaded and empty.

(3) Mix at a Crossing

As is the case with vehicle traffic, an estimate should be made of the type of train mix that could reasonably be expected to periodically transit a given grade crossing. Different operating costs and revenue potential by train type and service calls for the development of a composite train for the crossing.

(4) Frequency

The frequency of trains needs to be estimated to derive a total delay time and cost.

C. AREAS FOR FURTHER STUDY

The following represent areas requiring substantial refinement and in-depth analysis.

1. Delay Cost Factors

Application of sensitivity analysis to cost factors utilized for delay time to determine the degree of impact to systems costs as a result of parameter variations. The results of the sensitivity tests will determine if further investigation is required. If it is required, we suggest the study areas outlined below.

2. Motor Vehicle Operations

a. Development of vehicle approach speeds to grade crossings that reflect more refined influences of varied conditions, i. e., night vs. daytime driving, condition of roadway, presence of speed limits, and unusual site characteristics.

b. Observation and testing of vehicle reductions in speeds for grade crossings by road classification, vehicle type, and type of protective device.

c. Development of vehicle delay data due to train site occupancy by crossing type and railroad classification, i.e., mainline and switching.

3. <u>Economics of Signal Actuating Devices</u>

Development of a cost-benefit study to determine whether additional or supplemental signal actuating devices are warranted. This would involve use of the delay cost developed in 1. above.

4. <u>Train Operations</u>

Development of all the train-related factors that were excluded from the present study.

b. <u>Speed Characteristics</u>

The unique speed characteristics of "running" train operations focused our attention on railroad operations in general.

Speed limit restrictions placed upon trains in the vicinity of grade crossings are primarily attributable to state and local ordinances which are, of course, designed to enhance safety program aspects. While these vary widely depending upon local conditions and population density, an average speed reduction of 15 to 30 m.p.h. in the vicinity of an average grade crossing appears to roughly approximate the general magnitude of a regulated speed reduction, but this needs to be validated. These local speed reductions may be removed if crossings are eliminated by a system of improvements and closings of crossings. Indeed, this is an area of potential gain which a future study should investigate.

The presence of grade crossings can impose speed reductions and fluctuations. How many crossings are encountered and how close together they are constitute important questions to be answered. But perhaps the most important factors are the location and conditions at crossings within a city or a town. These factors cannot be adequately dealt with in a study of nationwide scope; rather, they must be assessed individually at the local level.

c. Delay Costs

Estimates as to average earnings of passengers and values of freight per unit of time need to be developed for determination of time delay cost factors.

Appendix C

ADDITIONAL DISCUSSION OF WARRANTS AND PRIORITIES

A. INTRODUCTION

The purpose of this appendix is to explore some methodological aspects concerning warrants and priorities with respect to grade crossing improvements. It is assumed that the reader is familiar with the chapter on warrants and priorities. This discourse on methodology is given because of the conflicting methodologies mentioned there.

This appendix is concerned primarily with various approaches considered for the cost-benefit studies. It reviews some of the methodological details that led to the approach taken in the present study.

B. GENERAL METHODOLOGY

The application of a quantified, scientific approach has the advantage of being objective. It has a tendency, however, to overlook or to consider insignificant non-quantitative factors. Among the foremost of these factors is the politico-economic reality of the situation. It may be a political reality that there is only a given, fixed amount of funds to be allocated for investment in grade crossing safety installations, and in that event the scientific method should be used to determine the distribution of this budget among the several crossings. However, it may be appropriate to employ the scientific method to determine the total amount of money which may be effectively spent in grade crossing protection. This approach is called <u>budget determination,</u> as opposed to the approach which assumes a <u>fixed budget.</u>

The problem is critical because different warrants and priorities will be assigned under the first assumption, that of given budget constraint, than under the second, that of budget determination. It is different because of the different conditions that are applicable.

The discussion in this appendix explains how to handle either problem, but the budget formulation approach is basic. Under this approach, the economic analysis of each of a group of crossings will justify the expenditure of, let us say, X dollars. This becomes the basis of a request for funds from the appropriate legislative bodies. The analysis is designed to convince them that the suggested investments should be undertaken for the sake of economic efficiency. If X dollars are not forthcoming, however, then the alternative approach may be taken, which assigns warrants and priorities subject to a budget constraint.

To assume a given budget to plan investments may waste resources, either as the result of over-building by doing some projects not economically justified or as the result of under-building, which would require additional expenditures at a later date to overcome original deficiencies, all at a greater total cost. Once a grade crossing safety installation is provided, it may be costly to replace it, given more money at a later date. It is more appropriate to discover what the final warranted device should be, and if its cost exceeds the budget constraint, postpone its construction until the funds are available, rather than proceeding via a circuitous route by installing another device first, and the warranted device later.

1. Warrants

a. Net Benefit Calculation -- There are several characteristics of the grade crossing decision which imply the following rule to determine warrants. At a specific crossing that grade crossing safety installation is warranted which maximizes the discounted benefits (B) minus the discounted initial and recurring costs (C) of all alternative installations. Significant characteristics are (a) as mentioned, it is difficult to employ a time-phased upgrading of crossings, (b) installations at a specific crossing are mutually exclusive, (c) installations are indivisible (half a device, e.g., is not an alternative), (d) installations cannot be efficiently applied in multiple doses (because commensurate benefits are not obtainable) and (e) a budget constraint is not applicable at this stage of the analysis.

In other words, these conditions imply B minus C calculations rather than B divided by C calculations, to determine warrants. For a given budget, the ratio B/C has appeal and usefulness, but in formulating the budget it becomes hazardous to look at B/C because this ignores the absolute size of the benefits over the costs. Following McKean,[1] the appropriate criterion is B minus C in selecting one of the mutually exclusive protective devices at the warranted crossings.

As an illustration of the validity of the proposition, device I may be a complete set of protective signs, and device II automatic gates. For each dollar invested in signs there may be a greater return in terms of lives saved and accidents reduced (as measured by the B/C calculation), but the absolute number of lives saved and accidents reduced may be much greater for the gates than for the signs (the B minus C

[1] McKean, Ronald N., Efficiency in Government Through Systems Analysis, New York: John Wiley and Sons, 1967, Chapter 2.

calculation). The savings afforded by the gates cannot be duplicated by investing, say, three times as much money in signs, because of diminishing returns (and it may be politically impossible and aesthetically distasteful to clutter the highway with signs). These considerations lead to the use of the net benefit calculation, since it is the absolute size of the net benefits that is important.

It is relevant to consider the analogy of a private, profit maximizing enterprise that "owns" the crossing and actually receives dollar payments for the benefits. (One may imagine several ways in which the dollar transfer could theoretically be transacted, but this is not important here.) Assume that the two projects I and II, signs and gates, are the only alternatives, and that each will return at least the firm's cost of capital. Since the firm can, at given levels of risk, obtain sums of money at its cost of capital (the cost of capital may increase with the amount of funds borrowed, but that is not a likely case for the situation studied in this report), it would select that project yielding the largest aggregate net profits, which translates as the largest aggregate net benefits. Economists ascribe efficiency to this selection by profit-making firms where there is competition (alternate routes of travel and many such firms operating on those alternate routes) and no externalities. Assuming competition and no externalities, which are very plausible assumptions, selection by the net benefit criterion yields maximum efficiency in resource allocation.

b. <u>The Discount Rate</u> -- The social discount rate used to relate benefits and costs at different points in time is defined as the opportinuty cost in terms of the consumption and private investment foregone because of the public investment project.[1] The use of a discount rate implicitly compares a given investment project to all the others in the entire economy. If there were no alternative uses of the funds, then there would be no need to use a discount rate. The discount rate used by the government serves the function of allocating investment funds between the private and public sectors. The higher that discount rate, the fewer public projects that will be warranted, as well as the fewer private investment projects. In this sense, the discount rate limits the total budget for public improvements.

The discount rate may be interpreted as the return funds would yield if they are not invested in a given project, such as grade crossing protective devices. The discount rate used by the Federal Railroad Administration should be the same as for all government agencies. This insures that investments for grade crossing safety compete with investments in highway safety, for example, on a standard, fair basis. Because there are competing uses for resources, a discount rate was employed.

c. Net Benefit Versus the Benefit/Cost Ratio -- The most obvious competitor to the net benefit criterion is the benefit/cost ratio, where benefits and costs are in discounted terms. The condition of B minus C being greater than zero implies that at least the rate of return, or discount rate, has been achieved,

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[1] See Baumol, William J., "On the Social Rate of Discount," American Economic Review, September, 1968.

thus the project is warranted. This condition is entirely equivalent to the B/C ratio being greater than one. But the ranking by the B minus C criterion may be different from the ranking by the B/C ratio. Thus, when some investment projects are mutually exclusive and indivisible, the choice of criterion is critical: selection of one investment by one criterion precludes selection of another even though the other criterion gives it a higher rating. The following illustration shows that the B minus C and B/C criteria rank projects differently: Estimates for a Specific Crossing (B and C are in discounted -- not current -- terms).

Device	B	C	B-C	B/C
I	$30,000	$10,000	$20,000	3.00
II	80,000	30,000	50,000	2.67

Using the ratio B/C, we would select device I first to replace the existing device at a crossing, but upon its selection, device II can no longer be employed. But the net benefit (B-C) calculation suggests device II. At a crossing, only one of the two devices may be installed. Which one do we choose?

One way to reconcile the two criteria is to put them on the same cost basis. Assume that the costs are all initial investment costs, and that we have at our disposal $30,000 (at a cost indicated by the discount rate). If we select project II, the funds are exhausted. If we select project I, we have $20,000 left after the investment. This $20,000 may be employed elsewhere in the economy at a return equal to the rate of discount, and its benefit in present value terms is $20,000 (it has a B-C = 0, or B/C = 1). So add $20,000 to the benefits of project I as well as to its costs. Then the B minus C calculation for project I is still $20,000, but the B/C calculation is now 1.67, less than that of device II (which is 2.67). Hence, the net benefit and benefit/cost ratio yield the same choice if the costs of the projects are thus adjusted to be equivalent.

2. Priorities

In determining the amount of funds to be requested and spent over time, account must be taken of two things: (1) expenditures are to be made in current dollars, not discounted amounts, and (2) the investment projects typically are not all initiated at once, rather, they are spread out over a number of years, which is accomplished by assignment of priorities. The guiding principle in assigning priorities under these restrictions is the maximization of the present value of all the projects. Under practical considerations, this is done by taking those with the greatest return per dollar of expenditure first. But if the two restrictions are not valid, then there is absolutely no need to assign priorities, and all the warranted projects are initiated at once.[1]

The first consideration (expenditures are in current dollars) leads to the formulation of a request for funds from legislative bodies. That is, the total budget is derived by adding all the initial construction costs of all the warranted projects, in current terms. (It may be relevant to

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[1] A third restriction is that there is a valid budget constraint, in that legislatures may grant only part of the requested funds, and the budget is to remain rigid over a long period of time so that the circuitous route of upgrading is not a possibility. This may be handled in a straightforward manner by selection according to the priorities of the projects.

add the recurring costs above those presently required, in current terms. Assume, for the sake of illustration, that these excess recurring costs are negligible). If the costs of the devices are expected to rise, then the budget calculation must be repeated with the inflated current expenditures after the priorities are assigned and the starting date of each project determined.

After adding all the current costs, the number of years over which the projects are to be initiated needs to be determined. For the sake of illustration, assume that it is ten years. Allocation over time may be accomplished by assigning amounts of money to be spent each year until the funds are exhausted. For example, if the expenditures are to be uniform over time, then the amount to be spent each year is the total cost divided by the number of years, or ten. This annual outlay serves as a budget constraint for each year. The priorities, then, should be selected so that those projects yielding the greatest amount of benefit for the given amount of funds are chosen first. In that case, if for whatever reason the funds run out, or new information appears, such as new devices being developed, then the investments already put in place would have been the best possible under the circumstances. And, in any event, aggregate discounted net benefits will be the largest by using the priorities.

a. Treatment of Service Lives -- The service lives of the various protective devices must be made equal, by appropriate means, before the devices may be compared to one another in an economy study. To illustrate the method and reasoning behind this, consider a comparison of crossbucks with grade separation for a given crossing where crossbucks are presently installed. Assume that the service life of a crossbuck is seven years and the service life of a grade separation is fifty years.

The benefits of a grade separation are measured by the reduction in accident costs, motor vehicle operating costs, and passenger delay time costs saved over the existing device, crossbucks. Since we are comparing a grade separation with crossbucks, and we cannot assume that the crossing simply disappears after seven years, we must assume that the crossbucks are to be replaced every seven years throughout the fifty-year life span of the separation.

There is a recurring initial cost of the crossbucks every seven years that must also be included and discounted properly. Even though seven years is not evenly divisible into fifty years, the discount factor reduces the already small investment in crossbucks to insignificance as fifty years are approached.

b. Treatment of Salvage Value -- Salvage values come into play in two instances. One is where an existing protective device is replaced by another. In this case, the present salvage value of the existing device is a negative cost (i.e., a benefit) when installing a new device. That negative cost should be combined with the installation cost of the new device to derive a net installation cost. The present salvage value of the existing device has no relevance unless the device is to be removed.

The second use of salvage is the end-of-life value of existing and alternative devices. The service life is supposedly established so that the only end-of-life salvage value would be the value of parts that have not worn out, even though the entire device has outlived its usefulness, by assumption. For active devices, these include economically recoverable parts of the circuitry as well as other physical equipment parts. We have assumed in this study that the costs of removing the device cancels any salvage value. Labor costs of initial installation are a major item and labor costs of removal are not likely to produce much net salvage value.

For a grade separation, the "parts" have little value, but the land purchased above that which is necessary for an ordinary crossing does have value. It is obviously the case that at the end of the "useful life" of a grade separation a choice exists as to what to do with the crossing. But the reality of the situation is clear cut: separations are rarely downgraded. On Federal-aid grade crossing projects over the period 1963-67, no separations were downgraded to protective devices. Of 1951 separations using Federal funds over this period, 5 involved relocation and 190 were reconstructed.[1] (All the rest were new separations). Only for those relocated, then, is there any possibility that the end-of-life land value is a "negative cost." But in relocation, if the highway relocates, access to the land becomes minimal, which may make the land worth less than it originally was. If the railroad relocates, the land then may have possibly substantial salvage value. On balance, then, it appears unrealistic to

[1] DOT Action Group on Grade Crossing Safety, "Federal-Aid Highway Railway Grade Crossing Projects, 1963-1967", January 1969, p. 5. The total of 1951 consists of 1756 separations built, 5 relocated, and 190 reconstructed.

include any salvage value for the land at the end of the useful life of a separation.

This proposition has its economic underpinings. If a separation is economically justified in the first place, the conditions most probably will remain, so that it will also be justified at the next decision point in the life of the separation.

The end-of-life salvage value, SV, may be converted to a present value, PV, by $PV = SV/(1+i)^n$, where i is the discount rate and n the useful life. The present value may be converted into an annual cost, A, by the capital recovery factor,

$$A = PV(crf\text{-}i\text{-}n) = SV(crf\text{-}i\text{-}n) / (1+i)^n = SV\left[i/((1+i)^n - 1)\right].$$

This value should, of course, be subtracted from the annual cost of installation.[1]

c. Treatment of Growth Factor -- Some of the benefits, or costs, grow over time. It appears to be somewhat more appropriate to use a growth rate rather than an absolute amount of growth for each year (called a "uniform gradient").

[1]Not only does Tirrell add the end-of-life salvage value to the cost of installation, but he uses the wrong factor as well to calculate the annual cost equivalent of the salvage value. See Steven E. Tirrell, "An Economy Study of the San Antonio Road Crossing of Alma Street and the Southern Pacific Railroad, Mountain View California," in Application of the Principles of Engineering Economy to Highway Improvements, Stanford University, Report EEP-8, March 1964, pp. 102-103, for example. His salvage value is, in addition, the right-of-way value, which appears to be inappropriate.

For an approximation of the present value (PV) of a cash stream growing at the rate of g per time period for n years, let PV = R_o / (crf-h-n), where R_o is the initial value of the cash stream and h = i-g, the discount rate less the growth rate. The logic is as follows: $R_j = R_o(1+g)^j$, the value of the cash stream for period j, is the initial cash value multiplied by the growth factor $(1+g)^j$. The present value of R_j is $R_j / (1+i)^j = R_o (1+g)^j / (1+i)^j$, so that the present value of the

the whole stream is $R_o \sum_{j=o}^{n} \left[\frac{(1+g)}{(1+i)}\right]^j$. But (1+g) / (1+i) is

approximately 1 / (1+i-g). Since $\sum_{j=o}^{n} \frac{1}{(1+i-g)^j} = 1/(\text{crf}-(i-g)-n)$,

PV = R_o / (crf-h-n). The annual cost equivalent is, then, R_o(crf-i-n) / (crf-h-n).

Rice and Cooper[1] use this approximation. They assume that a discount rate of 7 percent and a growth rate of 3 percent is equivalent to a "net" discount rate of 7 - 3 = 4 percent. It is actually equivalent to a "net" discount rate of 3.9 percent, so the approximation of 4 percent is very accurate. Indeed, it is not necessary to use the exact figure of 3.9 percent, since there is enough arbitrariness in selecting the 3 percent growth rate, as there is in selecting the 7 percent discount rate, so that the "net" discount rate of 4 percent is accurate enough.[2]

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[1] Op. cit., p. 1959.

[2] Winfrey, op. cit., gives exact present value factors for integer growth rates of 3, 5, and 7 percent, on pp. 59-65.

d. Closing a Crossing -- Although we did not consider the closing of a crossing as an alternative in the report, it will be of some value to list the relevant considerations in such a case. To close a crossing is primarily a political decision, but the economic factors may be at the base of the politics. Other than personal discomfort of breaking an old habit, the closing of a crossing may cause greater delay to motorists. This appears to be the primary economic cost factor involved, other than the effort required to physically close off the crossing.

It is typically the case that highway traffic is rerouted to an intersection with better protection, so that accidents are reduced. This is the first benefit of closing the crossing. These benefits may be sufficient to justify the simultaneous closing of a crossing and construction of a separation or an active protective device on an alternative highway route. Thus, accidents may be further reduced and, with the separation, aggregate motor vehicle delay time may even be reduced.

This is an area of further research, since consideration of the closing of crossings was impossible in the study reported here.

3. Summary

a. Warrants -- For each crossing, that protective device is warranted which produces the largest amount of the present value of benefits minus the present value of costs. The sum total of the current costs of the warranted improvements forms the basis of a request for funds to invest in grade crossing safety installations.

b. Priorities -- Under very practical and realistic assumptions, priorities are assigned to the warranted protective devices by the benefit/cost ratio in order to time-phase the construction of the devices.

c. Present Worth Versus Annual Cost -- Two alternative formulations to compare benefits and cost streams over time, present worth and annual cost, are equivalent, in that they yield the same warrants and priorities if each is done properly.

d. Treatment of Service Lives -- The service lives of each of the protective devices must be made equal, by assuming the same protective devices to be repeated over time up to the length of life of the one with the greatest longevity (or possibly even longer). The benefits of each device are the accident and motor vehicle operation and delay costs saved over the existing device, and comparisons of benefits may be made of alternative devices only under the existence of (hypothetically contrived) equal service lives.

e. Treatment of Salvage Value -- Salvage values are benefits derived from replacing an existing device or from the sale of parts of a device that has lived its useful life. For grade separations, the end-of-life salvage value should properly be zero.

f. Treatment of the Growth Factor -- The growth in average daily traffic and, hence, in accident and motor vehicle operation and delay costs, may be taken into account by discounting these cost streams by a "net" discount rate, which equals "the" discount rate less the rate of growth of these costs. Although it is only an approximation, it is quite accurate.

g. <u>Closing a Crossing</u> -- Although the decision to close a crossing is primarily a political one, economic factors are relevant. They are changes in (a) delay times, (b) accident costs, and (c) the value of operating speed of the railroad, attributable to the closing of a crossing. The application of the analysis needs to be made on a crossing-by-crossing basis, not in the aggregate.